COURT FILE NUMBER	2001-14300	Clerk's Stamp
COURT	COURT OF QUEEN'S BENCH OF ALBERTA	
JUDICIAL CENTRE	CALGARY	
APPLICANT	REBECCA MARIE INGRAM, HEIGHTS BAPTIST CHURCH, NORTHSIDE BAPTIST CHURCH, ERIN BLACKLAWS and TORRY TANNER	
RESPONDENTS	HER MAJESTY THE QUEEN IN RIGHT OF THE PROVINCE OF ALBERTA and THE CHIEF MEDICAL OFFICER OF HEALTH	
DOCUMENT	**AFFIDAVIT OF DR. DEENA HINSHAW**	
ADDRESS FOR SERVICE AND CONTACT INFORMATION OF PARTY FILING THIS DOCUMENT	Alberta Justice, Constitutional and Aboriginal Law 10th Floor, 102A Tower 10025 -102A Avenue Edmonton, Alberta T5J 2Z2 Attn: Nicholas Parker and David Kamal Tel: (780) 643-0853; (780) 415-2993 Fax: (780) 643-0852	

AFFIDAVIT OF DR. DEENA HINSHAW
AFFIRMED ON JULY 12, 2021

I, Dr. Deena Hinshaw, MD, MPH, FRCPC, CCFP, of the City of Edmonton, in the Province of Alberta, AFFIRM AND DECLARE THAT:

1. I am currently employed by the Government of Alberta as Chief Medical Officer of Health in the Ministry of Health. In this role, I provide public health expertise to support health surveillance, population health, and disease control initiatives on issues of public health importance under the authority of the *Public Health Act*, RSA 2000 c P-37.

2. I have personal knowledge of the facts and matters stated in this affidavit - except where they are based upon information and belief, in which case I believe them to be true.

A. Chief Medical Officer of Health and the Speciality of Public Health and Preventive Medicine

My education and training

3. I completed my medical degree in 2004, and my residencies in family medicine in 2006 and community medicine in 2009, at the University of Alberta. In 2008, I received my Master of Public Health degree from the University of Alberta, while completing my public health and preventive medicine residency (at the time, called "community medicine").

4. I am a member of the College of Physicians and Surgeons of Alberta and have been an active member since 2006. As a physician, I specialize in public health and preventive medicine.

5. I worked as a Medical Officer of Health in the Central Zone of Alberta Health Services (AHS) from January 2010 until July 2017. I also served as the Medical Officer of Health lead in the area of public health surveillance and infrastructure for AHS from 2014 to 2017. From 2017 until my appointment as the Chief Medical Officer of Health on January 28, 2019, I served as Alberta Health's Deputy Chief Medical Officer, supporting the Chief Medical Officer of Health in her duties. Attached and marked as **Exhibit "A"** to this Affidavit is a copy of my *curriculum vitae*.

6. As a part of my training and experience as a Public Health and Preventative Medicine specialist, I have expertise in assessing and interpreting evidence on public health matters, and my personal assessment of the facts in this affidavit based on my experience and expertise is that these facts represent the best currently-available evidence related to SARS-CoV-2 and COVID-19.

7. I can attest that the information contained in this affidavit is true based on two things:

   a. The rigorous framework of evidence assessment and use of this evidence in public health and healthcare standard and guideline development in Canadian and Albertan context; and

   b. My training and experience as a Public Health and Preventative Medicine specialist.

Appointment as Alberta's Chief Medical Officer of Health

8. I was appointed Alberta's Chief Medical Officer of Health by the Minister of Health pursuant to s. 13 of the *Public Health Act*, and I report directly to the Deputy Minister of Health.

9. While the Chief Medical Officer of Health plays a leadership role in Alberta's public health system within government and giving advice to AHS, the Chief Medical Officer of Health is not an independent officer of the Legislature like the Auditor General or the Child and Youth Advocate. Rather, as I serve at the pleasure of the Minister of Health, I can be removed from my position at any time. I am therefore subject to oversight within the democratic structure of the Government of Alberta.

10. I work alongside the Deputy Chief Medical Officer of Health (DCMOH) and the Deputy Medical Officer of Health (DMOH). The DCMOH role has been filled over this past year by Dr. Marcia Johnson and Dr. Andre Corriveau respectively, and the DMOH role is filled by Dr. Jing Hu. Alberta Health also employs numerous other experts in a variety of public health disciplines who provide me with information and advice to assist me in fulfilling my roles as the Chief Medical Officer of Health. Among these other experts that have been critical in supporting my office's work during the COVID-19 pandemic is Alberta's Emergency Operations Centre's Analytics team that provides modeling and surveillance support as detailed in the Affidavit of Dr. Kimberley Simmonds, and Alberta's Provincial Laboratory that provides PCR testing information as detailed in the Affidavit of Dr. Nathan Zelyas. I also work with various medical officers and other employees of AHS as detailed further in the next section of this Affidavit.

The Specialty of Public Health and Preventive Medicine

11. Chief Medical Officers of Health are public health physicians. Public Health and preventative medicine is a specialty within the field of medicine. The University of Alberta's Department of Medicine's website https://www.ualberta.ca/department-of-medicine/education/residency-programs/public-health-preventive-medicine/index.html, the relevant portion of which is attached as **Exhibit "B"** to this Affidavit, describes the specialty at p. 3 of 9 as follows:

> Public Health and Preventive Medicine deals with groups or populations, rather than individuals. Using population health knowledge and skills, the Public Health and Preventive Medicine specialist plays a role in the maintenance and improvement of the health and well-being of the community. This function is accomplished by evaluating the health needs of a population and developing, implementing and assessing programs that meet those needs. Recognition of specialty training in Public Health and Preventive Medicine by the Royal College of Physicians and Surgeons of Canada (RCPSC) began in the mid 1970's and specialty certificates are conferred by a dozen programs in Canada.

12. The Royal College defines the specialty as the branch of medicine "primarily concerned with the health of populations", focussing on controlling disease and preventing injury through health protection and health promotion activities. The College's training materials explain that the public health specialist achieves this by monitoring and assessing the health needs of a population and developing, implementing, and evaluating strategies for improving health and well-being through interdisciplinary and intersectoral partnerships. Attached as **Exhibit "C"** to this Affidavit is a copy of pages 1 and 2 of the Royal College's publication entitled "Objectives of Training in the Specialty of Public Health and Preventive Medicine (2014)" revised in March 2018, which sets out the Royal College's definition and goals of the Speciality, and contains the above descriptions.

My roles as Alberta's Chief Medical Officer of Health

13. The Chief Medical Officer of Health is a role that all provinces and territories have. Though several different legislative frameworks exist, all Chief Medical Officers have a common core set of responsibilities that, as reflected in the above descriptions of what a public health expert does, involve monitoring and assessing the health of a population, and developing and implementing strategies for improving health outcomes for the population.

14. Section 14 of the *Public Health Act*, which sets out my powers, reflects the responsibilities of a public health specialist described in the materials from the Department of Medicine and the Royal College. Section 14 requires that I shall:

> (a) on behalf of the Minister, monitor the health of Albertans and make recommendations to the Minister and AHS on measures to protect and promote the health of the public and to prevent disease and injury,

(b) act as a liaison between the Government and AHS, medical officers of health and executive officers in the administration of the Act,

(c) monitor the activities of AHS, medical officers of health and executive officers in the administration of this Act, and

(d) that I may give directions to AHS, medical officers of health and executive officers in the exercise of their powers and the carrying out of their responsibilities under the *Public Health Act*.

15. As can be seen from my powers, the *Public Health Act* gives Alberta's Chief Medical Officer of Health two main overarching roles. The first is to monitor and assess the health of the population and provide recommendations to the Minister of Health, to the Deputy Minister of Health, and to AHS, to protect and promote the health of the population. The second is to give directions to others who are specified in the *Public Health Act* such as medical officers of health and executive officers in the exercise of their responsibilities and authorities. All of this is done for the purpose of improving public health outcomes across a wide range of acute and chronic health issues affecting the population of Alberta.

16. As the Royal College's training materials explain, fulfilling these two overarching roles requires the Chief Medical Officer to have developed foundational competencies in clinical medicine and the determinants of health upon which are built further competencies in public health sciences, including but not limited to epidemiology, biostatistics, and surveillance, planning, implementation and evaluation of programs and policies, leadership, collaboration, advocacy, and communication.

17. Thus, Medical Officers of Health have training and practice based in large part on a population focus, which training and practice then provides us with a deep understanding of subjects such as molecular biology, human anatomy, and other basic science that is essential to an understanding of the interaction between people, their environment, and the social environment as well. In summary, my specialized training equips me to treat the population of Alberta as my patient.

The ethical framework in which public health decisions are made

18. The public health specialist's practice is founded on a common core of ethical principles and values that are an integral part of our five-year training program. These ethical principles guide our public health practice, including our decision-making.

19. The Canadian Public Health Association in a working paper entitled *Public Health: A Conceptual Framework* (second edition, 2017), a copy of which is attached as **Exhibit "D"** to this Affidavit also provides a definition of public health practice. The Association's definition connects the specialist's overarching roles with the ethical principles that provide a framework within which the specialist makes public health decisions. The Association's definition states:

> DEFINING PUBLIC HEALTH PRACTICE
>
> Public health practice can be viewed as an approach to maintaining and improving the health of populations that is based on the principles of social justice, attention to human rights and equity, evidence-informed policy and practice, and addressing the underlying determinants of health. Such an approach places health promotion, health protection, population health surveillance, and the prevention of death, disease, injury and disability as the central tenets of all related initiatives. It also means basing those initiatives on evidence of what works or shows promise of working. It is an organized, comprehensive, and multi-sectoral effort.
>
> This definition and the practice of public health have developed over time, and will continue to develop to meet the evolving health requirements of the population. As these demands grow, there will be debates concerning the role and purpose of public health practice and the scope of practitioners' activities. Underlying these debates and developments, however, are an amalgam of concepts and practices that are the foundation and building blocks of public health.https://www.cpha.ca/sites/default/files/uploads/policy/ph-framework/phcf_e.pdf

20. The various types of principles that have provided the framework for Alberta's public health actions and decision-making in response to the COVID-19 pandemic are explained in Alberta Health's document entitled "Alberta's Ethical Framework for Responding to Pandemic Influenza" published in January 2016, which is attached as **Exhibit "E"** to this Affidavit: https://open.alberta.ca/dataset/5ae20e2c-4d4a-4251-bf05-dcdf32d0cd97/resource/5621dbe3-4b27-4c37-9073-58d762312d6f/download/apip-pandemic-ethics-framework-2016.pdf

The proportionality principle and the use of least restrictive means

21. Chief among these core principles is the proportionality principle that requires actions taken to protect the public health from harm and that result in the restriction of liberties and freedoms to be proportionate to the risks and to the benefits of the proposed action. This requires not only that the proposed measures be required in order to achieve the public health purpose, but also that if it is necessary to restrict a right or freedom in achieving the purpose, the least restrictive means that will do so should be chosen. Thus, mandatory public health measures are only used when voluntary public health measures would not be sufficient to prevent the harm to public health.

My legislative authority

22. If necessary, I also have the tools under s. 29 of the *Public Health Act* to address communicable disease outbreaks or a state of public health emergency by judiciously applying restrictions when necessary to intervene on outbreaks and in public health emergencies ("CMOH Orders"). Section 29(2)(b)(i) of the Act has provided me with the power to take whatever steps I consider necessary: (A) to suppress COVID-19 in those who may have already been infected with COVID-19; (B) to protect those who have not already been exposed to COVID-19; (C) to break the chain of transmission and prevent spread of COVID-19; and (D) to remove the source of infection. I also have the authority under section 29(2.1), to take whatever other steps, in my opinion, are necessary in order to lessen the impact of the public health emergency.

23. Consistent with the proportionality principle, and the other principles framing Alberta's public health response, mandatory CMOH Orders are issued pursuant to s. 29 only as a last resort when other voluntary measures are not successful or not possible. Further, more wide-ranging orders are only used if targeted measures will not achieve the public health objective. Mandatory CMOH Orders under s. 29 are, however, sometimes necessary, for example, if the behaviour of an individual or a group will put the health of the larger public at risk. In such situations, the Chief Medical Officer of Health has the necessary powers to minimize the risk through mandatory orders that create restrictions that are both necessary and proportional to the risk. My legislative powers have been critical to Alberta's management of the COVID-19 public health crisis.

24. The physician appointed as the Chief Medical Officer of Health therefore has a tremendous responsibility to provide a trusted, credible voice both when there is an urgent need to assess risks, contend with fear, and galvanize groups to act during an emergency as well as in day-to-day responses to public health issues in the province, including when issuing voluntary public health guidance or mandatory public health restrictions.

The Chief Medical Officer of Health provides advice to elected officials who make the final decisions on Alberta's public health measures

25. The majority of the time and resources of the office of the Chief Medical Officer of Health have been spent responding to the COVID-19 pandemic since early in 2020. During this time, I have therefore obtained considerable knowledge and understanding about the SARS-CoV-2 virus and the COVID-19 disease.

26. Alberta Health's Emergency Operations Centre ("EOC") is the organizational unit in the Ministry of Health responsible for overseeing COVID-19 health policy development and implementation. The EOC is made up of staff from the Ministry of Health. I have worked closely with the EOC Incident Commander and have served as the Expert Advisor to the EOC in developing recommendations and policy options for the COVID-19 response.

27. I have also had the responsibility to provide advice to the Premier and Cabinet, including the Priorities Implementation Cabinet Committee (PICC) and the Emergency Management Cabinet Committee (EMCC) on the need to declare a state of public health emergency in response to the COVID-19 pandemic, and to discuss and finalize public health measures to address the threat caused by COVID-19. The Priorities Implementation Cabinet Committee includes the Premier, and the Ministers of Health; Treasury Board and Finance; Justice and Solicitor General; Energy; Transportation; Environment and Parks; Jobs, Economy and Innovation; and Children's Services. The EMCC includes the Premier, and the Ministers of Health; Treasury Board and Finance; Justice and Solicitor General; Transportation; Environment and Parks; Education, Indigenous Relations, Children's Services, Community and Social Services; and Member of the Legislative Assembly of Alberta Mickey Amery.

28. In my role, I am not directed by elected officials what advice to give, rather I give my advice as I am directed and required to do by the *Public Health Act*, and the advice that I give is always my best advice based on the best available evidence. As Chief Medical Officer of Health, I have done my best throughout the pandemic to monitor the health of Albertans and provide advice and recommendations to protect their health based on the best evidence available.

29. While my office and the Ministry of Health and AHS have played a lead role in informing the Province of Alberta's strategy to respond to the COVID-19 pandemic, under the *Public Health Act*, the Chief Medical Officer of Health is not the final decision-maker. Rather, the Chief Medical Officer provides advice and recommendations to elected officials on how to protect the health of Albertans. Those elected officials take that advice as one part of the considerations in the difficult decisions that they have had to make in response to COVID-19. The final policy decision-making authority rests with the elected officials, and these policy decisions are then implemented through the legal instrument of CMOH Orders.

B. The Ministry of Health and The Regional Health Authority (Alberta Health Services)

Alberta Health Services

30. The Chief Medical Officer of Health, and the Ministry of Health, as part of government, provide high-level direction and set health policy, and AHS, as the regional health authority, carries out the operationalization of that policy. AHS is a fully-integrated health system, responsible for delivering health services to nearly 4.4 million people living in Alberta, as well as to some residents of Saskatchewan, B.C. and the Northwest Territories.

31. AHS has more than 103,000 direct employees (excluding Covenant Health and other contracted service providers) and almost 11,800 staff working in AHS' wholly-owned subsidiaries such as Alberta Precision Laboratories, Carewest and CapitalCare Group. AHS is also supported by nearly 15,100 volunteers and more than 10,800 physicians practicing in Alberta, approximately 8,200 of whom are members of the AHS medical staff (physicians, dentists, podiatrists, oral and maxillofacial surgeons).

32. As explained in the pre-amble to the *Regional Health Authorities Act*, RSA 2000, c R-10, AHS is the sole regional health authority for Alberta; is Canada's first single province-wide health authority; and was established because the Government of Alberta believed a single regional health authority was the most effective and efficient way to deliver health services to Albertans. AHS brought together 12 formerly separate health entities in the province including nine geographically based health authorities as well as the Alberta Alcohol and Drug Abuse Commission, Alberta Mental Health Board and Alberta Cancer Board.

33. The AHS Emergency Coordination Centre (ECC) is AHS' incident response team for urgent situations. Working with me and other medical officers of health and emergency planners, ECC has addressed questions of health operations and operational policy across the organization as part of Alberta's response to the COVID-19 pandemic. I have worked very closely with AHS and the ECC during the pandemic. The Affidavit of Deb Gordon provides details on how AHS has planned and managed health care capacity in response to the COVID-19 pandemic as well as evidence on AHS' contact tracing efforts.

34. Section 5 of the *Regional Health Authorities Act* sets out AHS' responsibilities as follows, AHS shall: (a) plan for the provision of health services in the health region, and (b) provide health services in the health region. In carrying out its responsibilities under this section, AHS shall (a) promote and protect the health of the population in the health region and work toward the prevention of disease and injury, (b) assess on an ongoing basis the health needs of the health region, (c) determine priorities in the provision of health services in the health region and allocate resources accordingly, (d) ensure that reasonable access to quality health services is provided in and through the health region, and (e) promote the provision of health services in a manner that is responsive to the needs of individuals and communities and supports the integration of services and facilities in the health region.

35. Pursuant to s. 6 of the *Regional Health Authorities Act*, and subject to the Act and the regulations, AHS has the rights, powers and privileges of a natural person, and may delegate any of its powers and duties under the Act or any other Act to an AHS committee, or to any AHS employees, officers, agents, or to a community health council.

Lieutenant Governor and Ministerial Powers to control AHS

36. However, the *Regional Health Authorities Act* also gives the Lieutenant Governor in Council and the Minister very broad powers to control AHS and its members and to direct how AHS provides health services to Albertans. Pursuant to s. 8 of the Act, the Minister of Health may direct AHS for the purpose of (a) providing priorities and guidelines for it to follow in the exercise of its powers, and (b) co-ordinating the work of the regional health authority with the programs, policies and work of the Government and public and private institutions in the provision of health services in order to achieve the best health outcome and to avoid duplication of effort and expense.

37. The Minister may also by order, under s. 2 of the Act, establish any other regional health authorities in addition to or instead of the AHS, or disestablish the AHS and wind-up its affairs; and the Minister may by order, under s. 11, dismiss all the members of the AHS if he considers that AHS is not properly exercising its powers or carrying out its duties under the Act, or if he considers for some other reason it is in the public interest to do so.

38. The Minster also has the power under s. 16 of the *Regional Health Authorities Act*, to do any other thing that he considers necessary to promote and ensure the provision of health services in Alberta, and both the Minister, in s. 24, and the Lieutenant Governor in Council, in s. 17 and s. 23, have broad regulation making powers under the *Regional Health Authorities Act*.

C. SARS-CoV-2 is a New and Infectious Virus that Has Caused a Global pandemic

COVID-19 and the SARS-CoV-2 virus

39. On February 11, 2020 the World Health Organization announced an official name for the disease that is causing the 2019 novel coronavirus pandemic, first identified in Wuhan China. The new name given to this disease was coronavirus disease 2019, abbreviated as COVID-19, in which "CO" stands for corona, "VI" for virus, and "D" for disease. Formerly, this disease was referred to as "2019 novel coronavirus" or "2019-nCoV."

40. COVID-19 is a new respiratory disease caused by the Severe Acute Respiratory Syndrome Coronavirus 2, or "SARS-CoV-2" virus. The disease COVID-19 was first recognized in the city of Wuhan, China in late 2019. The SARS-CoV-2 virus is a type of coronavirus, which can infect humans and animals. Not all coronaviruses infect humans. Those strains that do, and

that are new to humans, are called "novel". The SARS-CoV-2 is a novel coronavirus as it was found to infect humans in January 2020.

41. COVID-19 primarily affects the respiratory tract and lungs but can also affect other organs. COVID-19 is highly communicable and contagious among people. SARS-CoV-2 is spread primarily from close person to person contact. The virus may be transmitted by respiratory droplets (>5-10 um in diameter) or smaller droplet nuclei (small-particle aerosols) (<5 um) produced when an infected person breathes, coughs, sneezes, talks, or sings. Aerosols remain airborne while traveling longer distances than droplets.

42. SARS-CoV-2 can be spread through direct or indirect (surfaces) contact with an infected person. A person becomes infected by inhaling the infected droplets or aerosols or by the droplets or aerosols coming into direct contact with the mucous membranes of the person's nose, mouth or eyes. The virus may also be transmitted by a person touching a surface of an object or other person (i.e. handshake) contaminated with the virus and then touching their own nose, mouth or eyes.

Activities and locations associated with a higher risk of transmission of the virus

43. Evidence shows singing, talking loudly and shouting, and activities that result in heavy breathing, such as heavy exercising, are higher risk activities for the spread of the virus. These higher risk activities pose a higher risk of transmission of the SARS-CoV-2 virus because they result in more expulsions of air than other activities, and with increased expulsions of air, there is an increased risk of respiratory droplets or aerosols, which is one factor that may increase transmission.

44. These higher risk activities may also occur in higher risk settings, such as in indoor settings or settings where individuals will remain for prolonged periods of time. Spending time in crowded indoor locations with inadequate ventilation is another factor that can lead to a higher risk of transmission. For example, choirs performing indoors are a particular concern for the spread of the virus.

45. The Government of Canada's website modified June 29, 2021 (https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-

infection/health-professionals/main-modes-transmission.html#_Settings_with_higher) provides the following information about locations with a higher risk of transmission, a print-out of which is attached as **Exhibit "F"** to this Affidavit:

> ***Settings with higher risk of transmission***
>
> Outbreak investigations and scientific studies are revealing more about COVID-19 and this new knowledge is being applied to reduce its spread. We know that the virus is most frequently transmitted when people are in close contact with others who are infected with the virus (either with or without symptoms). We also know that most transmission occurs indoors.
>
> Reports of outbreaks in settings with poor ventilation suggest that infectious aerosols were suspended in the air and that people inhaled the virus at distances beyond 2 metres. Such settings have included choir practice, fitness classes, and restaurants, as well as other settings. Transmission can be facilitated by certain environmental conditions, such as re-circulated air. Activities that increase generation of respiratory droplets and aerosols may increase risk in these settings (such as singing, shouting, or exercising).
>
> It is still unclear how easily the virus spreads through contact with surfaces or objects.

Pre-symptomatic transmission

46. The time from infection with SARS-CoV-2 until the development of observable symptoms is called the incubation period. The incubation period can last 14 days or very rarely longer. Unfortunately, infected people can transmit SARS-CoV-2 to others beginning about 48 hours before symptoms are present (pre-symptomatic transmission) until at least 10 days after, longer if symptoms continue past 10 days.

47. Evidence points to a small number of people being responsible for seeding a vast majority of new COVID-19 infections. The science of COVID-19 dispersion is not fully understood, but experts agree that some people emit more virus than others as described in the article by (Asadi et al.) attached as **Exhibit "G"** to this Affidavit while others seem to develop higher amounts of the virus in their system, increasing their odds of transmitting the virus, as described in the article attached as **Exhibit "H"** to this Affidavit by (Jones et al.) One study, attached as **Exhibit "I"** to this Affidavit by (Goyal et al.), estimates that about 62 percent of transmissions to multiple individuals happened when the index case was pre-symptomatic.

Asymptomatic transmission

48. Not all people infected with SARS-CoV-2 develop symptoms but, even without symptoms, an infected person can transmit the virus to others. This is called asymptomatic transmission. Asymptomatic and especially pre-symptomatic transmission of SARS-CoV-2 does occur. There is strong scientific evidence that virus transmission primarily occurs from a few days before symptom onset up to about five days after. This issue is discussed in further detail in Dr. Jason Kindrachuk's filed expert report in this matter.

49. While Dr. Bhattacharya at p. 10 of his report states "according to a comprehensive survey of the literature on reported cases through early June 2020, about 20 percent of COVID-19 cases are asymptomatic", the cited paper did not make an estimate of the contribution of pre-symptomatic transmission. However, importantly, it acknowledged that pre-symptomatic virus spread was substantial enough to justify continued social distancing measures.

COVID-19 symptoms and outcomes

50. Infection with the SARS-CoV-2 virus may involve a range of potential symptoms that can also vary in frequency and severity. The most common symptoms have included fever, cough, fatigue, shortness of breath, loss of appetite, and loss of smell and taste. Many who are infected experience only mild symptoms followed by a quick return to completely normal health. However, certain segments of the population suffer very serious symptoms only treatable through hospitalization, and some of these individuals require admission to an Intensive Care Unit (ICU) and ventilation. COVID-19 has also been fatal for over 2,300 people in Alberta. Finally, it is also important to note that a proportion of those with COVID-19, even some with initial mild illness, experience symptoms for many months following their infection, and these persistent symptoms can be life-altering.

51. Thus, COVID-19 has both morbidity outcomes (illness) and mortality outcomes (death), and these outcomes may both impact hospitalization and require significant and critical medical treatment, including admission to intensive care. The risk of serious outcomes, including deaths, hospitalizations and ICU admissions, grows with the age and presence of pre-existing conditions in the population.

COVID-19 and mortality in Alberta

52. In Alberta, as of July 6, 2021, there have been 2,307 deaths due to COVID-19. The average age of death is 80 (range: 20-107), and the majority of Alberta's deaths have been in the 80+ age range (1,353 or 59 percent). One in three deaths (766 people) have been between the ages of 60 and 79, and 187 of the people that have died in Alberta due to COVID-19 have been under the age of 60 (8.1 percent of total).

COVID-19: comorbidities and serious outcomes

53. COVID-19 disproportionally causes adverse health outcomes, including death, in people in two segments of the population: (1) those with pre-existing medical conditions, and/or (2) those over 65 years of age. People with these characteristics are more likely to have been hospitalized and more likely to have been admitted to ICUs with COVID-19.

54. Statistics Canada states the following on COVID-19 comorbidities and pre-existing conditions as of May 14, 2021 at https://www150.statcan.gc.ca/n1/daily-quotidien/210514/dq210514c-eng.htm, a printout of which is attached as **Exhibit "J"** to this Affidavit:

> The risk of severe outcomes due to COVID-19 varies depending on individual vulnerabilities. One of these susceptibilities is pre-existing health conditions. The Public Health Agency of Canada has advised that certain pre-existing conditions such as diabetes, chronic obstructive pulmonary disease, cancer and heart disease put individuals at higher risk of severe illness or death from COVID-19. In addition, the suggested Canadian vaccination rollout prioritizes vulnerable populations, including those with underlying conditions. The provisional data released today confirm that about 9 out of 10 Canadians who have died of COVID-19 had at least one other condition or complication, or comorbidity, reported on their medical certificate of death.
>
> **Almost 90% of people who died of COVID-19 in 2020 had at least one other comorbidity**
>
> Of the nearly 15,300 people who died of COVID-19 between March and December 2020, 89% had one or more other conditions or complications reported on their death certificate. In fact, almost two-thirds (65%) had two or more comorbidities and almost half (46%) had three or more comorbidities reported. These results, along with the specific conditions listed on the death certificate, highlight some of the populations in Canada most vulnerable to severe outcomes of COVID-19. Although

individuals had pre-existing conditions, it does not imply that they were at risk of dying if there had been no COVID-19 infection.

55. The Government of Canada outlines *"People who are at risk of more severe* disease *or outcomes from COVID-19"*, in its document of that name dated October 23, 2020 and published December 8, 2020, and which is attached as **Exhibit "K"** to this Affidavit (https://www.canada.ca/content/dam/phac-aspc/documents/services/publications/diseases-conditions/people-high-risk-for-severe-illness-covid-19/people-high-risk-for-severe-illness-covid-19-eng.pdf) as follows:

- Older adults (increasing risk with each decade, especially over 60 years).
- People of any age with chronic medical conditions including:
  - lung disease
  - heart disease
  - hypertension (high blood pressure)
  - diabetes
  - kidney disease
  - liver disease
  - dementia
  - stroke
- People of any age who are immunocompromised, including those:
  - with an underlying medical condition (e.g., cancer)
  - taking medications that lower the immune system (e.g., chemotherapy)
- People living with obesity (BMI of 40 or higher).

56. In Alberta, the majority of fatalities as of July 6, 2021 (76.3 percent) have had 3 or more comorbidities (1,760) as detailed in the following table found on the Government of Alberta's website at: https://www.alberta.ca/stats/covid-19-alberta-statistics.htm. A copy of Figures and Tables from this website as at July 6, 2021 is attached as **Exhibit "L"** to this Affidavit.

Table 6. Number and percent of health conditions among COVID-19 deaths. Data updated on 2021-07-01.

Condition	Count	Percent
Hypertension	1939	84.3%
Cardio-Vascular Diseases	1202	52.2%
Renal Diseases	1156	50.2%
Dementia	1054	45.8%
Diabetes	1038	45.1%
Respiratory Diseases	938	40.8%
Cancer	552	24.0%
Stroke	457	19.9%
Liver Diseases	102	4.4%
Immuno-Deficiency Diseases	66	2.9%

Note:

One individual can have multiple conditions.

57. The following graph from that website shows the percent of COVID-19 cases with no comorbidities, one comorbidity, two comorbidities, or three or more comorbidities by case severity: non-severe, hospitalized but non-ICU, ICU but not deceased, and deceased. The comorbidities included are indicated in the description under the graph.

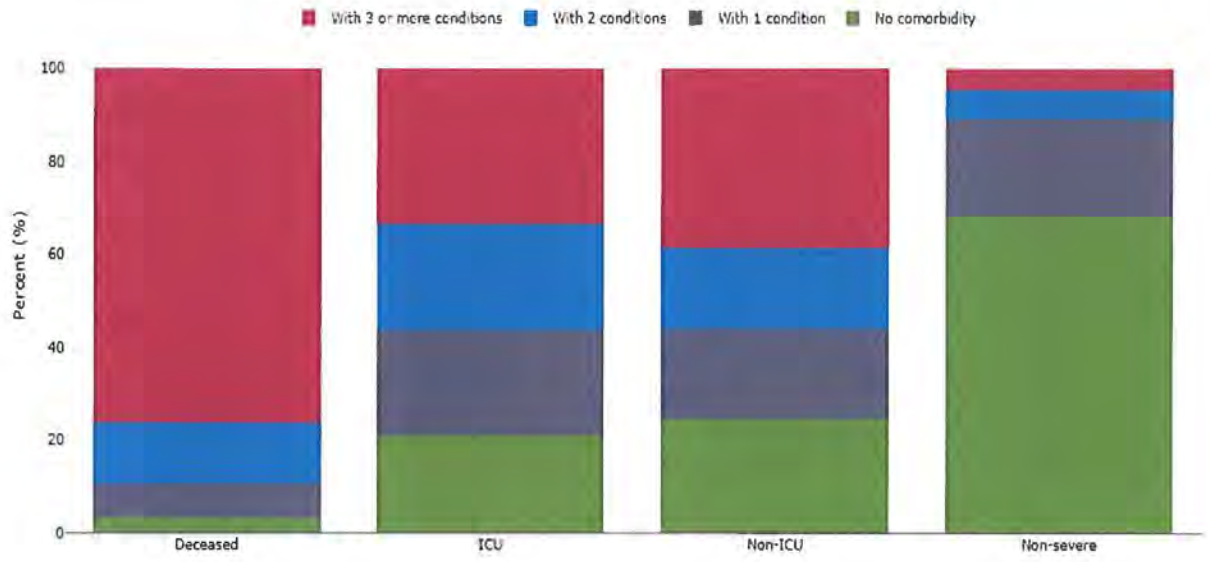


Figure 17: Percent of COVID-19 cases with no comorbidities, one comorbidity, two comorbidities, or three or more comorbidities by case severity (non-severe, hospitalized but non-ICU, ICU but not deceased, and deceased), all age groups and both sexes combined, all Alberta. Comorbidities included are: Diabetes, Hypertension, COPD, Cancer, Dementia, Stroke, Liver cirrhosis, Cardiovascular diseases (including IHD and Congestive heart failure), Chronic kidney disease, and Immuno-deficiency. Data updated on 2021-07-06.

58. However, to be clear, not all comorbidities are the result of pre-existing conditions: common comorbidities such as pneumonia and respiratory failure can also be the result of COVID-19 rather than underlying reasons why the individual had a severe COVID-19 outcome.

COVID-19 and children

59. Although risk of death is significantly higher in some groups, and while children tend to experience less severe symptoms of the disease (unless they have an underlying condition), COVID-19 continues to negatively impact young healthy adults. There is a body of evidence that supports this, for example:

a. Faust JS, Krumholz HM, Du C, et al. All-Cause Excess Mortality and COVID-19–Related Mortality Among US Adults Aged 25-44 Years, March-July 2020. JAMA. Published online December 16, 2020, and attached as **Exhibit "M"** to this Affidavit,

b. Cunningham JW, Vaduganathan M, Claggett BL, et al. Clinical Outcomes in Young US Adults Hospitalized With COVID-19. *JAMA Intern Med.* Published online September 09, 2020, and attached as **Exhibit "N"** to this Affidavit.

60. Evidence also supports that children can transmit the virus, and that older children and teenagers may transmit the virus as efficiently as adults. The issue of transmission by those under 18 is discussed in more detail in the expert report of Dr. Jason Kindrachuk.

61. Further, while it now is recognized that symptoms of SARS-CoV-2 infection can persist for months following acute COVID-19 disease, the understanding of the long term effects of COVID-19 are not yet completely understood. The current knowledge on long term effects of the disease is discussed in more detail in the expert report of Dr. Jason Kindrachuk.

COVID-19 and morbidity in Alberta

62. People not in a high risk group can also experience adverse health outcomes after becoming infected with the SARS-CoV-2 virus that may require hospitalization or admission to an ICU for treatment. In Alberta, as of July 6 the average age for COVID-19 cases with an ICU stay was 57 years (range: 0-90), the average age for COVID cases hospitalized was 60 years (range: 0-104), and the average age for COVID cases not hospitalized was 34 years (range: 0-

108): https://www.alberta.ca/stats/covid-19-alberta-statistics.htm#severe-outcomes, as shown on Figure 13 and Table 5 in **Exhibit L**. Since February 1, 2021, 40 percent of those hospitalized with COVID-19 in Alberta have been under 50.

63. The table below provides a breakdown of Alberta's total hospitalizations, ICU admissions and deaths among COVID-19 cases by age as of July 1, 2021. Of particular significance for the purposes of Alberta's ability to plan for health care capacity is that, as illustrated in the table below, for every 100 people testing positive for COVID-19 in Alberta, just over 4 of them (4.1) were hospitalized, just under 1 person (0.8) had to be admitted to ICU, and 1 person out of every 100 testing positive in Alberta died as a result of the disease. These numbers are very important in assessing and managing hospital capacity and resources as part of Alberta's response to the pandemic.

Table 5. Total Hospitalizations, ICU admissions and deaths (ever) among COVID-19 cases in Alberta by age group

Age Group	Cases	Hospitalized			ICU			Deaths		
	Count	Count	Case rate	Pop. rate	Count	Case rate	Pop. rate	Count	Case rate	Pop. rate
Total	232097	9626	4.1	217.7	1807	0.8	40.9	2301	1.0	52.0
Under 1 year	1406	58	4.1	112.1	14	1.0	27.1	0	0.0	0.0
1-4 years	8838	42	0.5	19.3	8	0.1	3.7	0	0.0	0.0
5-9 years	12247	25	0.2	9.0	12	0.1	4.3	0	0.0	0.0
10-19 years	31440	158	0.5	29.6	22	0.1	4.1	0	0.0	0.0
20-29 years	41874	517	1.2	87.4	61	0.1	10.3	11	0.0	1.9
30-39 years	44142	924	2.1	129.1	136	0.3	19.0	14	0.0	2.0
40-49 years	36447	1174	3.2	193.0	242	0.7	39.8	47	0.1	7.7
50-59 years	27064	1676	6.2	304.3	421	1.6	76.4	114	0.4	20.7
60-69 years	15592	1701	10.9	358.5	489	3.1	103.1	284	1.8	59.9
70-79 years	6648	1529	23.0	586.6	313	4.7	120.1	479	7.2	183.8
80+ years	6274	1819	29.0	1296.8	88	1.4	62.7	1351	21.5	963.2
Unknown	125	3	2.4	NA	1	0.8	NA	1	0.8	NA

Note:

Based on total hospitalizations and ICU admissions ever.

Row percent is out of the number of cases in each age group.

Each ICU admission is also included in the total number of hospitalization

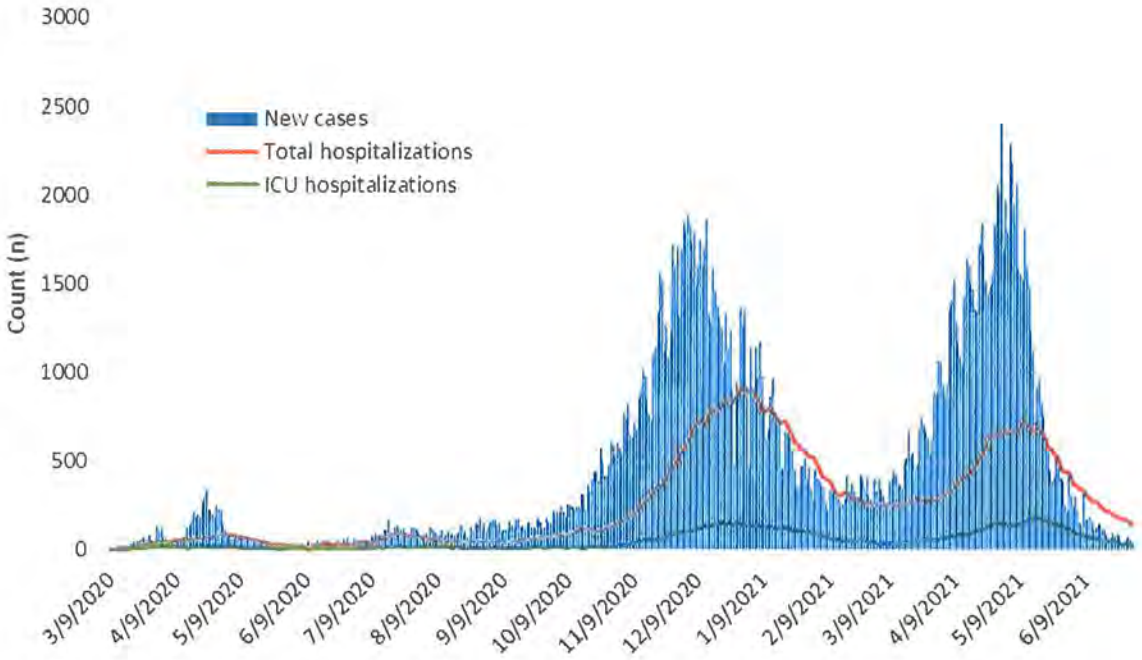
Case rate (per 100 cases)

Population rate (per 100,000 population)

COVID-19 cases and Alberta's health care capacity

64. The rapid spread of the SARS-CoV-2 virus and resulting COVID-19 disease is associated with a corresponding increase in hospitalizations, including ICU admissions and deaths. By comparison, this requirement for inpatient health care and deaths resulting from COVID-19 is significantly higher than that associated with seasonal influenza. Over the last 10 years combined, reported deaths from seasonal influenza total just 659 people in Alberta compared to the over 2,300 deaths reported resulting from COVID-19 in Alberta since the first case of COVID-19 was recognized on March 5, 2020.

65. Seasonal influenza also results in significantly fewer ICU and hospital stays than SARS-CoV-2. For example, the 2018-2019 influenza season resulted in a total of 341 ICU stays and 2,310 hospital stays, and the 2019-2020 influenza season resulted in a total of 262 ICU stays and 2,339 hospital stays over a year. By comparison, in Alberta between March 5, 2020 and June 15, 2021 there have been 1,785 ICU stays, and 9,600 COVID-19 hospital stays. The following graph illustrates COVID-19 cases in Alberta from March 2020 until July 1, 2021, and the corresponding impact on ICU and hospital admissions. As also illustrated in the graph below, the impact on hospital and ICU admissions can be seen to lag by approximately 2 weeks the identification of a rise in cases. This lag is because people who test positive for infection with the SARS-CoV-2 virus generally do not seek admission to hospital until their symptoms become more severe. To be clear, COVID-19 has threatened to overrun the health care system in Alberta twice in the last year. Seasonal influenza has never done so.



66. As shown in the following graph, deaths attributed to COVID-19 spiked significantly in Alberta between November 2020 to January 2021 during the second wave of the pandemic.

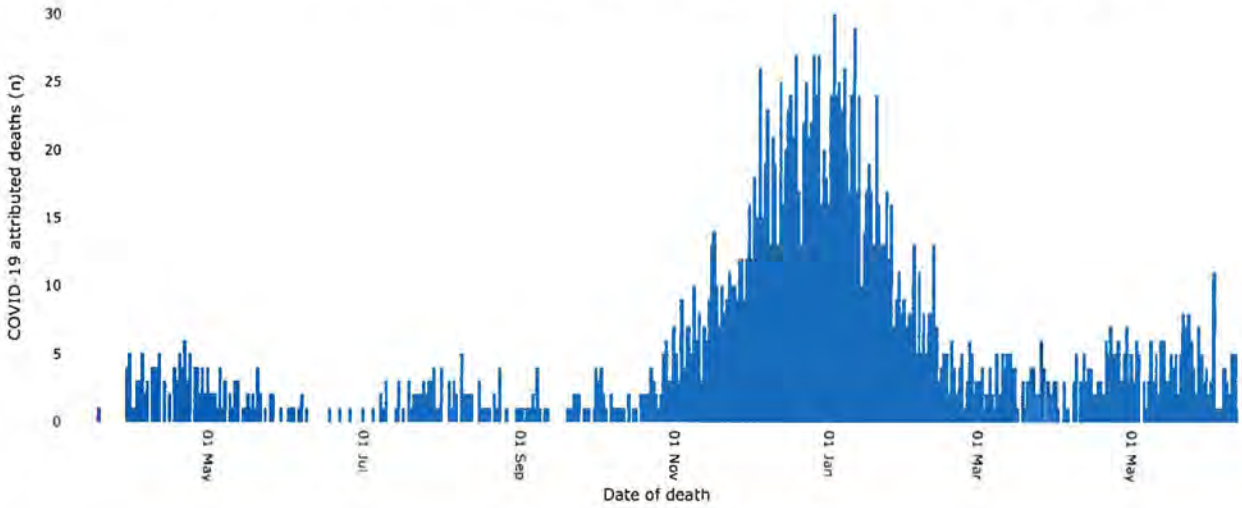


Figure 16: Daily COVID-19 attributed deaths. Data are subject to change; when death date is unavailable the date reported to Alberta Health is used until a death date is known.

67. However, although cases were higher in Alberta during the third wave than the second, Alberta was able to control the spread of the virus before it could overrun the health care system and avoid the equivalent spike in deaths through a combination of immunization and public health measures.

Reporting deaths resulting from COVID-19 in Alberta

68. Alberta Health uses the following definition from the Public Health Agency of Canada for COVID-19 deaths:

> A death resulting from a clinically compatible illness, in a probable or confirmed COVID-19 case, unless there is a clear alternative cause of death identified (e.g., trauma, poisoning, drug overdose).

69. All COVID-19 deaths are assessed by AHS and recorded as COVID-19 if there is a belief the death was directly or indirectly related to COVID-19. Since COVID-19 can impact such a large range of organs/systems, it was decided to leave it to the judgement of treating physicians to make the call rather than trying to specifically define a clinically compatible illness. A Medical Officer of Health or relevant public health authority may also use their discretion when determining if a death was due to COVID-19, and their judgement will supersede the above criteria. In summary, Alberta Health's routine reporting of COVID-19 deaths, as with Alberta Health's reporting of opioid deaths, do not wait for the cause of death information from Alberta Vital Statistics. Having timely reporting of COVID-19 deaths assists in making timely public health decisions. There is a lag from the time of death to the time of reporting the official cause of death such that Alberta's ability to make timely decisions would be further limited if it were to wait for Vital Statistics to report COVID-19 deaths.

70. COVID-19 deaths are submitted to Alberta Health from AHS *via* the Communicable Disease and Outbreak Management System. As reported by Alberta Health, deaths due to COVID-19 may be attributed when COVID-19 is either the cause of death or is a contributing factor.

COVID-19 and variants of concern

71. All viruses evolve and mutate over time as they replicate. Variants are viruses that have evolved while reproducing inside an infected person's cells and variants can be transmitted to others where they may continue to mutate as they spread. Thus, SARS-CoV-2 has evolved, leading to the detection of new variants. Not all variants raise significant concerns for public heath purposes. Rather, a variant becomes a variant of concern if it can spread more easily or decrease the efficacy of vaccines (increased transmissibility), or it can cause more serious

illnesses (increased severity) thereby resulting in increased hospitalizations, ICU admissions and deaths.

72. As of July 6, 2021 there are four Variants of Concern identified globally, all of which have been identified in Alberta as described at: https://www.alberta.ca/covid-19-variants.aspx#:~:text=Overview,data%20in%20Alberta, a printout of pages 1-3 of which is attached as **Exhibit "O"** to this Affidavit. These are the Alpha variant B.1.1.7 (first described in the United Kingdom), which is the dominant strain in Alberta, the Beta variant B.1.351 (first described in South Africa), the Gamma variant P.1 (first described in Brazil) and the Delta variant B.1.617.2 (first described in India).

73. As stated in Exhibit O, we know that all four variants spread more easily than the original COVID-19 strain. The Government of Canada's website at: https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection.html#a8 (modified June 15, 2021), a printout of which is attached as **Exhibit "P"** to this Affidavit, states that evidence demonstrates the Alpha (B.1.1.7) and Delta (B.1.617.2) variants are at least 50 percent easier to spread than the original virus.

74. The World Health Organization states the following on protecting against the transmission of variants on its website https://www.who.int/en/activities/tracking-SARS-CoV-2-variants/ as at July 8, 2021:

> Reducing transmission through established and proven disease control methods [and] measures, as well as avoiding introductions into animal populations, are crucial aspects of the global strategy to reduce the occurrence of mutations that have negative public health implications.
>
> Current strategies and measures recommended by WHO continue to work against virus variants identified since the start of the pandemic. Evidence from multiple countries with extensive transmission of VOCs has indicated that public health and social measures (PHSM), including infection prevention and control (IPC) measures, have been effective in reducing COVID-19 cases, hospitalizations and deaths. National and local authorities are encouraged to continue strengthening existing PHSM and IPC measures. Authorities are also encouraged to strengthen surveillance and sequencing capacities and apply a systematic approach to provide a representative indication of the extent of transmission of SARS-CoV-2 variants based on the local context, and to detect unusual epidemiological events.

COVID-19 and evolving scientific knowledge

75. Because COVID-19 is a new threat and we continue to learn new things about it, the best evidence with respect to COVID-19 has changed and evolved over the course of the pandemic. Throughout the pandemic we have sought to learn and adjust to the best evidence to allow Alberta to most effectively minimize both the risks of public health measures and the risks of COVID-19.

76. Given the rapidly evolving scientific knowledge on COVID-19 and the SARS-CoV-2 virus, many areas require further study, as discussed in more detail in the expert report of Dr. Jason Kindrachuk, including: long-term health consequences; the transmissibility of the virus by and among children; the degree of asymptomatic and pre-symptomatic transmission; duration of immunity after infection or vaccination; the effect of new variants of concern, including on the efficacy of the approved vaccines; the effect of infection on reproductive health, including of foetuses; the degree to which pre-existing conditions make people more vulnerable; and the benefits and detriments of various non pharmaceutical interventions.

77. Therefore, knowledge about the virus and disease is continually enhanced over time as more is learned. The state of the evidence at each given moment in time depends on what was known in the period of time being reviewed. At the very beginning of the pandemic, a lack of scientific evidence on the effectiveness of the public health measures, including the degree of public compliance and the collateral effects, meant decisions had to be taken in circumstances of significant uncertainty. Considerably less was known about the virus and the disease during the first wave of the pandemic in March and April 2020 than during the second wave in November and December 2020. More was known about the underlying science during the third wave than either of the two waves before.

78. Public health evidence is established over time through research, surveillance, epidemiology and community outreach. As new findings are made about the virus and disease, evidence is analyzed and assessed. Public health officials from Alberta, Canada and around the world have worked together to develop and share new information about how to best respond to the pandemic.

79. As explained in more detail in the Affidavit of Dr. Kimberley Simmonds, EOC's Analytics team conducts risk assessments to inform Alberta's pandemic response policy

decisions. The Analytics team reviews all the available data to identify key trends. The team also reviews the literature and experiences in other jurisdictions to supplement the local evidence. The role of the Analytics team during the COVID response was to provide the evidence to the Chief Medical Officer of Health and senior leadership at Alberta Health, who in turn determined what recommendations would proceed to elected officials who were ultimately the ones responsible for making the decisions.

80. In Alberta, various people and entities have exchanged knowledge about the disease and virus since the start of the pandemic, including:

- Public health experts and medical officers of health with Alberta Health and with AHS.
- Epidemiologists/data analysts/mathematical modellers - as explained in Dr. Simmonds' Affidavit, the EOC's Analytics team that supports Alberta's COVID-19 response has grown over the pandemic to approximately ten staff consisting of epidemiologists/data analysts, and a mathematical modeller supported by the University of Alberta's mathematics department. The Public Health Agency of Canada has also provided one to two epidemiologists to support the team's more complex outbreak investigations.
- Alberta Precision Laboratories - I work with the Provincial Laboratory for Public Health, currently operating as part of Alberta Precision Laboratories: a wholly owned subsidiary of AHS. The Provincial Laboratory's work is foundational in all of our public health work, and has been a critical component of our COVID-19 response as described in more detail below.
- 2019-nCoV Scientific Advisory Group (SAG) – SAG's membership consists of various subject matter experts and representatives from a number of disciplines as shown in SAG's Terms of Reference attached as **Exhibit "Q"** to this Affidavit. SAG's role is to create high-quality evidence syntheses to aid in the decision-making of Alberta Health and ECC, and to provide recommendations where possible based on quality and robustness of the evidence and resources available in Alberta. SAG's work is guided by existing review resources (e.g. Oxford University COVID rapid evidence review service and similar organizations).
- Health service providers, including acute care specialists (ER, ICU), and their representative organizations.
- Staff within the Ministry of Health within the structure of the EOC, senior policy advisors, and elected officials.

81. Nationally, various organizations have been involved in the COVID-19 response. For example, the Pan-Canadian Public Health Network (the "PCPHN") is an important Federal/Provincial/Territorial (F/P/T) coordinating body that has been working for many years on preparing a framework for responding to events such as this. The PCPHN's Federal/Provincial/Territorial Public Health Response Plan for Biological Events was published in 2018 as a guide to roles and responsibilities (the "F/P/T Public Health Response Plan"), which has informed the COVID-19 response in Canada. This plan was prepared:

> ... as an overarching governance framework to guide F/P/T public health responses to biological events. It was developed by an expert task group comprised of experts in public health and emergency management, as identified by members of the Public Health Infrastructure Steering Committee (PHI-SC) and the Communicable and Infectious Disease Steering Committee (CID-SC). It was approved by PHN on October 17, 2017.

82. Attached as **Exhibit "R"** to this Affidavit are sections from the F/P/T PH Response Plan containing the above quotation and providing information about how federal, provincial and territorial partners work together in a coordinated way during a pandemic. The entire F/P/T Response Plan is at: https://www.canada.ca/en/public-health/services/emergency-preparedness/public-health-response-plan-biological-events.html.

83. In addition to using the F/P/T Response plan as a foundation, I or a representative from my team have been involved in the following inter-jurisdictional bodies:

a. The **Special Advisory Committee** ("SAC"), established in January of 2020 with members from the PCPHN Council as well as Chief Medical Officers of Health from every province and territory, supports coordination of the COVID-19 response across the country, both directly and by providing advice to the Federal-Provincial Territorial ("FPT") Conference of Deputy Ministers of Health..

b. The **Technical Advisory Committee** (the "TAC"), also established in January 2020, is tasked with deliberating on technical information that impacts policy and response planning. Members include technical representatives from each province and territory as well as members from federal departments. Technical documents endorsed by TAC most often come to SAC for final approval, and SAC is able to delegate technical questions to TAC for input.

c. The **Council of Chief Medical Officers of Health** (the "CCMOH") is a body that provides public health clinical expertise to the F/P/T COVID-19 response and other public health issues. Members include the Chief Medical Officer of Health from each

provincial and territorial jurisdiction, Canada's Chief Public Health Officer, the most senior Public Health Physician of the First Nations and Inuit Health Branch of Indigenous Services Canada, the Chief Medical Officer from the First Nations Health Authority, and *ex-officio* members from other federal government departments. The CCMOH supports and coordinates with SAC.

84. Through the committees and mechanisms above, we have the opportunity to hear information from other jurisdictions internationally as the Public Health Agency of Canada is responsible for liaising with colleagues in other countries. Emerging information from other jurisdictions is shared with these groups across the country to inform our response.

D. Alberta's Approach to Responding to the COVID-19 Pandemic

The role of the CMOH in the decision-making process

85. In his critique of Alberta's approach to the pandemic, the report of Dr. Bhattacharya does not contemplate the role and participation of political officials representing a broad range of social and economic interests in the final decision making and approval of public policy related to COVID-19 and Alberta's public health measures. The policy cycle, in which Alberta's COVID-19 related public health measures were adopted and implemented in response to the pandemic occurred only after both legislative approval was granted by enactment of the *Public Health Act*, and by the involvement of government through the participation and decision-making of Cabinet Committees (originally EMCC, transitioned to PICC, then back to EMCC).

86. As I have previously testified, as the Chief Medical Officer of Health, I provide recommendations to Cabinet Committees (originally EMCC, transitioned to PICC) tasked with making the final decisions for implemented public health measures. In addition to the ministries represented on PICC and EMCC, Alberta Health has also engaged with other ministries and stakeholders to gain insight into the effects of the public health measures and alternatives that may balance the impacts of those measures.

Consideration and weighing of the costs and benefits of Alberta's public health measures

87. The Bhattacharya report implies there was no weighing of non-health related implications to Alberta's pandemic response. That is simply wrong. Alberta's guidance and mandatory public health measures are not made in a vacuum. Sound public health policy decision-making, due to its

underlying principles of multiple determinants of health and inter-sectoral collaboration approach, inherently includes consideration of a broad range of costs and benefits. Thus, Alberta's response has included the careful weighing of costs and benefits throughout the course of the pandemic.

88. As noted by Premier Kenney in his September 9, 2020 Facebook speech, at that time, Alberta had had the least restrictive COVID-19 public health measures in North America, with the exception of North Dakota. Premier Kenney explained that Alberta's balanced approach to responding to the pandemic required the focus to extend beyond saving lives to also protecting people's livelihoods. Using the least restrictive measures possible to achieve the public health objectives as mandated by the principles of public health practice assisted in trying to achieve this balance.

89. Alberta recognizes the impacts that COVID-19 and the collateral effects of the public health measures, required to mitigate transmission, have had on Albertans. In response, starting in 2019, Alberta has committed to investing $140 million over four years to increase access to services, expand programs and establish new publicly funded addiction and mental health treatment spaces, which will support over 4,000 Albertans in their journey to recovery. This funding also includes $40 million to specifically support Alberta's opioid response. Alberta has also committed an additional $53 million to expand online, phone and in-person addiction and mental health supports to make it easier for Albertans impacted by the COVID-19 pandemic to access information, support and referrals from anywhere in Alberta during and after the pandemic.

90. While we continue to monitor data on suicides, provincially, as detailed in the table below, Alberta's suicide rate for 2020 was 5 percent lower than the 5-year average from 2015 to 2019.

91.	2015	2016	2017	2018	2019	2020	2015-2019 average	2020 comparison to 2015-2019 average
Jan	66	49	61	47	43	51	53	-4%
Feb	32	54	46	53	49	49	47	5%
Mar	64	42	58	54	68	48	57	-16%
Apr	61	57	52	55	58	43	57	-24%

May	53	42	57	49	52	53	51	5%
Jun	58	49	51	61	34	53	51	5%
Jul	68	60	47	50	46	54	54	0%
Aug	43	46	62	46	46	70	49	44%
Sep	62	62	56	54	40	38	55	-31%
Oct	59	54	53	46	59	56	55	3%
Nov	55	47	41	59	55	41	50	-17%
Dec	47	47	63	56	51	45	53	-15%
Annual total	**668**	**609**	**647**	**630**	**601**	**601**	**631**	**-5%**

Note: not all 2020 cases are completed and therefore, the numbers may change, including an increase or decrease to the overall count.

92. As comprehensively reviewed in the Affidavits of Chris Shandro (Assistant Deputy Minister, Agency Governance and Program Delivery, Ministry of Jobs, Economy and Innovation) and Darren Hedley (Sr. Assistant Deputy Minister, Budget Development and Reporting, Treasury Board and Finance) there are various provincial and federal programs and benefits, including a number providing emergency financial relief programs targeted to help those in need of assistance during the COVID-19 pandemic.

Alberta's response to COVID-19 has been equitable

93. I agree with Dr. Bhattacharya that health equity is an important principle governing good public health policy. The WHO has stated that good public health policy is characterized by an explicit concern for health and equity in all areas of policy, and by accountability for the overall health and societal impact of public health measures.

94. Indeed the principle of equity has been described by the Canadian Public Health Association in its working paper *Public Health: A Conceptual Framework* (see above **Exhibit "D"** to this Affidavit) as foundational to public health practice. As the Association explains, public health practice is based on five main building blocks of: (1) evidence, (2) risk assessment, (3) policy, (4) intervention and (5) evaluation, and these are supported by a foundation of: (1) health equity, (2) social justice, and (3) the social determinants of health.

95. The principle of health equity is the absence of avoidable or remediable differences among groups of people, however those groups are defined. Thus, all groups should have had

equitable access to public health initiatives to prevent the COVID-19 disease. Where groups did not have equitable access to prevent exposure to and transmission of the SARS-CoV-2 virus, Alberta acknowledged this and tried to remediate by, for example, offering free masks, or extra funding to shelters so they could ensure physical distance between cots; or by providing free isolation hotel rooms for people living in poverty or for groups of workers, such as Cargill, who were not reasonably able to isolate "at home".

96. However, importantly, equity of opportunity to choose diminishes when the behavioural choices of some members of the population impose risks on others.

97. The objective of Alberta's public health guidance and measures has been to protect the community and prevent widespread transmission. Nonetheless, the framework for Alberta's balanced approach in response to the COVID-19 public health threat was, where reasonably possible, to allow people to decide for themselves the risks they wanted to take as individuals. For example, Alberta did not restrict activities of those over age 70 as was done in Sweden, because these individuals should be able to choose for themselves the risks they feel comfortable with.

98. In addition, restrictive measures to control widespread transmission of COVID-19 were used as a last resort in the second and third waves when advice and voluntary guidance were not sufficient to stop rising case numbers and rising hospitalizations, ICU admissions and deaths due to COVID-19.

99. Within this framework and in furtherance of the public health objective, in Alberta, we have strived to ensure that all groups have had, and will continue to have, equitable access to multiple ways to protect themselves from infection and transmission, and from the potential repercussions of infection. If a group did not have this equality of opportunity then that was not because of the group's demographics, geography or economics.

Making public health decisions in the absence of evidentiary certainty

100. Because COVID-19 is still a relatively new threat, and we continue to learn new things about it, the best evidence upon which Alberta's public health recommendations and decisions have been made has had to continue to evolve and progress over time. The Bhattacharya report downplays the use of (international) best practices in public health in considering "the strength of

the scientific evidence regarding the measure in achieving the aims it proposes" when academic literature or other evidence is unavailable. As Alberta's understanding of the disease and the virus has evolved, it has at times been necessary to make decisions in situations of uncertainty about the best evidence as well as uncertainty about the effects of unprecedented public health measures.

101. However, public health decision-making also needs to consider plausibilities and possibilities in the absence of evidentiary certainty. The Government of Canada's website "Public health ethics framework: A guide for use in response to the COVID-19 pandemic in Canada", https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/canadas-reponse/ethics-framework-guide-use-response-covid-19-pandemic.html, a printout of which dated June 21, 2021 is attached as **Exhibit "S"** to this Affidavit, explains that when weighing public health options to promote well-being and minimize harm, the precaution principle means that while the search for scientific evidence should nonetheless be a goal, scientific uncertainty should not impede public health decision-makers from taking necessary actions to reduce the risks associated with COVID-19.

102. An example of one area in which the science has continued to be studied closely is symptomatic and pre-symptomatic spread. These were contemplated in the design of Alberta's initial closure (discussed below) from March 2020 to May 14, 2020, and Alberta continues to study the science and assess the importance of these factors in its public health measures.

103. Given the early evidence in March to May of 2020 that suggested that asymptomatic and pre-symptomatic spread does occur, even without conclusive evidence at that time, considering the potential for asymptomatic spread in Alberta's public health measures has been the responsible course of action to take throughout the course of the pandemic. Some of the evidence Alberta has relied on to assess asymptomatic and pre-symptomatic spread during the course of the pandemic is reviewed below, printouts of which are attached as **Exhibits "T", "U" "and "V"** to this Affidavit. This issue is also addressed in more detail in the expert report of Dr. Jason Kindrachuk.

104. In the summer of 2020, the 2019-nCoV Scientific Advisory Group advised SAG: https://www.albertahealthservices.ca/assets/info/ppih/if-ppih-covid-19-sag-asymptomatic-transmission-rapid-review.pdf (**Exhibit "T"**) that while most transmission of COVID-19 seemed

to occur from symptomatic people to others in close contact, there was growing evidence that a significant portion of people who have COVID-19 do not show symptoms, while infectious. These individuals can be asymptomatic (15-20 percent of infected individuals), meaning they are infected with COVID-19, but do not develop any symptoms; or pre-symptomatic (6-12 percent of infected individuals), meaning they are infected, but have not developed symptoms yet. In September 2020, Eric Topol published a review of the studies available at that time and found that the rate of asymptomatic transmissions was between 40 and 45 percent. (Oran et al.) **(Exhibit "U")**

105. The Center for Disease Control's (CDC) conclusion in January 2021 was that in the absence of effective and widespread use of therapeutics or vaccines that can shorten or eliminate infectivity, successful control of SARS-CoV-2 cannot rely solely on identifying and isolating symptomatic cases (Johansson et al.) **(Exhibit "V").**

106. A model developed and published by the CDC in **Exhibit "V"** estimated that 59 percent of all transmission came from people without symptoms, under the model's baseline scenario. This included 35 percent of new cases from people who infect others before they show symptoms (pre-symptomatic) and 24 percent that came from people who never develop symptoms at all (asymptomatic).

Alberta's public health guidance

107. Risk of SARS-CoV-2 transmission depends on many variables, such as location (indoors versus outdoors), quality of ventilation, and activity. There are no drug therapies to cure COVID-19 or prevent the spread of SARS-CoV-2. In the absence of such treatments and sufficient vaccine supplies, public health measures were the only available resources to prevent or reduce transmission of the SARS-CoV-2 virus.

108. These measures include, but are not limited to personal protective measures (handwashing, respiratory etiquette, mask wearing), environmental measures (cleaning and disinfection of surfaces, ventilation), surveillance and response measures (including contact tracing, isolation, and quarantine), physical distancing measures (limiting the size of gatherings, maintaining distance in public or workplaces, domestic movement restrictions), and international

travel-related measures. The recommended measures are designed to be implemented together as no one measure alone will prevent all SARS-CoV-2 person-to-person transmission.

109. Based on the knowledge of droplet and aerosol spread throughout the pandemic, which is the main way the virus spreads between people, Alberta Health has continued to recommend that people maintain a distance of two meters from one another.

110. Another health measure Alberta has employed to control the spread is to implement mandatory masking. Masks, when worn properly, are a valuable tool in reducing the transmission of SARS-CoV-2. The use of masking can prevent an infected person from transmitting the virus to others and use of masks, especially medical masks, can help protect a healthy individual from infection, particularly in indoor settings. The available evidence shows that widespread public masking, in addition to other public health measures, such as reducing time spent indoors with large groups of people (relative to the size of the room and the spacing of people within the room) while engaging in high risk activities, can contribute to controlling the overall transmission of SARS-CoV-2. Masking, on its own, is not sufficient to control the spread of COVID-19. The benefits to controlling the spread of the virus by masking are reviewed in detail in the expert report of Dr. Jason Kindrachuk.

111. The report of Dr. Bhattacharya ignores that there has not been a global pandemic to the extent of COVID-19 for over a century. The Bhattacharya report also fails to account for the following factors in assessing Alberta's response to the pandemic:

- Whether the general population has a true understanding of the risk of COVID-19, especially the potential impact to the health care system (and how the overall system needs to be protected to be able to respond to non-COVID health issues), and how the measures (voluntary and mandatory) mitigate these impacts.

- Behaviour fatigue – Alberta adopted the use of voluntary measures to motivate individuals in taking action, however, not everyone took them seriously or was able to maintain them.

- People do not always protect themselves from disease risk even if they perceive the danger of infection to be high – people have unprotected sex even when they know the risk of sexually transmitted infections is high, for example during an outbreak.

- The role of conspiracy theories, naysayers and non-believers, and the power of social media to propagate misinformation and create a groundswell of people who do not believe COVID risk is real and therefore do not change their behaviours.

- It is understood from other public health interventions, such as immunization, there is a percentage of the population that do not change their behaviour, despite knowing the risk, because they don't believe in the risk or because they exaggerate the risk of the vaccine.

- Societal context plays a role: a disease like COVID, where people need to change behaviour and can thereby be inconvenienced, may spur deep-seated beliefs, cultural viewpoints and values (like personal freedom) that oppose behaviour change.

112. Further, Dr. Bhattacharya's reliance in his report on Sweden's approach to the pandemic ignores that Sweden did very poorly in the spring of 2021, and experienced a huge wave of hospitalization and ICU admissions. Sweden's hospitals were forced to ration ICU space by not admitting those with a lower chance of survival, such as those over 80 or with a body mass index of over 40. Sweden also experienced a large death toll in the spring, with total deaths per capita 10 times higher than Alberta at that time. Further, although measures were not mandatory in the spring of 2020, Sweden had many measures in place to minimize spread, and polling indicates that 80 percent of Swedes voluntarily follow government advice. Sweden also introduced regional targeted measures in the fall to limit activities with high risk of accelerating virus spread in places that saw escalating cases with an impact on acute care.

Alberta's use of PCR testing

113. As indicated previously, my work with the Provincial Laboratory has been critical to my office's response to the pandemic. The laboratory's PCR testing along with information provided by EOC's Analytics team has greatly assisted Alberta's ability to assess, plan and respond to the pandemic as it has proven to provide accurate evidence of anticipated admissions to hospital and ICUs. Evidence of a positive test has proven to provide critical data in AHS' management of Alberta's healthcare capacity in response to the pandemic. Knowing that slightly over 4 of every 100 people testing positive for COVID-19 in Alberta over the past 16 months have been admitted to hospital and that just under 1 has been admitted to an ICU has provided Alberta with critical

and timely data to allow AHS to assess and respond to critical hospital capacity and resource demands.

114. Clinically, PCR testing has been used for many years to rapidly diagnose infectious diseases because PCR (1) is very specific, (2) is faster than older methods of identifying infectious agents, such as viral culture, and (3) can identify infectious illness early in the course of the disease so isolation and treatment can start earlier. PCR is routinely used to identify the influenza virus, Zika virus, Ebola, and many other infectious agents.

115. While the PCR test does not specifically identify living, infectious virus in an individual, it is a reliable surrogate indicator of viable virus. We know from research and real world experience that when detectable viral genetic material is present, infectious virus is usually present as well. Testing individuals with symptoms greatly increases the likelihood of individuals being infectious at the time of testing.

116. As evidence on testing implications have evolved, so has Alberta Health's policy. For example, on August 28, 2020 Alberta changed our notifiable disease policy to not consider cases that test positive within 90 days of a previous positive result as infectious and to not require isolation for these individuals.

117. The PCR test used in Alberta has been confirmed to be highly specific for SARS-CoV-2. It does not react to other viruses, even other coronaviruses. Alberta's Provincial Laboratory ("APL") has evaluated the risk of false positives by testing samples known to be negative for COVID-19, in order to confirm that the standard testing procedure will not generate a positive result in these cases. Based on the evaluations that APL has carried out, false positive results occur very rarely. To minimize the potential impact of the occasional false positive result, public health instructions take into account the context surrounding the individual such as presence and type of symptoms and the likelihood of exposure to COVID-19.

118. It is true that a small proportion of people who test positive are not contagious, however, the policy change to not require isolation if an individual tests positive again within three months of a previous positive result is a change that mitigates this risk. There is not a clear and reliable guarantee that an individual with a positive result and high Ct value is not infectious. An

individual whose test Ct value is high may have had a problem with the sample collection or could be either early or late in infection when viral loads can be lower. These individuals may still have a high and contagious viral load or they may have a low viral load and not be contagious – there is no way to reliably differentiate between these possibilities with a single test result.

119. For this reason, in the early pandemic, all positive results were treated as a positive. Changes to notifiable disease policy have continued to evolve based on the evidence on disease processes and have been adapted as necessary. Advice around the length of time an individual may be contagious is based on the timing of suspected exposure and symptom start date rather than on Ct value.

120. The criticisms in Dr. Bhattacharya's report regarding the probable case definition (i.e. that Alberta counts "Probable cases" as "cases" for its official case surveillance, and a probable case can include an "un-tested person" who was in close contact with a confirmed case of COVID-19, so that un-tested person may be counted as a COVID-19 case in error) doesn't take into consideration that the probable case definition is rarely used and is often just used temporarily until a person can be tested. As of June 18 2021 of the total number of cases (129,715) only 1.1 percent (1,385) were "Probable" while 98.9 percent (128,230) were "Confirmed". How PCR testing is used to identify the SARS-CoV-2 virus and diagnose COVID-19 and related issues are explained in detail in the expert report filed in this matter of Dr. Nathan Zelyas who is an employee of the Provincial Laboratory for Public Health and a member of SAG.

Alberta's use of contact tracing

121. AHS leads Alberta's contact tracing efforts. Contact tracing has proven to be a helpful tool to address and curtail the spread of the virus. When a person tests positive for COVID-19, a Contact Tracer from AHS will contact the infected person using the information provided at the testing center and determine who else may have been exposed to the infected person while they were infectious, as well as determining where the individual may themselves have been exposed. When an infected person is contacted they are asked if they use the ABTraceTogether app. If they do they will be asked to voluntarily upload the encrypted data from the app to AHS. This information is critical in helping increase the speed and effectiveness of Alberta's COVID-19

response. If the individual does not have this app, contact names are taken manually and contacts are notified by the contact tracing team.

122. If an infected person has the app, once AHS receives the encrypted data, AHS Contact Tracers use that information to reach the other app users who have had close contact with the infected person. Promptly identifying those people that had close contact with the infected person enables AHS to provide the necessary guidance and care to those exposed, including having them self-isolate thereby reducing the spread of COVID-19. The Affidavit of Dr. Simmonds provides an overview of Alberta's approach to COVID-19 case identification and management, which follows the *Alberta Public Health Disease Management Guidelines -Coronavirus-COVID-19* and is found at: https://open.alberta.ca/dataset/a86d7a85-ce89-4e1c-9ec6-d1179674988f/resource/7645a408-3ac3-4b02-b9ca-398bfa4608b8/download/health-disease-management-guidelines-covid-19-2021-06-28.pdf, and is attached as **Exhibit "W"** to this Affidavit.

Community spread of the virus in Alberta during the pandemic

123. While a person has COVID-19 and is still able to spread the virus to others that person is called an "active case." As the number of active cases of COVID-19 increases in the community, the possible sources of infections increase. This makes it more difficult for the infected person to know how or when they may have been infected with the SARS-CoV-2 virus. Community spread refers to the spreading of a disease from person to person in the community. Community spread can occur when the source is known or unknown.

124. A source of infection is identifiable if a case of COVID-19 can be linked to: (1) a close contact of another confirmed case; (2) an associated outbreak; or (3) travel. Community spread where the source of infection is not known poses a serious threat to the community, and the effectiveness of contact tracing is greatly reduced in such cases.

125. In addition, as the number of individuals testing positive for COVID-19 increases, the capacity of the health care system to contact cases, identify contacts and link cases is significantly limited. Therefore, the capacity to identify and control the spread in a targeted way is severely curtailed. For instance, of the active COVID-19 cases in Alberta on December 18, 2020, during

the height of Alberta's second wave, 78 percent of cases did not have an identifiable source. Because of the high number of active COVID-19 cases, including those cases with no identifiable source of exposure to SARS-CoV-2, reducing the number of contacts all people have with others is a key way to reduce the risk of spread.

126. SARS-CoV-2 can spread exponentially if left unchecked, thus it has been critical over the course of the pandemic for Albertans to follow public health guidance in order to minimize the spread of the virus, reduce the long-term consequences, and reduce the number of hospitalizations and deaths. Otherwise, left unchecked, SARS-CoV-2 virus will spread within a population resulting in the exponential growth in the number of people infected. This is illustrated by Alberta's experience with COVID-19 over the last 16 months.

Alberta's COVID-19 data analysis and modeling

127. Another important tool in Alberta's public health response to the pandemic has been the use of models to forecast likely health care scenarios for planning purposes. I receive several daily reports from EOC's Analytics' team, including: a Morning Ballpark Report (Monday to Saturday at 8AM) providing an initial estimate of daily cases, lab tests and positivity rate along with active case estimates and variants of concern; a Health Surveillance Epidemiology Report (Monday to Friday at noon) providing a full scale daily epidemiology report for internal use; and a similar Health Surveillance Report providing daily epidemiology report for external posting and use. I also receive periodic forecast projections.

128. This data and information has been important in assessing the spread of the disease and the need for public health measures, including the need for stricter mandatory measures when current evidence combined with previous trends has shown that new daily and active cases are anticipated to surge as occurred during October and November 2020 and again in March and April 2021.

129. In April 2020, Alberta used modelling to demonstrate potential COVID-19 case trends during the summer months. While many jurisdictions used data from other countries, like China or Italy, to model the spread of COVID-19, due to Alberta's extensive testing and surveillance program, Alberta case data was used to develop more accurate model scenarios. The modelling

was updated as new data became available. Alberta modelled two core scenarios – Probable and Elevated. This helped us make decisions and prepare hospitals to care for critical and acute patients as we learned how to better treat and prevent the virus.

130. In the "Probable Scenario" for every case, 1-2 more people are infected. This scenario is comparable to the more moderate growth seen in the UK and countries that have had some success in "containing" growth. Given Alberta's early and aggressive interventions and contact tracing to limit spread, this was expected to be the most likely scenario for Alberta. In the "Elevated Scenario" for every case, 2 people are infected. This is comparable to the more rapid growth initially seen in the Province of Hubei, China. Planning for this scenario in Alberta was prudent and responsible given the catastrophic impacts should the health system have become overwhelmed. In the "Extreme Scenario" for every case, 3 more people are infected. This scenario assumed limited and late interventions so that COVID-19 would have rapidly spread through the population. This scenario shows what would have happened if Alberta had not undertaken early and aggressive interventions and contact tracing to limit spread. Case numbers in these models represented all cases, not just diagnosed cases (which are always an under-count of all cases in a population).

131. For further comparison, on a per population basis, what Ontario experienced during the first wave of the pandemic was essentially equivalent to our "Elevated Scenario" and what Quebec experienced during the first wave was essentially equivalent to our "Extreme Scenario" with respect to impact on the acute care system.

132. Graphs illustrating Alberta's modeling for both hospitalizations and ICU admissions for these three scenarios as at April 28, 2020 are on slides 10 and 11 of the PowerPoint found at: https://www.alberta.ca/assets/documents/covid-19-case-modelling-projection-april-28.pdf. As can be seen from those graphs, although the actual admissions were initially above the elevated level for both ICU and non-ICU, they were quickly controlled, and the province's hospitalization rate continued to be significantly lower than the estimates in the low scenario. Over the course of the first wave of the pandemic, Alberta was able to build up months of data and experience to inform our response to COVID-19 over the course of the second and third waves.

133. Data analysis and predictions were particularly critical during the second wave in assisting Alberta in determining that the continued use of targeted measures could not reasonably be expected to stop the spread of the virus after transmission began to rise post-Thanksgiving and Halloween. In December of the second wave the focus of the Analytics team was on the short-term effects of the province-wide mandatory public health measures with forecasting closely approximating the actual peak admissions at the end of that month.

Continuation of essential health care services

134. Throughout the pandemic, Alberta has supported the continuation of essential health care services. During the first wave in March/April 2020, patients were triaged, including cancelling some surgical procedures. This was done taking into account the modeling, which then showed a potential for high levels of cases with severe outcomes, and given the high state of uncertainty surrounding the disease and its transmission at the time.

135. In April 2020, AHS planned to increase ICU capacity, if needed, by adding ICU beds to existing ICU rooms, converting operating and recovery rooms to ICU capacity, converting procedure and treatment rooms to ICU capacity, and using more aggressive step down care. AHS also planned at that time to significantly increase ventilator capacity and was also carefully tracking stocks of personal protective equipment. AHS was also developing plans to add critical care nurses by accelerating training, contacting retired nurses, and redeploying other staff with appropriate skills.

136. Alberta's capacity for hospitalization due to COVID-19 is dependent on demand for other health issues. As deaths spiked during Alberta's second wave, the capacity of Alberta's hospitals and ICUs due to COVID-19 patients was pushed to the limit. On December 17 and 18, 2020, during the second wave, there were 763 people in the hospital due to COVID-19 and 138 in the ICU: https://www.alberta.ca/stats/covid-19-alberta-statistics.htm#healthcare-capacity (see Figure 18 on Exhibit "L" to this Affidavit); and Alberta's main hospitals were operating at over 90 percent capacity for COVID-19 inpatient care.

137. This high level of hospitalizations and patients in ICU due to COVID-19 continued to force the cancellation of treatments for non-COVID-19 patients with non-urgent conditions for

several months in late 2020 and early 2021, including the cancellation of non-urgent, but necessary, surgeries. The cancellation of these non-urgent, but necessary, treatments can have health impacts, such as ongoing pain and mobility issues.

138. If Alberta's COVID-19 hospitalization capacity had been significantly exceeded, it could have resulted in the need to ration acute care resources. This could have meant that some patients, who were in need of critical care supports, may not have received those supports. If the requirements for in hospital care had continued to escalate, a need to triage access to care supports, especially supports in intensive care, may have been required necessitating doctors and nurses to make decisions between which patients lived and which died. Fortunately, the public health measures in place in December 2020 worked to reduce hospital and ICU admissions before this could occur.

139. However, again, during the third wave of the pandemic in Alberta on April 29 when the active case count hit a record high, and on May 11 when hospitalizations peaked at 568, and on May 18 when ICU patients peaked at 184, the risk of the health care system being overrun was significant. In both the second and third waves the real and present danger to Alberta's health care system necessitated the mandatory public health measures instituted at those times in order to bend the curve by driving transmission down and avoiding dire consequences.

Can certain activities, businesses and locations be opened safely and what are their benefits?

140. Alberta acknowledges and supports that interventions can be implemented in any sector that can minimize the risk in a specific setting. However, these will not eliminate the risk across the entire sector, due to inadvertent deviations or intentional non-compliance. Small risks add up in each sector to transmission increases. As cases get a foothold and increase, these minor risks are compounded and disease rates start to grow (which can accelerate into exponential growth). Due to this, Alberta needed to act during the second and third waves to 'remove the fabric of transmission potential' in many sectors together in order to bring transmission under control.

141. There is no one "at fault" sector; rather all sectors contribute to growth based on the evidence that widespread non-pharmaceutical interventions seem to be required to control

COVID-19 in all jurisdictions. When disease is low we can allow more risk, but it quickly increases in risk when cases grow.

Places of worship

142. Alberta has acknowledged the importance of allowing faith-based activities throughout the pandemic. In-person attendance at a place of worship has never been prohibited. Capacity limitations have been instituted in alignment with other restrictions. I along with elected leaders in Alberta have met regularly with Faith Leaders to ensure they had access to reliable information in order to support implementing voluntary and mandatory measures, as well as supporting their congregants. The vast majority of Alberta faith communities have been excellent partners in the pandemic response and have shown great innovation in providing services in alignment with measures, such as online and drive-in services.

143. There have though been noteworthy outbreaks associated with places of worship in Alberta. Exhibit B to the Affidavit of Dr. Simmonds details that in total in Alberta there have been 35 outbreaks identified that are associated with places of worship from March 1, 2020 to May 15, 2021 with a total of 704 directly associated cases.

Restaurants

144. The social aspect of eating and drinking in restaurants has been implicated in many outbreaks. Drinking alcohol is a known contributor to decreased inhibitions during socialization; individuals are less likely to maintain physical distancing in these situations. Take out, delivery and curbside pickup of food were allowed throughout the pandemic to facilitate ongoing operations of restaurants in a risk-reduced way. In addition, the imposition of additional measures (both on Nov 24 and Dec 11) were announced as short term, with dates for review. Alberta acknowledged that this sector was likely to be able to stay up to date with guidance and would be able to enforce the measures, which is why they were included early in reopening following both the second and third waves.

Physical activity venues

145. Alberta acknowledges that physical activity is important for the physical and mental health of Albertans. However, the very nature of some types of physical activity can result in forceful droplet expulsion or generate an increased amount of smaller respiratory droplet sizes. For example, heavy exertion or increased breathing rates occurring from intense exercise can increase the quantity of smaller respiratory particles.

146. There have been some noteworthy outbreaks and CMOH Order violations throughout some outbreaks associated with gyms and other physical activity venues. As detailed in Exhibit B to the Affidavit of Dr. Simmonds there have been 33 outbreaks identified associated with Sports and Fitness Facilities between March 1, 2020 and May 15, 2021 with a total of 501 directly associated cases.

147. A common trait of these outbreaks was high attack rates – meaning that most or all participants in attendance became infected through a single source. There have also been several anecdotal incidents where members of the industry have continued high risk activities despite public health measures being in place. However, despite these incidents, Alberta has acknowledged that this sector was likely to be able to stay up to date with guidance and to enforce the measures, which is why they were included early in reopening.

148. The Bhattacharya report downplays that industry was able to utilize outdoor physical activity and online/virtual options to continue their businesses throughout the duration of the public health measures. The Bhattacharya report also does not contemplate the trends in all of these sectors to have online and virtual or distanced models of service delivery. These sectors, more than others, have been adopting alternate service delivery models in the past several years, which was a consideration in the development of the restrictions. In addition, the imposition of additional measures (both on Nov 24 and Dec 11) were announced as short term, with dates for review.

Risk of transmission by children

149. Younger children do not drive outbreaks; they are less likely to be to be infected. However, their potential to spread the virus has been considered, as is appropriate. Individuals under 18 are also more likely to have a mild disease or be asymptomatic. However, in periods of

high community prevalence, teenagers are a much bigger transmission risk than younger children given the normal behaviours of the age group, which would put them at higher risk for the same reasons that risk of meningococcal bacteria is higher in teens - spread by kissing or the sharing of food, water bottles, cigarettes. It is thus important to note the difference in prevalence between age groups of children, and not lump "children" into one category of 2-18 years when considering public health measures.

150. The report of Dr. Bhattacharya also groups together schools with other settings and activities, without addressing risks associated with those activities in the report. The following settings will have different risk profiles than school settings:

- Camps (could be referring to overnight camps and congregate living settings);
- Sports (teams sports, high intensity physical activities and social gatherings associated with these activities);
- Contact with friends (not defined, could be referring to visiting each other residences).

151. Alberta has safely opened K-12 schools for in-person learning with reasonable precautions during the second and third waves of the pandemic with limited closures only when targeted measures became necessary. Alberta has also taken a more nuanced approach than suggested by Dr. Bhattacharya's report in differentiating risks associated with different school grades. There are several effective mitigation strategies (including consistent and correct use of masks; physical distancing; handwashing and respiratory etiquette; cleaning and maintaining healthy facilities; and contact tracing in combination with isolation and quarantine) to limit transmission in the school setting. The Bhattacharya report is unclear on how and when to layer these strategies, and how and when to pull them back, suggesting, incorrectly, these measures are unique to school circumstances.

152. Though outbreaks do occur in school settings, multiple studies have shown that transmission within school settings is typically lower than – or at least similar to – levels of community transmission, when mitigation strategies are in place in schools. Increases in case incidence among school-aged children parallels trends observed among adults in the community and do not appear to pre-date increases in community transmission. Although they have a low

mortality rate, young adults are susceptible to infection and transmission. Importantly, young adults are more likely to live at home with older adults. Alberta also has continued to have policies that accept some risks of transmission in younger populations as demonstrated by the re-opening of post secondary institutions in September 2020.

Immunization

153. There are now three licenced vaccines for COVID-19 available in Alberta (Pfizer BioNTech, Moderna, and AstraZeneca/COVISHIELD) which Alberta Health and Alberta Health Services began to deploy in December 2020 at first to health care workers and the groups most vulnerable to severe outcomes. The vaccines require two doses, and an additional period of 7-10 days after the second dose before becoming maximally effective. Presently, everyone 12 and older can book first and second doses. We anticipate having sufficient vaccine supply to be able to offer a second dose of vaccine to all Albertans who choose to receive vaccine by the end of July 2021.

154. The approved vaccines for SARS-CoV-2 have been distributed in a manner that has prioritized the most vulnerable groups. As supply allowed, the vaccines were administered as quickly and as widely as possible. We anticipated that if the vaccine proved effective in providing lasting immunity, it would allow us to eventually remove the public health restrictions.

155. In Alberta, as of July 6, 2021, 4,673,582 doses of COVID-19 vaccine have been administered, and 73.6 percent of 12+ population has received at least one dose (62.6 percent total population). 50.7. percent of 12+ population fully vaccinated (43.1 percent total population): https://www.alberta.ca/stats/covid-19-alberta-statistics.htm#vaccinations (see pages 15 -20 of Exhibit L for Alberta's Figures and Tables on vaccinations at July 6, 2021).

Alberta's present situation: Stage 3 of the roadmap

156. Alberta announced a 3-stage roadmap outlining how restrictions will ease while protecting the health-care system and increasing vaccination rates in the province. The 3 stages, the targets of which have all been met, were as follows: Stage 1: Two weeks after 50 percent of Albertans 12+ (born in 2009 or earlier) have received at least one dose, and hospitalizations are

below 800 and declining. The first stage took effect June 1 and the following public health measures were then put in place province-wide:

- Places of worship – 15 percent of fire code occupancy (effective May 28)
- Outdoor social gatherings – up to 10 people (indoor social gatherings still not permitted)
- Outdoor physical, performance and recreation activities – up to 10 distanced people, all ages
- Personal and wellness services – re-open, by appointment only
- Funeral services – up to 20 people, not including facility staff, funeral clergy or organizers not considered guests (receptions remain prohibited)
- Wedding ceremonies – up to 10 people, including officiant, bride/groom, witnesses (receptions remain prohibited)
- Restaurants – outdoor patio dining for up to 4 household members per table, or 3 people if diners who live alone are with their 2 close contacts
- Retail - 15 percent of fire code occupancy (must maintain ability to distance)
- Distancing and masking requirements remain in effect

157. Stage 2: Two weeks after 60 percent of Albertans 12+ (born in 2009 or earlier) have received at least one dose, and hospitalizations are below 500 and declining. The second stage took effect June 10 and the following public health measures were then put in place province-wide:

- Outdoor social gatherings – up to 20 people with distancing (indoor social gatherings still not permitted)
- Indoor recreation, entertainment and other settings (rec centres, arenas, casinos, cinemas, theatres, museums, galleries, libraries, etc.) – open at 1/3 of fire code occupancy
- Gyms and fitness studios – open for solo and drop-in activities and indoor fitness classes with 3 metre distancing
- Funeral services – up to 20 people, indoors and outdoors (receptions permitted outdoors only)
- Wedding ceremonies – up to 20 people, indoors and outdoors (receptions permitted outdoors only)
- Places of worship – 1/3 of fire code occupancy

- Personal and wellness services – resume walk-in service
- Post-secondary – resume in-person learning
- Restaurants – 6 people per table max, indoors or outdoors
- Retail – 1/3 of fire code occupancy (must maintain ability to distance)
- Youth activities (day camps, overnight camps, play centres) – resume with restrictions
- Youth and adult sports – resume with no restrictions, indoors and outdoors
- Outdoor public gatherings (concerts/festivals) – up to 150 people
- Outdoor fixed seating facilities (grandstands) – 1/3 seated capacity
- Work from home order is lifted but still recommended
- Distancing and masking requirements remain in effect

158. Stage 3: Two weeks after 70 percent of Albertans 12+ (born in 2009 or earlier) have received at least one dose. Effective July 1 when only the following public health restrictions will be in place province-wide:

- All business restrictions lifted, as well as the ban on indoor social gatherings.
- Isolation requirements for individuals with symptoms of COVID-19 and confirmed cases of COVID-19 as well as quarantine requirements for close contacts who are not fully immunized remain
- Some protective measures in continuing care settings remain.
- The general indoor provincial mask mandate has been lifted, but masking is still required in limited and specific settings such as public transit, taxi cabs, ride shares, continuing care, and health care settings operated by AHS and Covenant Health.

159. Albertans must still remain vigilant, and the work of my office continues despite the lifting of these restrictions on July 1. Although our case count numbers, positivity rates and other important indicators have again been brought under control through both Alberta's public health measures in April and May, and by the level of immunization reached in the province's population, Alberta continues to see infections from the variants of concern, especially the B.1.617.2 (Delta) variant.

160. Therefore, the situation must continue to be assessed carefully given how extremely contagious that variant of concern appears to be based on current best evidence. Thus, COVID-19 transmission will continue to be monitored, and if required, a stage may be paused to respond to trends at regional or provincial levels with appropriate public health guidance or other measures. As Alberta's reopening announcement stated, sustained reopening will require as many Albertans as possible to choose to be protected with 2 doses of vaccine during the summer to prevent future spread.

161. The above description sets out the policies of the Government of Alberta and the various factors considered in shaping the application of that policy during Alberta's approach to addressing the COVID-19 pandemic. These factors also influenced when it was necessary for Alberta to move from guidance and voluntary measures to mandatory measures, and when it was necessary to extend the scope of targeted mandatory measures province-wide.

E. Alberta's Voluntary and Mandatory Public Health Measures: March 2020 to June 2021

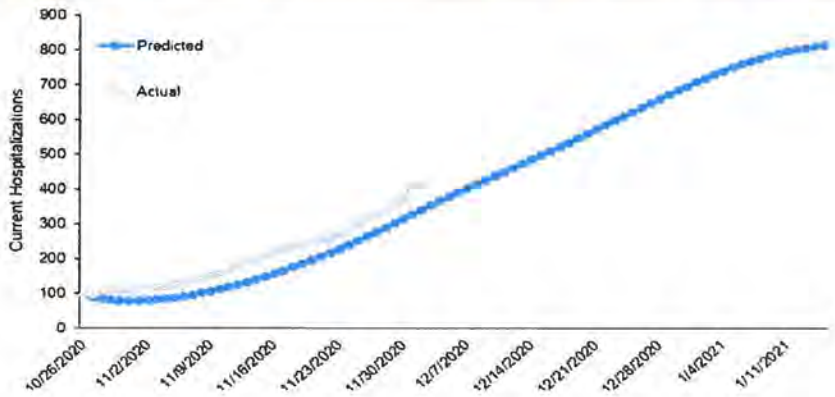
162. Alberta has implemented various public health measures in response to the COVID-19 pandemic since March 2020. Alberta's approach is consistent with that taken throughout Canada and across much of the world. Globally, public health experts have sought to limit the number and duration of contacts between people, particularly when indoors, in order to prevent or reduce transmission of the SARS-CoV-2 virus. However, the extent to which mandatory measures have been implemented in a given jurisdiction has depended on local metrics, including active case rates, positivity rates, R-values, and hospital and ICU capacities.

163. Alberta's objective, in common with all other Canadian jurisdictions, has always been to use the least restrictive measures required to prevent or limit the spread of the virus thereby minimizing the number of serious outcomes, in terms of both deaths (mortality) and illness (morbidity), while balancing the collateral effects of public health restrictions and minimizing the overall harm to society.

164. No single measure alone is sufficient to control the spread of COVID-19. Therefore, Alberta has attempted to control transmission by implementing a variety of voluntary and

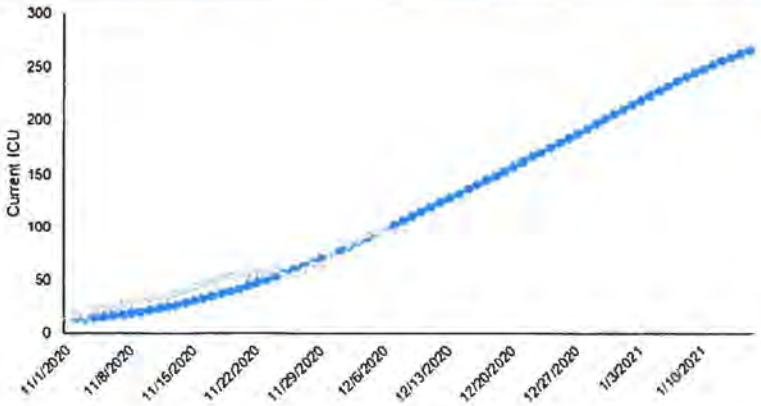
mandatory public health measures. Evidence shows that without widespread immunization, restrictions on how people interact with others outside of their households are necessary to prevent the transmission of SARS-CoV-2 and are effective in reducing cases of COVID-19. The first two graphs below demonstrate actual and predicted numbers of (1) hospital and (2) ICU admissions and show what would have been anticipated if case growth had not been slowed by public health measures. The third graph shows anticipated case growth both with and without the additional public health measures announced by Alberta in December. These measures were necessary to minimize viral transmission, reduce case growth, and thereby prevent continued growth in COVID-19 hospitalization and ICU admissions.

Actual Hospitalizations vs Predicted



Results based on model run Oct. 26. No adjustments for any public health measures after October 26

Actual ICU Admissions vs Predicted



Results based on model run Oct. 26. No adjustments for any public health measures after October 26

165. Alberta's approach has always been to attempt to control the spread of the virus while protecting, as much as possible, an individual's ability to interact with others and participate in work, recreational, religious and social activities. However, as the number of COVID-19 cases and related hospitalizations, ICU stays, and deaths increased, Alberta's public health measures in response also had to adapt.

166. Alberta's pandemic response includes public health measures enabled by Chief Medical Officer of Health (CMOH) Orders under s. 29 of the *Public Health Act*, which are issued as the legal instrument to implement and enforce mandatory measures deemed necessary by elected decision makers to lessen the impact of the public health emergency. The following outlines the timeline, and the CMOH Orders and measures which were instituted, along with the corresponding case count and the subsequent trajectory of the pandemic response to June 30, 2021.

Alberta's initial closure between March 17 and May 14, 2020

167. The initial closure (March 17 to May 14) was to address the increasing number of cases in the province. Alberta used testing and surveillance measures along with public health measures to bring the case numbers down. Alberta eased most public health measures in place at that time in a step-wise fashion beginning with the May 14, 2020 relaunch. After May 14, 2020, Alberta

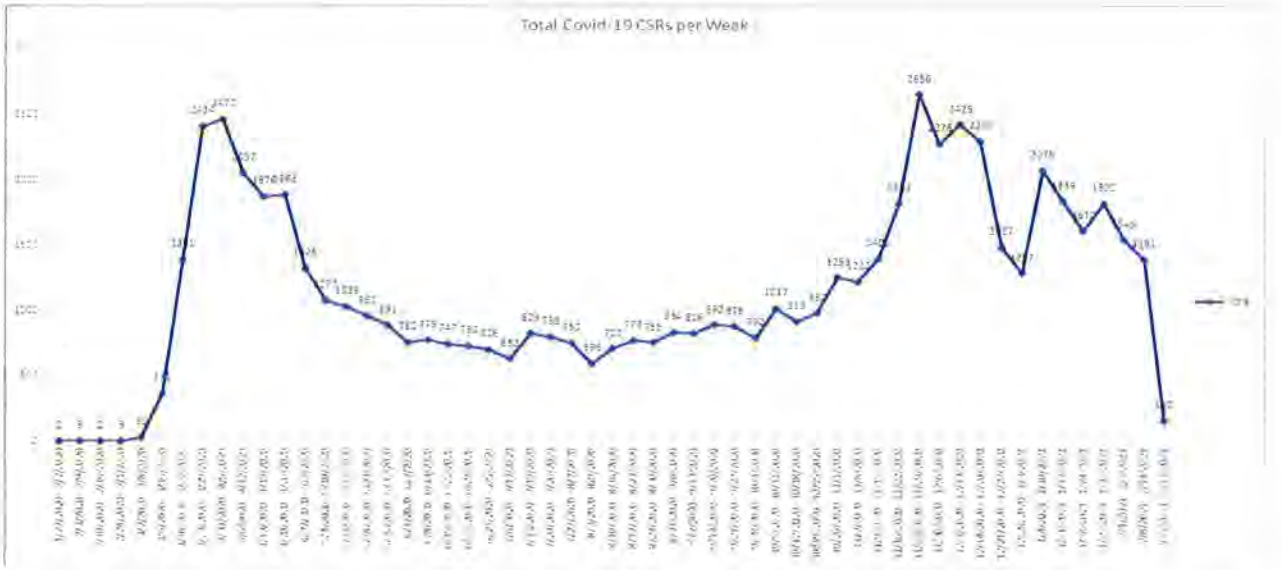
used targeted measures only as required to keep spread manageable and to ensure that our health system was able to cope with demands.

168. Following Alberta's initial closure between March 17 and May 14, 2020, Alberta pursued a strategic and accelerated relaunch to facilitate opportunities for individuals and businesses to recuperate from both a financial and well-being perspective. Alberta was among the first jurisdictions in Canada to enter into the relaunch phase, and was often at the forefront of safely reopening sectors. Alberta made efforts to limit the quantity of mandatory measures in place, opting for an approach featuring both general and sector-specific guidance to empower Albertans and businesses in navigating the summer months, while mitigating risk of transmission.

169. Alberta continued with an aggressive system of testing, including monthly serological testing to determine the extent of spread in the community, as well as strong tracing and tracking of contacts leveraging technology to do so, along with the recommended continued use of masks and strong border screening to keep numbers down. Seasonality obviously also benefitted our containment efforts during this time. During July and August the daily cases and corresponding hospital and ICU numbers remained stable, as shown in the following table.

Week Beginning	**Cases (Average Daily Increase)**	**Hospitalizations (Average Daily Total in Hospital)**	**ICU Count (Average Daily)**	**Daily Deaths (Average per Week)**
July 13	89	86	11.5	1.2
July 20	114	85	15.4	2.2
July 27	99	75	14.2	1.8
August 13	90	47	12.8	1.0

170. As the following graph illustrates public complaints regarding COVID-19 restriction non-compliance began steadily increasing from the summer into the early fall, indicating people were increasingly not complying with mandatory measures. In early fall, Alberta began to experience an increase in disease rates, corresponding to an increase in compliance issues and surveys reporting of behavior fatigue. In an effort to address disease spread while minimizing the burden to individuals and businesses, Alberta initially implemented voluntary restrictions, targeted at transmission mitigation.



171. Alberta provided the population with opportunities to demonstrate their willingness to implement the voluntary measures. However, evidence (case numbers and complaint numbers) indicated that voluntary measures were not being taken seriously enough by some, which negatively impacted the outcome for many.

172. The following CMOH Orders were in place as of October 1, 2020:

a. CMOH Order 05-2020 requiring Albertans with COVID-19 to isolate for a minimum of 10 days from the start of their symptoms, or until symptoms resolve. Travellers returning from outside Canada and close contacts of a confirmed case are required to isolate for a minimum of 14 days.

b. CMOH Order 10-2020 restricting staff members of long term care and designated supportive living to a single site (by April 23, 2020) and updating operational and outbreak standards, including requiring continuous masking when providing direct patient care or working in patient care areas (by April 15, 2020).

c. CMOH Order 11-2020 requiring the Calgary Airport Authority and Edmonton Regional Airports Authority to implement public health measures related to cleaning, disinfecting and physical distancing, and enabling passenger screening of travellers returning from international locations.

d. CMOH Order 25-2020 to adjust restrictions on public access to businesses, schools and places of worship. Amusement parks, indoor children's play centres and nightclubs remain closed to the public. Calgary and Edmonton lifted their local states of emergency.

e. CMOH Order 26-2020, outlining the mandatory physical distancing requirement of at least two metres from every other person who is not a member of the same household or cohort.

f. CMOH Order 27-2020 to update operational and outbreak standards for residential addiction treatment service facilities.

g. CMOH Order 28-2020 to clarify that any person entering Alberta after having travelled internationally must be in quarantine for a minimum of 14 days.

h. CMOH Order 29-2020 relaxing visitor restrictions, under certain conditions, for long-term care, licensed supportive living facility or any residential facility offering hospice services (effective July 23).

i. CMOH Order 32-2020 outlining updated operational and outbreak standards for health care facilities, effective September 17. The Order gives continuing care facilities and hospices more flexibility with isolation requirements, recreation, dining, and volunteers.

j. CMOH Order 33-2020 outlining requirements for non-medical mask use for Grade 4 to 12 students, all staff, and visitors in indoor spaces, including on school buses and in shared areas such as hallways, effective August 31.

k. CMOH Order 34-2020, permitting indoor children's play centres to open.

Voluntary measures recommended on October 5 and 8

173. On October 5, voluntary safety measures were advised for the Thanksgiving weekend; limiting gatherings to only household or cohort members and advising to eat outdoors if possible and not to share serving spoons or dishes. On that date, there were 207 new cases, 1,783 active cases, 79 hospitalizations and 16 patients in ICU. Calgary, with 32 percent of the population, had 35 percent of the active cases while Edmonton, with only 25 percent of the provincial population, had 55 percent of the active cases.

174. Given the disproportionate case count in Edmonton, on October 8, voluntary measures were announced for the Edmonton Zone to help combat rising case numbers:

- Residents and visitors to the zone should limit gatherings to no more than 15 people;
- Wear non-medical masks in all indoor work settings, except when alone in workspaces or where there is adequate separation or barriers; and

- Individuals should limit their cohorts to no more than three (a core/household cohort, a school cohort, one additional sport, social or other cohort), except young children, who can be part of four cohorts if they attend childcare.

175. As case counts continued to rise, and voluntary measures were insufficient, Alberta then took a targeted approach to implementing mandatory measures on a regional basis, to address the areas where cases were identified to be the highest.

Mandatory and voluntary measures put in place between October 20 and November 12

176. On October 20, Alberta paused on asymptomatic COVID-19 testing to help reduce testing wait times, speed up results and limit the spread. Suggested Halloween guidelines were published and voluntary Halloween measures were recommended. Messaging reinforced the importance of compliance with restrictions on social gatherings. On that date there were 392 new cases, 3,203 active cases, 113 hospitalizations and 15 patients in ICU. Edmonton had 50 percent of the active cases while Calgary had 32.5 percent.

177. On Monday, October 26, Alberta had 417 new cases and 4,477 active cases (48.6 percent Edmonton and 32 percent Calgary), and hospitalizations had increased slightly to 118 with ICU admissions remaining at 15. However, as detailed in the Affidavit of Dr. Simmonds, on this date - two weeks after Thanksgiving – the daily Rt value and positivity rate were at record highs indicating that hospitalizations would rise in the coming weeks.

178. Accordingly, at this time, mandatory measures were introduced for Edmonton and Calgary *via* CMOH Order 35-2020, which mandated a 15-person limit on all social gatherings (indoor and outdoor) in the cities of Edmonton and Calgary effective immediately for at least one month. This gathering limit applied to gatherings such as dinner parties, wedding and funeral receptions, banquets and other gatherings, but excluded structured events such as dining in restaurants, theatres, worship services or wedding and funeral ceremonies.

179. The previous voluntary public health measures for the Edmonton Zone (wear non-medical masks in all indoor work settings, except when alone in workspaces or where there is adequate separation or barriers; and limit cohorts to no more than three, except young children, who can be part of four cohorts if they attend child care) remained in place and were now also recommended for the City of Calgary.

180. However, even with some public health measures in place, since the summer, the number of recognized SARS-CoV-2 infections (COVID-19 cases) had grown dramatically to 830 average new cases per day by the week of Sunday, November 8. Hospitalizations, ICU admissions and deaths also grew dramatically over that time.

181. Rising case rates in early November, as anticipated given the rates of positivity and transmission, confirmed that Thanksgiving and Halloween events likely catalyzed and amplified the growth in case numbers. Private social gatherings were identified as a high-risk transmission activity. Therefore, on Friday, November 6, in an attempt to curb caseloads that had grown to 826 new daily cases and 6,822 active cases, Alberta extended effective immediately the mandatory 15-person limit on all social gatherings to all communities under watch status (having more than 50 active cases per 100,000 with at least 10 active cases) *via* CMOH Order 36-2020 (previously this only applied to the cities of Edmonton and Calgary).

182. In addition, all Edmonton and Calgary residents were asked to voluntarily stop holding social gatherings within their homes and instead socialize in structured settings where it is easier to limit risk of exposure, and voluntary measures already in place for Calgary and Edmonton (to limit cohorts to no more than three and to wear masks in indoor work settings unless able to safely distance) were also strongly recommended for any community on the watch list, regardless of location.

183. Everyone was also encouraged to download the secure ABTraceTogether app, which was integrated with provincial contact tracing in order to stop the spread by notifying people who were exposed to a confirmed case, so they could be tested and isolated. Additional steps undertaken as of November 6 to bolster Alberta's public health response included AHS prioritizing the hiring of *about* 380 additional contact tracing staff to expand the contact tracing team to more than 1,100 people, and shifting back to the daily reporting of case numbers and information, including on weekends and holidays.

184. New targeted measures were announced on November 12 effective November 13 *via* CMOH Order 37-2020. CMOH Order 37-02 aimed to limit the spread by introducing mandatory measures for all communities on the enhanced list (Calgary area, Edmonton area, Fort McMurray, Grande Prairie, Lethbridge, and Red Deer) from November 13-27 prohibiting: indoor group

fitness classes and team sports (excluding outdoor sports, individual sports and exercise, and junior, collegiate, university or professional sports, and indoor group low-intensity fitness with 5 or fewer participants); and group singing, dancing and performing activities (excluding professional venues). In addition, from November 13-27, all restaurants and pubs in communities on the enhanced list were required to stop liquor sales by 10 pm and close by 11 pm; and effective November 13, all indoor and outdoor wedding ceremonies and funeral services were limited to 50 people.

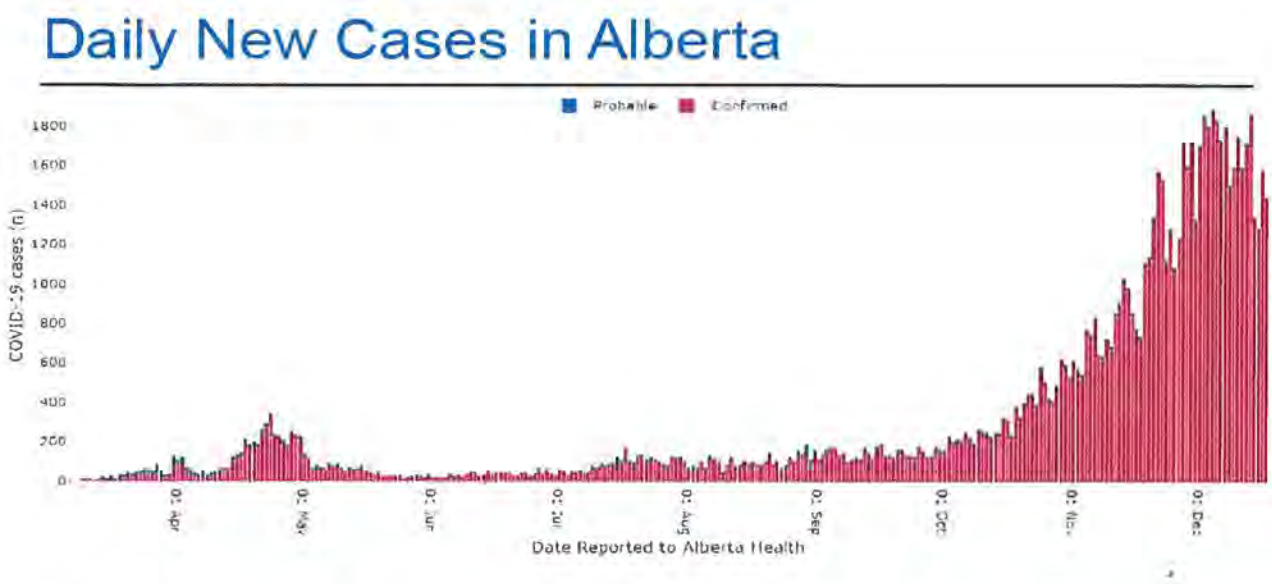
185. Recommendations were that employers in office settings should implement measures to reduce the number of employees in the workplace at one time; and faith-based gatherings should be limited to one-third of the building capacity. Strongly recommended for all communities on the watch status was to stop hosting social gatherings in homes (recommendation previously only applied to Calgary and Edmonton), and for Albertans living in areas under enhanced precautions to not move social gatherings to neighbouring communities with lower rates.

186. Nonetheless, the continued rapid growth in cases necessitated a stronger response heading into winter and the significant religious and social holidays, such as Hanukkah and Christmas that traditionally involve many Albertans in indoor social gatherings.

November 24, 2020: Alberta Declares a Public Health Emergency

187. On November 24, 1,115 new cases had been identified over the last 24 hours, and there were 348 people in hospital, including 66 in ICU. The province had 50,410 active cases. In response to this growth, and because of increasing community transmission with unknown source, which made tracing contacts harder, Alberta declared a state of public health emergency on November 24, 2020.

188. The very nature of exponential growth means even in areas with low numbers of COVID-19 cases, the number of cases can grow very quickly. The graph below shows the exponential growth in the number of COVID-19 cases Alberta experienced during its second wave up to December 18.



189. On November 24, effective immediately, stricter mandatory province-wide measures and measures targeted at regions under enhanced status were enacted *via* Public Health Order 38-2020 for at least three weeks. The new restrictions along with increased enforcement were put in place to reduce the spread of COVID-19 in communities, protect hospitals, keep schools and businesses open as much as possible, and better protect vulnerable Albertans.

190. Under these measures no indoor social gatherings were permitted, including workplaces (people who lived alone could have up to two indoor contacts). There was a 10 person limit for outdoor gatherings, and for funerals and weddings with no receptions permitted. No festivals or events were allowed, and working from home had to be considered, where possible.

191. In addition to these province-wide measures, in regions with enhanced status effective immediately and for at least three weeks places of worship were required to limit attendance to 1/3 of occupancy (previously a voluntary measure) with mandatory masking. The following businesses were closed for in-person service: banquet halls, conference centres, trade shows, non-approved markets, community halls, concert venues, indoor play places, and all levels of sport (leagues can apply for exemptions). Restaurants and bars had to continue to stop bar service at 10 pm and close at 11pm with a maximum of six people from the same household permitted per table. People who lived alone could dine with two close contacts.

192. Retail businesses and some entertainment and event services (movie theatres, museums and galleries, libraries, casinos (no table games), indoor entertainment centres, and indoor fitness and recreation centres (no group classes or practices) could stay open, but were restricted to 25 percent of occupancy. Personal, wellness, and professional services, private one-on-one lessons, and motels, hotels, and hunting and fishing lodges could remain open by appointment only.

193. Mask wearing became mandatory effective immediately and for at least three weeks for all indoor workplaces in the Calgary and Edmonton areas, except when working alone in an office or safely distanced cubicle or a barrier is in place. Not following mandatory restrictions could result in fines of $1,000 per ticketed offence and up to $100,000 through the courts.

194. However, the case trajectory continued to accelerate through November, as illustrated in the table below.

Week Beginning	Cases (Average Daily Increase)	Hospitalizations (Average Daily in Hospital)	ICU Count (Average Daily)	Daily Deaths (Average per Week)
November 8	830	217	48.7	6.8
November 15	1072	286	55.4	8.8
November 22	1366	368	75.4	9.2
November 29	1729	507	96.8	14.0

195. On November 27, Alberta by CMOH Order 39-2020 made mandatory province-wide all the November 24 measures that had previously only been made applicable to regions with enhanced status. CMOH Order 39-2020 also rescinded the parts of CMOH Order 37-2020 regarding businesses and entities, restaurants, cafes, bars and pubs, group physical activity and group performance activity (primarily removing references to region-specific orders and applying mandatory measures province-wide and specifying that prohibited activities could not occur in a food serving establishment (i.e. live performances, billiard/arcade/dart games, video lottery terminals)).

196. Alberta also announced on November 27 that province-wide students in grades 7 to 12 would be shifted from in-person to at-home learning for November 30, 2020 to January 11, 2021,

and students in ECS to Grade 6 from in-person to at-home learning from after the Christmas break until January 11, 2021

197. On November 28, by CMOH Order 40-2020, Alberta amended CMOH Order 38-2020, regarding places of worship to specify that 1/3 limitation is determined by the total operational load as determined in accordance with the Alberta Fire Code and the fire authority having jurisdiction. CMOH Order also amended 39-2020 by removing the prohibition on food-services business and entities offering dine-in services in order to allow persons in those places access to video lottery terminals.

198. On November 28, there were 15,572 active cases with 468 people hospitalized with COVID-19 and 85 in ICU. Just 10 days later on December 8, active cases had jumped to 20,388, and the admission numbers had shot up to 722 in hospital with 122 in ICU. There was also evidence of behavior fatigue and misconceptions that the initial measures were still unnecessary because transmission rates were low in summer. Based on the experience in October and November where private social gatherings were seen to have been significant drivers of transmission, Alberta anticipated that additional measures would need to be enhanced to protect the already overwhelmed health system.

199. As the number of active cases of COVID-19 increased in the community, the possible sources of infection increased. This made it more difficult for the infected person to know how or when they may have been infected. The level of community spread in Alberta where the source of infection was unknown therefore posed a particularly serious threat to the already overwhelmed health care system.

200. In December 2020, the sharp increase in unknown community transmission meant the effectiveness of contact tracing was greatly reduced. As the number of individuals testing positive for COVID-19 increased, the capacity of the health care system to contact cases, identify contacts and link cases was significantly limited. Contact tracing was unable to keep up with the demand and therefore the capacity to identify and control the spread in a targeted way was severely curtailed. By December 18, 2020, 78 percent of all active COVID-19 cases did not have an identifiable source.

201. Transmission of the virus could not be contained with only the existing guidance and voluntary measures and the limited mandatory measures then in place. The robust set of provincial measures implemented on December 8 were necessary to combat this emergent growth. Even though the population of Alberta is smaller than Ontario, Quebec, or British Columbia, at that time, Alberta had more active cases than any province in Canada.

202. Forecasting showed we were at an extremely critical stage. As detailed in the Affidavit of Dr. Simmonds, in mid-December our short-term forecasting accurately estimated the peak in hospitalizations (December 30) and ICU admissions (December 28) would occur in the last week of December. In response to increasing case numbers, and with hospital and ICU beds approaching record highs, Alberta announced new restrictions aimed at limiting the spread in high-risk settings or in settings with high-risk activities *via* Order 41-2020 on December 8, 2020. These measures aimed to slow the spread of the virus by reducing time people spent indoors with large groups and reducing the time spent indoors engaging in high-risk activities.

203. Order 41-2020 prohibited all indoor and outdoor gatherings, both private and public. Effective immediately, Albertans could only gather with members of their own household with exceptions made for individuals who lived alone who could have up to two close contacts, and for funerals and weddings with 10 or fewer people and without receptions.

204. Province-wide masking became mandatory, also effective immediately. Festivals, parades, events, concerts, exhibitions, competitions, sport, and performances remained prohibited.

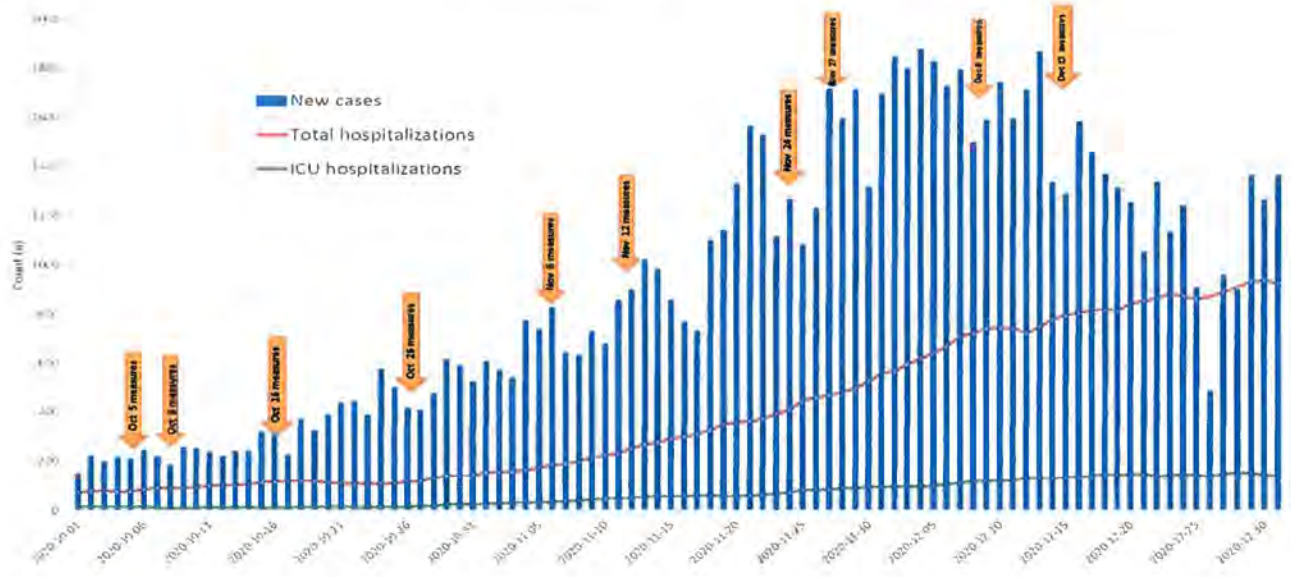
205. CMOH Order 42-2020 came into effect at 12:01 a.m. on December 13, and implemented additional province-wide restrictions for at least four weeks, including business closures and restrictions on other services, retail businesses and attendance at places of worship.

206. All staff were required to work from home unless a physical presence was required for operational effectiveness. Restaurants, pubs, lounges, and bars were closed to in-person service, but takeout, curbside pickup and delivery were still permitted. Places of worship were limited to 15 percent of fire code occupancy for in-person attendance (previously was 1/3 of capacity), but could hold drive-in services without capacity limits.

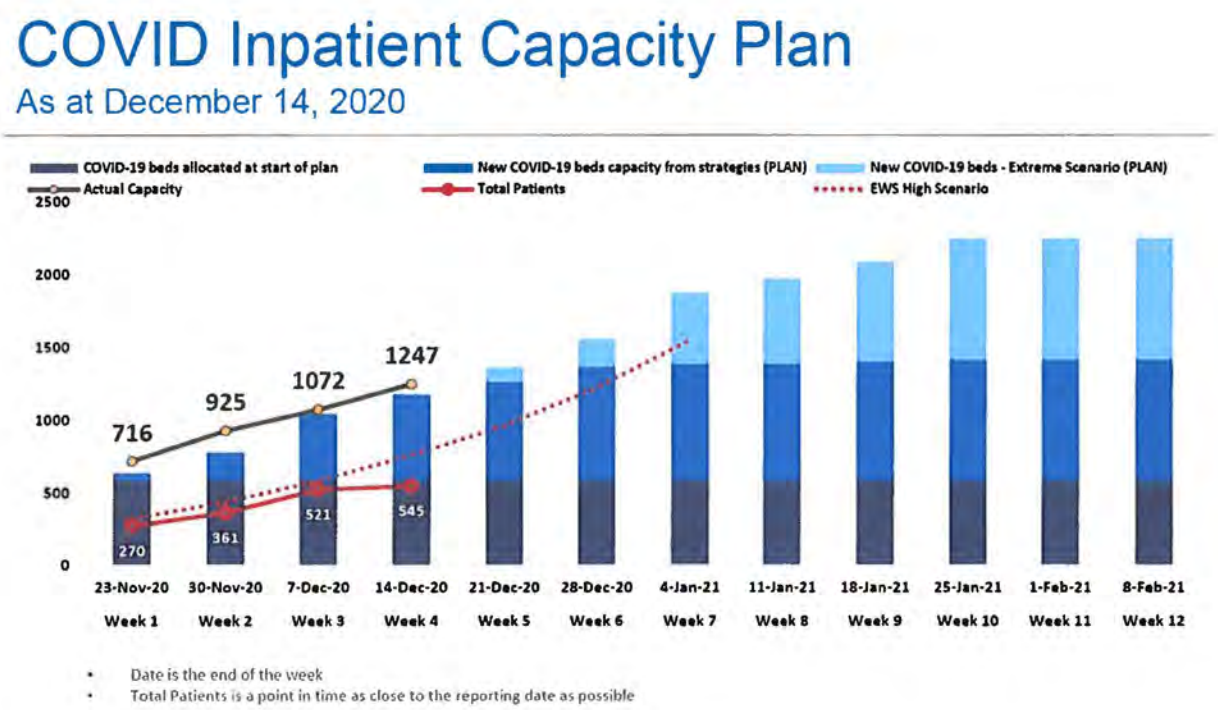
207. Retail services, including malls, were limited to 15 percent of fire code occupancy (previously 25 percent of occupancy), and businesses required to close as of November 27 (CMOH Order 39-2020) remained closed. The following additional types of business also had to be closed to the public:

- personal and wellness services (e.g. massage, hair salons, nail salons, tattoos and piercing);
- recreational facilities (e.g. fitness centres, recreation centres, pools, spas, gyms, studios, day and overnight camps, indoor rinks and arenas); and
- entertainment businesses (e.g. libraries, science centres, interpretive centres, museums, galleries, amusement parks, water parks, bingo halls, casinos, gaming and racing entertainment centres, horse tracks, raceways, bowling alleys, pool halls, legions, private clubs) (outdoor recreation was permitted and hotels could stay open with certain restrictions).

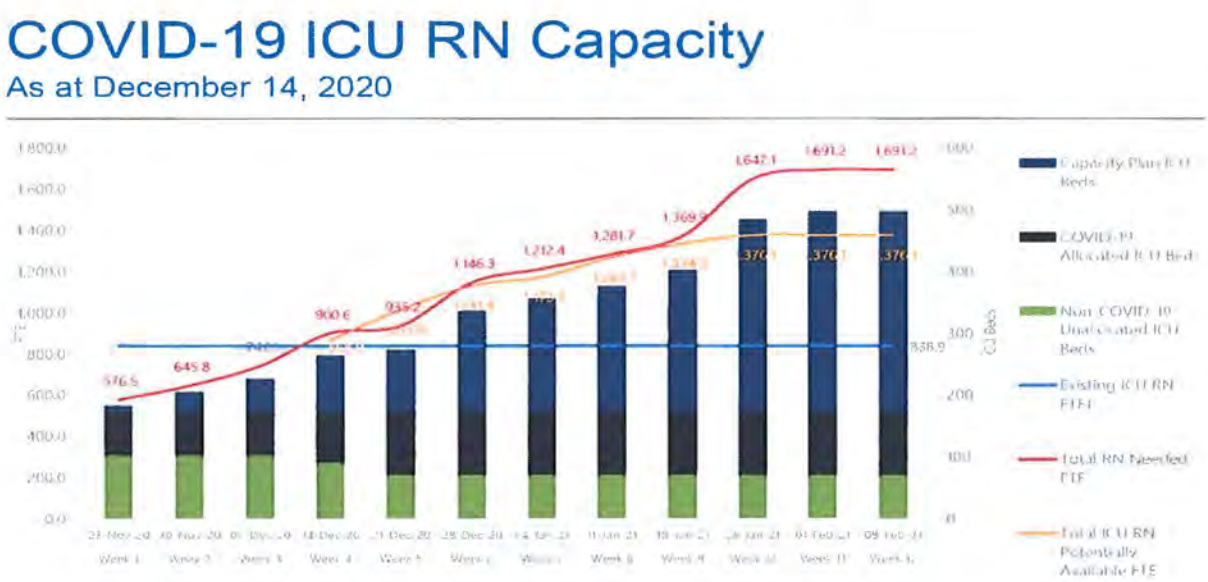
208. The enhanced measures enacted in November and December 2020 restricted some in-person attendance to certain businesses/activities that had a demonstrated higher risk of transmission. The following graph illustrates the number of hospital and ICU admissions relative to the implementation of public health measures between October 5 and December 30, 2020.



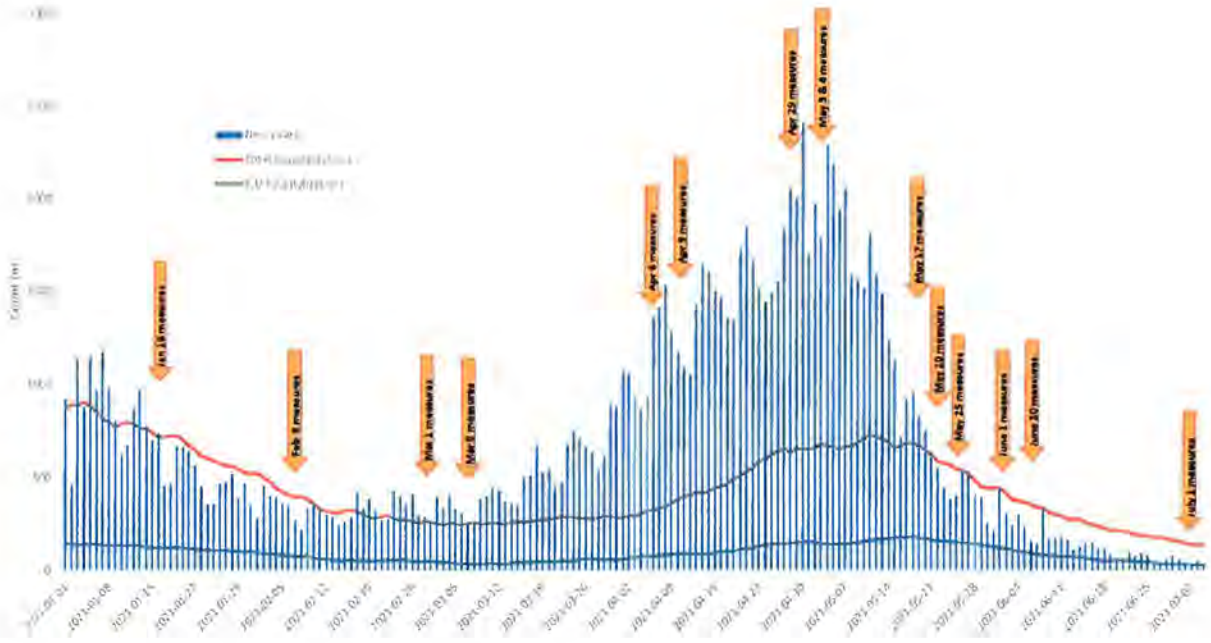
209. As of December 14, AHS had developed and was implementing a COVID Inpatient Capacity Plan as shown on the graph below to address the forecasted critical capacity situation in hospital beds that was just 2 weeks away.



210. At the same time, AHS had also developed a plan to address to the maximum extent possible critical care nursing capacity as shown in the graph below.



211. Fortunately, the public health measures implemented in late November and December worked to slow transmission and bend the curve in new cases and hospitalizations. As shown in the graph below, following the implementation of the December 8 measures, daily new cases peaked on December 13, and then began to drop. This trend continued through January and into February 2021, indicating the effectiveness of the measures. As such, on January 29, 2021, Premier Kenney announced Alberta's plan to set clear benchmarks for the easing of public health restrictions across the province. Given Alberta's recent experience, these benchmarks were based on hospitalizations and ICU admissions.



Alberta's Third Wave: March to May 2021

212. On February 8, 2021, CMOH Order 02-2021 rescinded CMOH Order 42-2020 to allow Albertans to attend certain locations and engage in certain activities where it was felt the risk of virus transmission could be mitigated if people adhered to public health measures and guidelines. However, as shown in the above graph, when public health measures were eased in February and March, cases and admissions to hospitals and ICUs plateaued and began to rise again in early March due to the increasing variant strains appearing in the community, especially the variant B.1.1.7, first identified in the UK. Even with some public health measures in place, the number of

recognized SARS-CoV-2 infections (COVID-19 cases) continued to grow dramatically from late March to early May as illustrated in the graph.

213. Daily cases began to rise significantly in March, doubling from approximately 400 new cases per day during the second week to over 800 new cases identified on March 30 and well over 1,000 new cases per day by early April. As a result of this increase, the province announced on April 6 that it would return to the level of restrictions last seen in early February.

214. On April 7, 2021, due to the rising spread of COVID-19, the province announced it would return to Step 1 of the Path Forward, and issued CMOH Order 08-2021 with new restrictions for retail, fitness and performance activities. The new restrictions reduced capacity in retail businesses to 15 percent of capacity, and prohibited group fitness and performance activities.

215. On April 9, 2021, CMOH Order 10-2021 restricted restaurants to providing only takeout, delivery and patio service.

216. The critical stage of the third wave was reached during late April to mid-May when on April 30 a record daily high of 2,408 new cases were identified and on May 3 when the positivity rate reached a record high of 13.37 percent (daily). By comparison, the positivity rate during the critical point of the second wave was only 8.43 percent (week ending December 13). The critical stage for acute care capacity was reached on May 18 when COVID-19 ICU admissions peaked at 184 (total ICU 229 or 98.7 percent capacity). In response, Alberta returned to targeted measures for areas where there were at least 350 cases per 100,000 people and 250 active cases. Specifically, Part 4 of CMOH Order 17-2021 prohibited all students in grades 7 through 12 in areas with more than 350 active cases per 100,000, and at least 250 active cases, from attending a school location effective May 3, 2021. This included schools in Edmonton, Calgary, Red Deer, Grand Prairie, Lethbridge, Airdrie, Strathcona County and St. Albert.

217. Because cases and positivity continued to climb, on May 3, measures were expanded to additional areas. Order 18-2021 modified Order 17-2021 by increasing the number of municipalities affected by additional COVID-19 measures.

218. On May 6, 2021, in order to stem the tide of rising cases and acute care admissions, Order 19-2021 was put into effect, outlining COVID-19 measures for areas with 50 or more active cases of COVID-19 per 100,000 and 30 or more active cases:

- Outside gatherings were limited to five people (down from 10);
- All indoor fitness closed, including one-on-one training;
- No more than 10 people could attend funeral services (down from 20);
- All post-secondary learning shifted to online learning only;
- Faith services were limited to in-person attendance of 15 people (down from 15 percent of capacity);
- Hotels/motels could remain open but pools and recreation facilities closed;
- Working from home remained mandatory, except where in-person presence was needed for operational effectiveness;
- Workplaces (except work camps and essential and critical services) with transmission of three or more cases were required to close for 10 days;
- In-person dining on patios at restaurants, bars, pubs, lounges and cafes was prohibited as of 11:59 pm on May 9 (take out or delivery services permitted);
- Personal and wellness services (hair salons, barbers, nail salons, estheticians, tattoos and piercing) must be closed as of 11:59 pm on May 9;
- Health, social and professional services (e.g. physicians, dentists, chiropractors, massage therapists, lawyers, photographers) could remain open by appointment only as of 11:59pm on May 9. (Exception: Services such as shelters and not-for-profit community kitchens, can remain open); and
- All outdoor sports and recreation were prohibited except with members of your household or, if living alone, two close contacts (down from 10 people) as of 11:59 pm on May 9.

219. Additionally, Alberta Education shifted Kindergarten to Grade 12 students to at-home learning from May 7 to May 24.

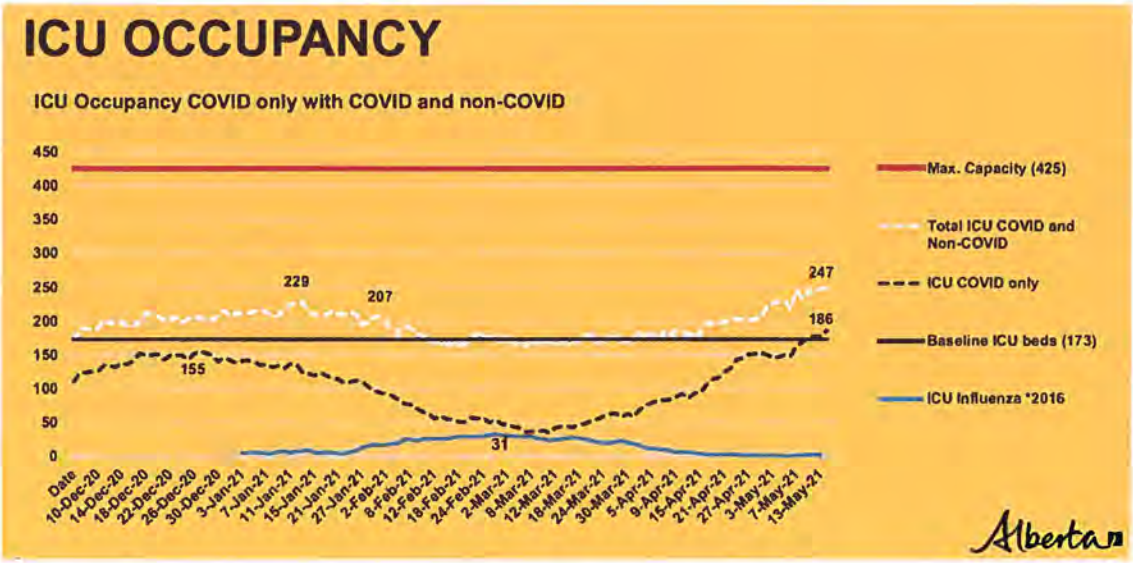
220. Also on May 6, CMOH Order 20-2021 was issued, outlining COVID-19 measures for areas with fewer than 50 active cases of COVID-19 per 100,000 and 30 active cases:

- mandatory masking in indoor spaces

- indoor social gatherings limited to households or and individual who lives alone and their 2 close contacts;
- Outdoor social gatherings/activities and indoor/outdoor weddings limited to a maximum of 10 individuals; funerals up to a maximum of 20 individuals.
- Retail services, including malls, were limited to 15 percent of fire code occupancy
- In-person dining on patios at restaurants, bars, pubs, lounges and cafes was prohibited as of 11:59 pm on May 9 (take out or delivery services permitted);
- Personal and wellness services (hair salons, barbers, nail salons, estheticians, tattoos and piercing) must be closed as of 11:59 pm on May 9;
- Faith services were limited to in-person attendance of 15 percent of capacity
- Indoor physical activity, performance activities, and youth group recreational activities were prohibited;
- All post-secondary learning shifted to online learning only.

221. In order to provide more specificity regarding the medical exemptions for mask wearing, on May 13, 2021, CMOH Order 22-2021 announced a change to the mask-wearing requirement. People with certain health conditions that prevent them from wearing a mask (e.g. sensory processing disorders, mental illness, clinically significant acute respiratory distress) were now required to have a letter from a health professional to verify that a medical exemption existed.

222. In May 2021, Alberta provided an update on the health system capacity. Of particular concern was ICU occupancy and the ability of the system to respond to the rising, and record, numbers. Variants of concern continued to drive these numbers. As shown in the graph below, at that time ICU occupancy was at a critical juncture, with total ICU (COVID and non-COVID occupancy combined) at 61 people more than the baseline number of ICU beds in the system, and on an upward trend. This graph also shows the significant difference between ICU occupancy in a typical influenza season (peaking at 31 total in ICU at one time) and the ICU volume driven by COVID-19 (peaking at 184). Note that the graph below indicates an ICU COVID-19 occupancy of 186 as there were some out of province cases in Alberta hospitals at that time. The peak occupancy of 184 referenced elsewhere in the document is the peak of Alberta cases in ICU at any one time for COVID-19 treatment.



223. CMOH Order 29-2021 was put into effect May 27, 2021 to address the escalating frequency of public protests in Alberta while the health care system was still in at a critical point due to a spike in cases, particularly driven by the highly contagious variants of concern. Order 29-2021 established specific rules applicable to protest gatherings, which had previously been covered by measures applicable to "private social gatherings".

224. CMOH Order 30-2021 was put into effect on June 1, 2021 (parts in relation to Places of Worship in effect May 27) to allow for the implementation of Stage 1 of Alberta's re-opening plan as described above. CMOH Orders 31-2021 and 32-2021 went into effect on June 10 to implement Stage 2 of the re-opening plan. Order 32-2021 outlines COVID-19 masking restrictions for Stage 2 of Alberta's Open for Summer plan.

F. "Focussed Protection" – Herd Immunity and the Great Barrington Declaration

My October 2020 response to the Great Barrington Declaration

225. I have previously addressed this issue in my article "Herd Immunity and the Great Barrington Declaration", posted October 28, 2020, and attached as **Exhibit "X"** to this Affidavit: https://www.alberta.ca/herd-immunity-and-the-great-barrington-declaration.aspx.

226. To summarize, what I said in October was that the claim of the Great Barrington Declaration is very appealing to those tired of restrictions and where those at a lower risk of

severe outcome are keenly feeling the economic and social effects of the restrictions. Unfortunately, the claim that this approach is achievable with minimal impact is not correct for several reasons.

227. First, evidence around long-lasting immunity is still unclear. The concept of achieving herd immunity through community spread of a pathogen rests on the assumption that people who survive an infection will become immune. However, it is not presently known whether building herd immunity though infection will confer long-lasting protection. Seasonal coronaviruses that cause common colds provoke a waning immunity that seems to last approximately a year. If SARS-CoV-2 is the same, then it is likely that a population would never reach herd immunity through natural transmission.

228. Second, it is not accurate to assert that herd immunity could be achieved with few costs in health related to COVID. Based on Alberta's actual data, infecting 50 percent of those in the Alberta population under 60 would cost approximately 1,000 lives in that same younger population. Assuming we could somehow successfully segregate those over 60 from those under 60, we would expect over 39,000 hospitalizations to achieve an infection rate of 50 percent in the population under the age of 60.

229. If these infections were allowed to spread unchecked over a short period of time, the hospitalization volume alone would be sufficient to impair the ability of our acute care system to manage all the other health care needs of our population. In order to manage the demand for hospital beds and ICU care, other services would have to be paused or stopped in order to care for the acutely ill. This would worsen, not improve, the outcomes of concern in the Barrington document such as cardiac care, cancer screening, and childhood immunizations.

230. The premise that we could successfully shield continuing care facilities and hospitals from COVID-19, and that we would be able to support all those over 60 (and presumably those with high risk chronic conditions) to stay home with limited activities is not supported by evidence.

231. The Barrington document implies that "lockdown" is binary – all or none, and that no restrictions should be in place for the young. This is a false dichotomy. The best way to prevent

severe illness and death from COVID-19 is to prevent large spreading events, quickly identify cases, trace and isolate contacts, and keep the spread of the virus to a manageable level. This is exactly what Alberta has done.

232. We are not in lockdown in Alberta. We must continue to pursue this balanced approach, learning as we go along how best to minimize both the risks of public health measures and the risks of COVID-19. Herd immunity by natural infection is not a wise, or possibly even an achievable, goal to pursue.

Updated response to the Great Barrington Declaration

233. Evidence on the strength of immunity continues to be reviewed and reinfection is building. However, the length of time an individual remains immune is still unknown. Researchers can test whether people have antibodies that are specific to SARS-CoV-2, but they still don't know how long any immunity might last. Additionally, based on the December results of the Alberta Residual Sera study, only about 2.5 percent of Alberta's population had detectable antibodies to the virus that causes COVID-19. These results indicated that a very low proportion of Albertans had been infected, which implied the province was a long way from herd immunity, yet had experienced significant burdens and costs associated with morbidity and mortality.

234. It is unknown what the actual herd immunity threshold for COVID-19 is, but various organizations have estimated it to be between 60-70 percent.

235. As stated above, building herd immunity through natural infection will result in significant morbidity and mortality in the population, and stress on the health system regardless of the protections in place for those known to be at risk of serious outcome (e.g., seniors). In order to do this through natural disease and not overwhelm capacity of the health care and critical care system to respond (health and critical), we have to limit the amount of disease at any one time.

236. It was more likely, as has now proven to be the case, to have vaccine induced immunity in order to safely achieve herd immunity. Despite significant interventions and controls, community based COVID disease inevitably results in outbreaks in congregate living facilities that also results in morbidity and mortality.

237. It is possible that vaccine hesitancy may challenge achieving long-term immunity amongst the population. If significant proportions of the population refuse or delay vaccination, then those over 60 (and those with chronic conditions) could be forced to remain sequestered for even longer before a sufficient level of immunity could be achieved in the population, if it could be achieved at all. There is also an assumption that vaccine availability, efficacy and deployment will not be interrupted by supply or other issues.

238. I have also reviewed the peer-reviewed article published in the Lancet, referred to as the John Snow Memorandum https://www.johnsnowmemo.com/john-snow-memo.html, which offers a critique of the Great Barrington Declaration. It is attached as **Exhibit "Y"**. I agree with the conclusions in the Snow Memorandum.

239. I make this Affidavit in response to the Applicants' application.

AFFIRMED BEFORE ME in the City of Edmonton, Province of Alberta, this 12th day of July, 2021. I certify that Dr. Deena Hinshaw satisfied me that she is a person entitled to affirm.

H Veale

(Commissioner for Oaths in and for the Province of Alberta)

Heather L. Veale
Barrister & Solicitor

Deena

Dr. Deena Hinshaw, MD, MPH, FRCPC, CCFP

CURRICULUM VITAE
Dr. Deena Hinshaw, M.D., F.R.C.P.(C)
(updated Mar 2020)

THIS IS EXHIBIT " A " referred to in the Affidavit / Declaration of Dr. Deena Hinshaw affirmed ~~Sworn / Declared~~ before me this 12th day of July A.D., 2021
H. Veale
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public.
Heather L. Veale
Barrister & Solicitor

Business Address: 24th Floor, ATB Place North Tower
10025 Jasper Avenue
Edmonton, Alberta T5J 1S6
Office: (780) 415-2809

Education and Training:

1993-1997	B.Sc. (Biology and Chemistry), Augustana University College, Camrose, Canada
1999-2004	M.D., University of Alberta, Edmonton, Canada
2004-2006	Resident, Family Medicine, University of Alberta, Edmonton, Canada
2006-2008	MPH (Community Health), University of Alberta, Edmonton, Canada
2004-2009	Resident, Community Medicine, University of Alberta, Edmonton, Canada
2007-2009	SEARCH Canada program completed (health research and knowledge translation cohort training)
2009 (July-Dec)	Resident, Care of the Elderly, University of Alberta, Edmonton, Canada

Licensure and Certification:

2005	Licentiate of the Medical Council of Canada (# 99050)
2006	Certificant of the College of Family Physicians of Canada (#220401)
2006	License, College of Physicians and Surgeons of Alberta (#014415)
2009	Fellow of the Royal College of Physicians of Canada (Community Medicine #692636)

Academic Appointments:

2011-2017	Assistant Clinical Professor, Division of Preventive Medicine, Department of Medicine, University of Alberta, Edmonton, Canada
2017-present	Associate Clinical Professor, Division of Preventive Medicine, Department of Medicine, University of Alberta, Edmonton, Canada
2017-present	Clinical Assistant Professor, Department of Community Health Sciences, Cumming School of Medicine, University of Calgary

Medical Staff Appointments:

2010-2017	Medical Officer of Health, Central Zone, Alberta Health Services
2017-2018	Acting Deputy Chief Medical Officer of Health, Alberta Health
2019-present	Chief Medical Officer of Health, Alberta Health

Awards/Honors:

2008	Alumni Award for Academic Excellence, Master's Course-based student, School of Public Health, University of Alberta.
2008	The Ancient and Accepted Scottish Rite of Freemasonry Gordon Denchfield Thompson Scholarship, University of Alberta. (Awarded for academic standing and community service in a residency program)
2009	Canadian National Specialty Society for Community Medicine President's Award (for outstanding contributions to the society)
2010	Top Poster award for: Hinshaw D, Chandran A U. Evaluation of a Geriatric Inpatient Influenza Immunization Program. Glenrose Rehabilitation Hospital Annual Research Symposium, Edmonton, Alberta. November 3, 2010.

Professional Memberships and Administrative Activities:

Memberships:

2009-present	Member, Royal College of Physicians of Canada
2009-present	Member, Public Health Physicians of Canada (Formerly the Canadian National Specialty Society for Community Medicine, serving as treasurer from 2009-2010)
2009-present	Member, Alberta Medical Association Section of Public Health and Preventive Medicine (serving as secretary from 2010-2018)
2009-present	Member, Canadian Public Health Association
2009-present	Member, Alberta Public Health Association

Grant Review, Advisory Committees, Scientific Societies:

2018	Member of Royal College Specialty Committee for Public Health and Preventive Medicine
2016-2017	Planning Committee for the Canadian Public Health Association-led Public Health 2017 Conference held in June, 2017
2016-2017	Planning Committee for the Canadian Alliance for Regional Risk Factor Surveillance Symposium held in June, 2017

Institutional Administrative and Leadership Contributions:

Major Committees:

2011-2018	Member of Public Health and Preventive Medicine Residency Program Committee, University of Alberta
2011-2017	Chair of Central Zone Infection Prevention and Control Committee
2011-2017	Member of Provincial Infection Prevention and Control Committee

2011-2017	Lead Medical Officer of Health for the Central Zone, involving administrative responsibilities in addition to clinical public health responsibilities
2013-2017	Co-chair of Central Zone Hand Hygiene Committee
2013-present	Member of the Alberta Population and Public Health Council
2013-2017	Member of Central Zone Emergency/Disaster Management Steering Committee
2013-2017	Member of Central Zone Medical Advisory Committee
2013-2017	Member of AHS Population and Public Health Leaders Committee
2014-2017	Lead Medical Officer of Health for Public Health Surveillance and Infrastructure within Population, Public and Indigenous Health, AHS, in addition to zone responsibilities
2015-2017	Co-chair of Alberta Population and Public Health Council Surveillance Sub-Committee
2015-2017	Member of Central Zone Executive Quality Council
2015-2017	Member of Community Cancer Profiles Advisory Committee
2016-2017	Member of Provincial Ambient Air Quality Committee
2016-present	Member of Population and Public Health Strategic Clinical Network Core Committee
2016-2017	Member of Public Health Service Excellence Team for accreditation preparation in AHS
2017-2018	Co-chair of Minister's Opioid Emergency Response Commission's Opioid Surveillance and Analytics Working Group
2018-2019	Co-chair of Minister's Opioid Emergency Response Commission
2018-2019	Co-chair of Emerging Substances Working Group, Valuing Mental Health
2019	Member of the Alberta Public Laboratories Board, and Board Committees of Quality and Safety and Governance and Human Resources
2019-20	Member of Alberta Mental Health and Addictions Advisory Committee
2020	Member of Alberta Precision Laboratories Advisory Committee

Teaching Contributions:

Classroom Instruction:

2011-2017	Invited lectures to Public Health and Preventive Medicine Residency half days on Public Health Law and Public Health in Seniors' Populations (Nov 2011, May 2012, Aug 2014, Jan 2016, and June 2017)
2016-2018	Invited lecture on poverty and health for Nursing 490, Augustana Campus of the University of Alberta, April 2016, March 2017 and March 2018
2018-2019	Invited lecture on influenza, and invited panel member for case study discussions of legal and ethical considerations in public health practice for Infectious Disease Epidemiology, SPH 697, School of Public Health, University of Alberta, Feb, April, October and December, 2018, and October and December 2019

CME Instruction (Invited CME presentations are listed at the end of the CV):

2010	Geriatric Grand Rounds: "Geriatric Inpatient Influenza Immunization", Glenrose Rehabilitation Hospital, January 26, 2010
2010	Family Medicine Rounds: "Blood and Body Fluid Exposures", Red Deer Regional Hospital, April 8, 2010
2011	Family Medicine Rounds: "Influenza Immunization", Red Deer Regional Hospital, Oct 13, 2011
2014	Emergency Medicine Rounds: "Communicable Disease Update", Red Deer Regional Hospital, Oct 21, 2014
2014	Alberta Health Services provincial town hall: "Ebola – Key Messages", province-wide via telehealth, Oct 20, 2014 and in Central Zone via telehealth on Nov 4, 5, 7, 10, and 12, 2014
2014	Family Medicine Rounds: "Ebola – Key Messages", St. Mary's Hospital, Camrose, Alberta on Nov 10, 2014 and Smith Clinic, Camrose, Alberta, on Dec 4, 2014
2016	Emergency Medicine Rounds: "Blood and Body Fluid Exposures", Red Deer Regional Hospital, February 29, 2016
2017	Public Health Works Speaker Series: "Rare Pathogen, Basic Methods: Follow-up of Healthcare Workers (HCWs) Caring for the First Patient Diagnosed with Avian Influenza A H5N1 in North America", Nationally broadcast telehealth event based at Coronation Plaza, Edmonton, January 17, 2017
2017	Emergency Medicine Rounds: "Vaccine Preventable Diseases", Red Deer Regional Hospital, March 16, 2017
2017	Public Health Physicians of Canada Annual CPD Symposium: "Nightmares and Dreams in Public Health Practice: Public Health M&M Rounds", Presentation title: "Jurisdictional Jungle", World Trade and Conference Centre, Halifax, June 5, 2017
2017 - 2019	Alberta Health Centre of Organization Learning (COOL) 200, Evidence and Policy: "Perspectives from Public Health", Edmonton, Oct 12, 2017, Oct 17, 2018, and October 16, 2019
2018	Council of Public Health Physicians: "Chronic Wasting Disease", Edmonton, Feb 13, 2018
2019	Campus Alberta Student Conference on Health: "Public Health is Everyone's Business", Edmonton, Oct 5, 2019

Clinical Instruction and Supervision:

2011-2017	Medical Officer of Health Lead for resident and medical student rotations in Rural Public Health, Central Zone, Alberta Health Services
2016-2017	Medical Officer of Health Lead for resident rotations in Surveillance and Health Status Assessment, Alberta Health Services
2017-present	Medical Officer of Health Lead for resident rotations in Public Health Policy, Alberta Health

Clinical Contributions:

Current Clinical Service:

Up to July 31, 2017: Medical Officer of Health appointment in the Central Zone and with the Alberta Health Services portfolio of Public Health Surveillance and Infrastructure with clinical public health duties at a 0.8 FTE including a week of on call duties every third week.

Aug 2017 – Jan 2019: Acting Deputy Chief Medical Officer of Health at Alberta Health, working at a 0.8 FTE including a week of on call duties every third week.

Jan 2019 – present: Chief Medical Officer of Health at Alberta Health, working full-time, including a week of on call duties every two to three weeks.

Clinical Innovation, Outreach and Global Health Initiatives:

2010-2017 Worked to create linkages via a formal connection to zone operations with the Indigenous Health Program and Indigenous communities in the Central Zone to ensure this population is considered in planning and programs.

2014-2017 Worked to create a Community of Practice for public health analytics staff working across portfolios and zones. This involved planning a workshop for face-to-face connections and exchange of ideas followed by development of a formal community of practice for this group of public health practitioners, with one key activity being monthly analytic-focused information sharing forums. Several cross-portfolio projects have been initiated as a result, enhancing the use of data to inform public health practice.

Publications:

Peer-Reviewed Original Research (trainees directly supervised by me are underlined):

Hinshaw, D., Chandran A.U. Evaluation of a Geriatric Inpatient Influenza Immunization Program. *American Journal of Infection Control.* 2011; **39(4)**:342-44.

Invited Reviews and Editorials:

Hinshaw, D., Copes, R. Bisphenol A: Baby bottles, water bottles and more. *Family Health.* 2008; **24(4)**:34-5

Abstracts:

1. Hinshaw D, Chandran A U. Evaluation of a Geriatric Inpatient Influenza Immunization Program. Glenrose Rehabilitation Hospital Annual Research Symposium, Edmonton, Alberta. November 3, 2010. (Awarded "Top Poster")
   Presented: Poster Presentation
2. Goodison K and Hinshaw D. Evaluation of a Lookback Investigation into a Dental Office with Breaches in Infection Control. Presented at the Canadian Public Health Association Conference, Vancouver, BC. May 26, 2015.
   Presented: Oral Podium Presentation
3. Harrison R, Hinshaw D, Fonseca K, Joffe M, Lavoie M, Li Y, Predy G, Tipples G and Tsekrekos S. Serologic Follow-up of Healthcare Workers (HCWs) Exposed to Influenza A H5N1. Presented at the AMMI-CACMID Conference, Vancouver, B.C. March 31, 2016.
   Presented: Oral Podium Presentation
4. Hinshaw D, Harrison R, Fonseca K, Joffe M, Lavoie M, Predy G, Tipples G and Tsekrekos S (2016) Follow-up of Healthcare Workers (HCW) Caring for the First Patient Diagnosed with Avian Influenza A H5N1 in North America. Presented at the Canadian Public Health Association Conference, Toronto, ON. June 15, 2016.
   Presented: Poster Presentation
5. Birk-Urovitz E, Li Y, Drews S, Sikora C, Hinshaw D, Biel RK, Habib F, Rivera L, Usman H, Strong D, Johnson I. Correlation of School Absenteeism and Laboratory Results for Flu A in Alberta, Canada. International Society for Disease Surveillance, Atlanta, Georgia, December 6-8, 2016
   Presented: Poster Presentation
6. MacDonald A, Usman HR, Hinshaw D, Meurer D, Sikora C. Open the Door to In-House Surveillance Product Development. International Society for Disease Surveillance, Atlanta, Georgia, December 6-8, 2016
   Presented: Poster Presentation
7. Happe J, Cortright A, Hinshaw D. Driving Physician Hand Hygiene Compliance from Unacceptable Lows to Sustainable Highs. Infection Prevention and Control Canada 2017 National Education Conference, Charlottetown, PEI, June 19, 2017
   Presented: Oral Podium Presentation

Invited International Scientific Presentations:

2011 "El Sistema de Salud de Canada". [The Canadian Healthcare System]. - Fifth Annual Canadian Studies Workshop, Universidad de Oriente, Santiago de Cuba, Cuba. April 6, 2011

Invited Local/Regional and CME Presentations.

2013 Family Medicine Rounds: "Influenza Immunization", Central Zone-wide via telehealth on September 17, 2013 and at the Red Deer Regional Hospital, October 10, 2013, invited by Central Zone Medical Director, Dr. Evan Lundall

2016 "Public Health: The Force Awakens". Invited to present the Alberta perspective on a panel addressing the topic of public health's ability to reorient the health system in different structures across the country. Canadian Public Health Association Conference, Toronto, ON. June 15, 2016, invited by Pegeen Walsh, Executive Director of the Ontario Public Health Association

2017 "Changing Governance Structures" Invited to present the rural Alberta perspective regarding the impact of changing governance structures on rural public health. Rural, Remote and Northern Public Health Network National Webinar. Broadcast across Canada. May 5, 2017. Invited by Dr. Sandra Allison, Chief Medical Health Officer of the Northern Health Region of British Columbia and Chair of the Rural, Remote and Northern Public Health Network.

2018 Invited to be part of a cannabis legalization panel, with presentations on March 20, 2018 at the Augustana Campus of the University of Alberta, Camrose, and general public events on June 14, 2018 and Sept 10, 2018 – invited by Dr. Timothy Parker, Professor of Psychology, Augustana Campus.

The purpose of this website is to provide you with information about a career path in Public Health and Preventive Medicine and to provide a resource for residency training in Public Health and Preventive Medicine. As each resident has unique needs and aspirations, we encourage you to consult widely so that you can make the most informed possible choice. Residents should refer to the University of Alberta website for information on facilities, registration, fees, etc. As with the other programs at U of A, the Public Health and Preventive Medicine program is part of the Canadian Residency Matching Service (CARMS) process. To access the C a R M S program please see their website.

What is Public Health and Preventive Medicine?

Public Health and Preventive Medicine deals with groups or populations, rather than individuals. Using population health knowledge and skills, the Public Health and Preventive Medicine specialist plays a role in the maintenance and improvement of the health and well-being of the community. This function is accomplished by evaluating the health needs of a population and developing, implementing and assessing programs that meet those needs. Recognition of specialty training in Public Health and Preventive Medicine by the Royal College of Physicians and Surgeons of Canada (RCPSC) began in the mid 1970's and specialty certificates are conferred by a dozen programs in Canada.

What do Public Health and Preventive Medicine specialists do?

A specialist in Public Health and Preventive Medicine must be able to:

1. Assess the health needs of the population by identifying the appropriate information or generating new information that recognizes the interactions of biological, behavioral, social and environmental factors that affect health.
2. Recognize the strengths and weaknesses inherent in the various measurements of health and characteristics of society and understand the principles of the statistical methods required to summarize and analyze the information.
3. Set priorities and develop programs to meet the health needs of the population.
4. Implement programs taking into account the socioeconomic, educational, occupational and political factors that influence the distribution and use of health services. Such program implementation involves a knowledge of health care systems and the ability to take into account their limitations. In addition, it requires both interpersonal and organizational skills and a knowledge of systems theory and management processes.
5. Develop skills in evaluating programs and in providing consultation to others involved in the planning, management or evaluation of health services.
6. Maintain competence through continuing education and demonstrate ethical and professional responsibility.

Where do community specialists work?

The Public Health and Preventive Medicine specialist careers include:

1. the practice of public health at a local, regional, provincial, national or international level;
2. the planning and administration of health services in institutions or government;
3. community-oriented clinical practice with an emphasis on health promotion and disease prevention;
4. the assessment and control of occupational and environmental health problems;
5. teaching; and
6. research.

A list of Public Health and Preventive Medicine specialists and their work locations can be found through the National Specialist Society. The University of Alberta Public Health and Preventive Medicine program emphasizes the role of local public health officer and health administration.

Our Program

The University of Alberta Residency Program aims to focus on giving residents the practical experience they need to develop skills to work in all areas of public health and preventive medicine.

1.
2.

THIS IS EXHIBIT " B " referred to in the Affidavit / Declaration of
Dr. Deena Hinshaw
affirmed
~~Sworn / Declared~~ before me this 12th day
of July A.D., 2021
H Veale
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public.
Heather L. Veale
Barrister & Solicitor

Previous Next

2021 Public Health and Preventative Medicine (PHPM) Resident Event

Program Highlights

A focus on the front-line practice of Public Health and Preventive Medicine.

Close/frequent contact with preceptors.

The program has training options with the Occupational Medicine residency program and the School of Public Health.

Wide range of available training options; flexibility to meet individual interests of residents.

Continual exposure to Public Health and Preventative Medicine through Academic Half Day, even during Family Medicine training.

4th and 5th year rotations include: Communical Disease Control, Provincial Lab, Infection Prevention and Control, Chronic Disease Prevention, Injury Prevention, Environemtal Public Health, Health Policy, First Nation & Inuit Health, Rural Public Health, and Senior Management.

Overview Video

Here from our Program Director, Assistant Program Director, and our Co-Chief Residents. They explain the profession of Public Health & Preventative Medicine, and the Residency Program here at the University of Alberta.

Timestamps —

0:00 - 7:47 Dr. Karen Lee, Program Director
7:47 - 9:40 Dr. Alexander Doroshenko, Assistant Program Director
9:40 - 11:35 Dr. Ekua Amponsah Agyemang, Co-Chief Resident
11:35 - 16:09 Dr. Samantha Cheuk, Co-Chief Resident

Residency at a Glance

Learn about each year of the program with an overview of each year.

PGY1 and PGY2

Emphasis in the first two years of the Public Health and Preventive Medicine residency is on solidifying clinical and decision making skills which may be obtained by rotations in internal medicine, pediatrics, psychiatry, obstetrics and gynecology, surgery, family medicine or emergency medicine. Some residents may choose to complete the requirements for Family Medicine Certification at the University of Alberta. Selection of one of these is typically done at the time of interviewing for the program.

Clinical rotations

Infectious diseases
This clinical rotation allows the resident to manage a variety of infectious disease under the mentorship of an infectious disease specialist in the setting of hospital consultations and ambulatory care clinics.

Microbiology
This laboratory investigation allows the resident to participate in the routine collection, preparation, isolation and identification of microbiological specimens in a tertiary care/provincial laboratory under the guidance of a microbiologist.

Infection control
This clinical rotation allows residents to participate in nosocomial and community infection control practice (surveillance, isolation practices, quality control, outbreak investigation, contact investigations) within the setting of a tertiary care hospital or community setting.

Occupational medicine
This rotation gives the resident the opportunity to work with an occupational medicine physician.

Communicable Disease Control (CDC) (outbreaks, immunization, notifiable diseases methods, surveillance methods, infectious control)
This rotation provides the resident with a brief introduction to the content and methods of communicable disease control by moving the resident through various assignments with different CDC practitioners.

Environment (air, water, sewage, food, built environments, ICS training, inner city)
This rotation allows the resident to experience the various components of environmental health by spending time with environmental health officers and attending a series of site visits.

Travel medicine
This rotation provides the resident with a brief exposure to the prevention of disease in travelers.

STI clinic
This rotation provides the resident with experience in the diagnosis and treatment of STI within the setting of a STI clinic.

TB clinic
This rotation allows the resident to diagnose and treat patients referred to a provincial TB clinic for Northern Alberta. As well residents will be exposed to the methods of contact tracing and TB screening.

Clinical rotations in STD/HIV, tuberculosis, and international travel, provide an experiential focus for these important public health topics, plus an opportunity to examine how services are planned and delivered on a regional population basis.

PGY3
Residents can apply to do their coursework at the University of Alberta's School of Public Health that leads to a Masters in Public Health (MPH). Information concerning the MPH program streams can be accessed at https://www.ualberta.ca/public-health/programs/mph-programs/index.html. The PGY3 year includes protected time for both coursework and practicum as well as some clinical rotations.
PGY4 and PGY5

Clinical Rotations

Inner City Health
The rotation provides the resident with experience in dealing with the issues facing the urban disadvantaged population.

Aboriginal Health/Multicultural Health
The rotation provides the resident with experience in dealing with the contemporary aboriginal and multicultural health issues.

Rural Public Health
This rotation provides the resident with experience in working in a rural public health setting.

Provincial Public Health
This rotation provides the resident with the experience of public health at the provincial level with mandates for notifiable disease collection, analysis and reporting; policy formation, inter and intra provincial communications, liaison with regional public health offices.

Environmental Health
The rotation provides the resident the opportunity to work in local and provincial department of public health environment and understand how to apply the knowledge acquired in the academic year.

Communicable Disease Control (CDC)
To understand how to assess and manage an environmental health issue. The rotation provides the resident with exposure in communicable disease control in local as

well as provincial public health departments. The resident works with Medical Officers of Health, epidemiologists, public health nurses and environmental health officers in dealing with control of vaccine preventable diseases, enteric infections, bloodborne pathogens, tuberculosis, sexually transmitted diseases, travel-related illnesses and others of public health significance.

Health Status Assessment and Reporting
During this rotation the resident works with staff that produce health status/health needs reports.

Health Promotion/Disease Prevention
During this rotation the resident works with preceptors to develop and implement a health promotion approach to community health issues(s).

Health Planning
This rotation gives the resident experience in program planning in a Zone (regional) health authority setting.

Risk Communication and Media Relations
This rotation provides the resident with the opportunity to apply the concepts learned in the academic course work.

Disaster/Emergency Response Planning
This rotation provides the resident with the experience in planning for mass casualty events including bioterrorism and pandemic influenza.

Health Policy/Advocacy
The rotation builds upon the health promotion rotation and provides more specific experiences in policy and advocacy.

Management of Public Health Programs
This rotation provides the resident with experience of "shadowing" a senior manager in a public health department.

Field Experience and Placement Sites

The Public Health and Preventive Medicine program at the University of Alberta offers a broad range of clinical, academic, and field experiences and placement sites, including:

University of Alberta: Department of Family Medicine

Alberta Health Services, Coronation Plaza

Alberta Health Services, Edmonton, North, and Central Zones (Urban and Rural areas)

Alberta Health Services, Sexually Transmitted Infections Clinic

Alberta Health Services, Travelers Health Clinic

Indigenous Services Canada: First Nations and Inuit Health Branch

Provincial Laboratory of Public Health for Northern Alberta

University of Alberta Hospital

Royal Alexandra Hospital

Grey Nuns Community Hospital

Misericordia Community Hospital

Alberta Health Services

Northeast Community Health Centre

Academic Half Days

Every Friday afternoon from 1:00-4:30pm. Our Academic Half Days include:

- Guest speaker presentations

- Resident presentations
- Basic epidemiology and infectious diseases
- Management
- Journal Club
- Mock Exams, practice questions and reviews

*Currently, all academic half days are via Zoom (virtual)

Frequently Asked Questions

What are some strengths about your specialty? What draws and keeps people in your specialty?

The focus on population health, prevention or early intervention in disease processes.

There are extensive opportunities to collaborate with other professionals and provide physician leadership in program and/or policy development and evaluation and research – every day is different! Opportunities for broad health impacts through programs and policies (eg. vaccination program that have prevented and eliminated diseases).

What are some common complaints about your specialty?

Direct patient care work can be limited, depending on the type of work chosen within the specialty.

Why did you choose your specialty?

- Opportunity to be proactive and deal with preventing problems/disease.
- Opportunity for large-scale health impacts across the population.

What types of clinical cases do you commonly see?

Although there are opportunities for direct patient work (e.g. in community clinics or specialized clinics i.e. STI, TB, Inner City medicine, Travel), the specialty is focused on dealing with the needs and problems in populations or groups of people. So instead of a stethescope and lab tests we are using population diagnostic tools such as epidemiology, to study trends and risk factors in diseases and instead of individual treatments,we provide programs and policies to improve population health outcomes.

Because a set of infectious diseases are reportable to Public health, we deal routinely with these diseases that are reportable (eg. TB, STIs, travel medicine, foodborne/waterborne illnesses), and environmental exposures; however, injuries and non-communicable diseases such as diabetes, cardiac disease, cancers and smoking-, nutrition- and sedentary-related illnesses are also dealt with through a population-based approach (surveillance,disease prevention, health promotion).

Briefly describe a typical day.

- Consulting with physicians, nurses and other professionals on public health issues.
- Responding to infectious disease outbreaks by working with a team of professionals investigating and working to control the outbreak.
- Chairing meetings, such as on emergency planning and management.
- Meeting with staff to plan for chronic disease prevention program
- Clinical work.
- Research / literature search / policy review.
- Help lead the response to emerging public health threats.

What are the varieties of lifestyles within your field?

- Very flexible and accommodates varying needs.
- Primarily office hours in addition to on call taken from home.

Specifically, how able is your specialty to accommodate family life?
Most of the work is done during office hours on weekdays.
After hours call is taken from home, and most emergency issues can be dealt with from home by phone.
Opportunities for part-time work, including patient-care duties.
Range of incomes?
Most positions are salaried and include health benefit plans, vacation, pensions, etc.
Salary range: $200,000 to $400,000, depending on years of practice and position, plus benefits which are considered to be about 20% of salary.
Patient-care work would be added onto this base salary.
How do you see your discipline changing over the next decade?

Continued demand for Medical Officers of Health.

Over the next ten years, there will be more demand for public health and preventive medicine specialists to work in areas outside of traditional public health roles, for example in Primary Care Networks / Family Care Clinics, community clinics, or as medical administrators.

Emergency areas (infection control, emergency preparedness) will offer new career choices.

Increasing work in Chronic Disease Prevention and Healthy Built Environments to address high and growing burdens of non-communicable diseases.

Academic positions may also be available.

Residency Program Questions

What are you looking for specifically in an impressive candidate?

- Self starter who is able to use or adapt current resources and shape them in order to meet a different needs.
- Can consider issues form a broader perspective – system or population level.
- Knows how to ask and answer question.
- Demonstrates interest in specialty through his/her electives.
- Thrives in muti-disciplinary environment.

What can a potential candidate do now in order to be an appealing applicant to your program?

- Do one or more electives in public health and preventive medicine.
- Do an elective in related disciplines, e.g. inner city health, travel medicine, TB clinic, STI, Indigenous health, etc.
- Demonstrate an ability to work within a complicated organization.
- Demonstrate leadership/managerial talent.
- Demonstrate orientation to prevention and population health.
- Volunteer with a community agency.

What is your residency program's orientation and focus?
The focus of the rotations will be to give the residents as much "hands on" experience as possible while still maintaining an academic focus. For most rotations, the residents are expected to write a brief paper or complete a dedicated project while also participating actively in the day-to-day work at the rotation site.
What is the availability of experiences in subspecialty areas during training?

Subspecialties do not specifically exist in public health and preventive medicine. However, some rotations and electives can be shaped to help to increase focus on a resident's areas of interest. Additional training in Field Epidemiology may be available through Public Health Agency of Canada.

Note: Occupational Medicine is now a subspecialty residency program that can be applied to by those completing internal medicine or PHPM.

Are there sufficient elective opportunities during training to explore your special interests?
For residents with interest in additional electives the MPH Practicum Project can be streamlined to meet some rotation requirements to allow some additional elective time.
What is the on-call schedule during each year of residency?
During family medicine and clinical rotations, call will be in-house, following the practices of the specific rotation.
Public Health and Preventive Medicine call will normally commence in the PGY-3 year. Call is typically
home call, and conforms to PARA requirements.
What distinguishes the U of A program from other programs?
The program has a focus on practical application of public health and preventive medicine skills. There are opportunities for working with U of A program faculty with strong expertise in both communicable diseases and non-communicable disease prevention and control.
Residents are directly involved at an early stage in their career planning. This program is housed in the Division of Preventive Medicine, alongside Occupational Medicine. PHPM residents participate in
Occupational Medicine rotations (one of only two programs in Canada).
How competitive is it to get in, and then to succeed in your field?
Recently, there have been approximately 25 – 40 applicants for the two Public Health and Preventive
Medicine positions through CaRMS/AIMG. All graduates of the University of Alberta PHPM program have been successful in finding jobs utilizing their training.
What local, national or international conferences would be of benefit to candidates interested in your residency program?

- Canadian Public Health Association annual meeting
- American Public Health Association Conferences
- Canadian Immunization Conference
- Practice Management Institute courses through the CMA

ROYAL COLLEGE OF PHYSICIANS AND SURGEONS OF CANADA
COLLÈGE ROYAL DES MÉDECINS ET CHIRURGIENS DU CANADA

Objectives of Training in the Specialty of Public Health and Preventive Medicine

2014
EDITORIAL REVISION – MARCH 2018
VERSION 1.1

This document applies to those who begin training on or after July 1, 2014.

DEFINITION

Public Health and Preventive Medicine is the medical specialty primarily concerned with the health of populations. The discipline's focus is disease and injury prevention and control, which is achieved through health protection and health promotion activities. A Public Health and Preventive Medicine specialist monitors and assesses the health needs of a population and develops, implements, and evaluates strategies for improving health and well-being through interdisciplinary and intersectoral partnerships.

Building on foundational competencies in clinical medicine and the determinants of health, the Public Health and Preventive Medicine specialist demonstrates competencies in public health sciences, including but not limited to epidemiology, biostatistics, and surveillance, planning, implementation and evaluation of programs and policies, leadership, collaboration, advocacy, and communication. These competencies are applied to a broad range of acute and chronic health issues affecting a population, including those that may be related to environmental exposures.

The Public Health and Preventive Medicine specialist may pursue and engage in a number of different types of careers in a variety of settings including but not limited to:

- a municipal, regional, provincial, or federal government
- an international inter-governmental organization
- a non-profit or private sector health or social services organization
- a community-oriented clinical practice with an emphasis on health promotion, disease prevention, and primary health care
- in an academic environment as a researcher, scholar, or educator

Within these diverse settings, a Public Health and Preventive Medicine specialist may be a consultant, advisor, medical health officer, executive, manager, researcher, scholar, or educator.

THIS IS EXHIBIT "C" referred to in the Affidavit / Declaration of
Dr. Deena Hinshaw
affirmed
~~Sworn / Declared~~ before me this 12th day
of July A.D. 2021
H. Veale
A Commissioner for Oaths in and for the Province of Alberta
A Notary Public.
Heather L. Veale
Barrister & Solicitor

GOALS

Public Health and Preventive Medicine residents must demonstrate a comprehensive knowledge of the science and art of Public Health and Preventive Medicine, and the skills to apply this knowledge to a broad range of population health issues in the socioeconomic, political, and environmental contexts in which they occur. Residents must demonstrate the knowledge, skills, and attitudes related to assessing the determinants of health, including but not limited to income, environment, gender, education, social support systems, health behaviours, and access to health care, of the populations with which they work. Further, residents must demonstrate competence in incorporating these determinants of health into research methodology, data presentation and analyses as well as in strategies that will improve the health of these populations.

Upon completion of training, a resident is expected to be a competent specialist in Public Health and Preventive Medicine capable of assuming a public health leadership and management role in a health-related organization, including as a consultant in the specialty. The resident must demonstrate a working knowledge of the theoretical basis of the specialty, including its foundations in the clinical sciences, public health sciences, and humanities.

Residents must demonstrate the requisite knowledge, skills, and attitudes to effectively provide community-focused care to diverse populations. In all aspects of specialist practice, the resident must be able to address issues relating to the determinants of health in a professional, ethical manner. In addition, residents are encouraged to have developed a higher level of expertise in one of the core fields, including but not limited to communicable disease, environmental health, chronic disease, and to acquire competency in an area of practice relevant to their own professional and personal development objectives, including but not limited to education; global health; leadership, management and administration; and occupational health.

PUBLIC HEALTH AND PREVENTIVE MEDICINE COMPETENCIES

At the completion of training, the resident will have acquired the following competencies and will function effectively as a:

Medical Expert

Definition:

As *Medical Experts*, Public Health and Preventive Medicine specialists integrate all of the CanMEDS Roles, applying medical knowledge, clinical and public health skills, and professional attitudes in their provision of care at the individual, family, group, organization, community, and population levels. *Medical Expert* is the central physician role in the CanMEDS framework.

THIS IS EXHIBIT " D " referred to in the Affidavit / Declaration of
Dr. Deena Hinshaw
affirmed ~~Sworn / Declared~~ before me this 12th day
of July A.D. 2021
H Veale
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public.
Heather L. Veale
Barrister & Solicitor

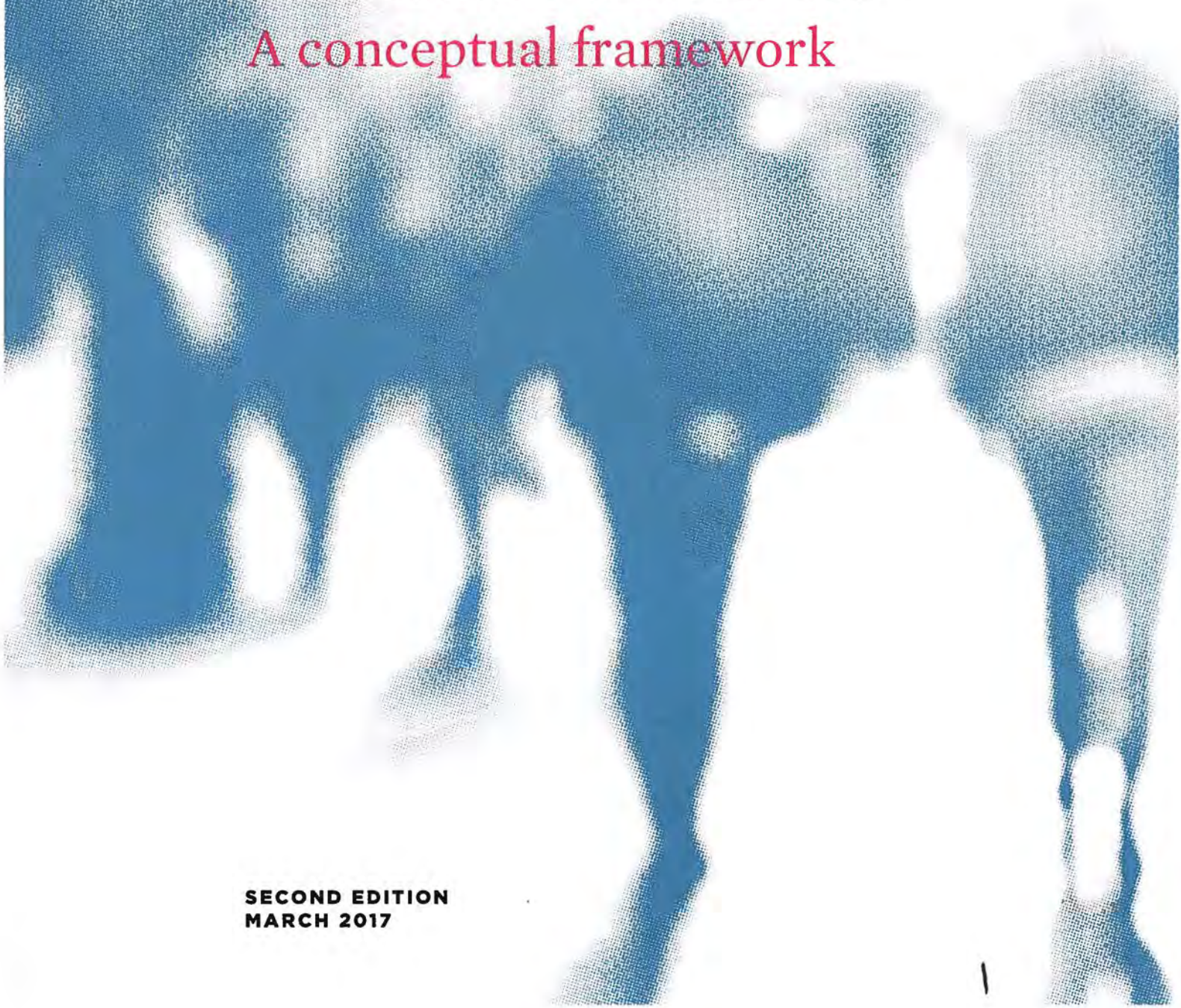
CANADIAN PUBLIC HEALTH ASSOCIATION

The Voice of Public Health

CANADIAN PUBLIC HEALTH ASSOCIATION WORKING PAPER

PUBLIC HEALTH:

A conceptual framework



SECOND EDITION
MARCH 2017

THE VOICE OF PUBLIC HEALTH

The Canadian Public Health Association is the independent national voice and trusted advocate for public health, speaking up for people and populations to all levels of government.

We champion health equity, social justice and evidence-informed decision-making. We leverage knowledge, identify and address emerging public health issues, and connect diverse communities of practice. We promote the public health perspective and evidence to government leaders and policy-makers. We are a catalyst for change that improves health and well-being for all.

We support the passion, knowledge and perspectives of our diverse membership through collaboration, wide-ranging discussions and information sharing.

We inspire organizations and governments to implement a range of public health policies and programs that improve health outcomes for populations in need.

OUR VISION
A healthy and just world

OUR MISSION
To enhance the health of people in Canada and to contribute to a healthier and more equitable world.

For more information, contact:
Canadian Public Health Association
404-1525 Carling Avenue, Ottawa, ON K1Z 8R9
T: 613-725-3769 | F: 613-725-9826 | info@cpha.ca

www.cpha.ca

2

PREFACE

Health professionals often refer to looking at an issue from a "public health perspective" or "through a public health lens" and yet this concept has not been clearly defined. The following is a first effort at defining such a perspective, lens or approach. It is presented for consideration, and feedback is welcomed. All comments will be considered and may be incorporated into future iterations of what we hope will be an 'evergreen' document. Comments should be directed by e-mail to: policy@cpha.ca.

The development of this working paper began with our attempts to define a "public health approach" during the development of the Association's discussion paper *A New Approach to Managing Illegal Psychoactive Substances in Canada*. CPHA's Board of Directors subsequently directed that a more substantive effort be undertaken to provide a summary document that would describe the principles and practices that underlie public health activities. As a result, practicum students working at CPHA developed an initial manuscript followed by an extensive internal review process. It was then reviewed by public health professionals who voluntarily support CPHA activities. The result of those efforts was ultimately reviewed, edited and approved as an evergreen document by our Board. The Board of Directors and staff of CPHA thank all those who participated in developing *Public Health: A Conceptual Framework*.

PURPOSE

This working paper is meant to provide a **quick reference guide** to and portrait of the underlying principles that support current public health practice; **it is not intended to be the definitive treatise** on this topic. It defines the perspective that CPHA will use to develop its policy options.

PUBLIC HEALTH: A HISTORY OF CHANGE

The practice of public health can perhaps find its roots with the development of aqueducts during the Roman/Byzantine era for the transportation of clean water into populated areas, and the management of human waste. Its true beginnings, based on a causal relationship to the prevention of infectious disease, might be better traced back to actions that were taken in Europe during the fourteenth century to limit the spread of plague. One of the first documented actions was in Venice around 1348, with the appointment of three guardians of public health to detect and exclude ships with passengers infected with that disease. Similarly, the first quarantine actions seemed to be taken in Marseille (1377) and Venice (1403), where travellers from plague-infected countries were

detained for 40 days to protect against transmission of the infection. The first surveillance systems can be dated to the "bill of mortality" established in London, England in 1532 and subsequently John Graunt's publication of his "Natural and Political Observations" (1662) that was based on findings from the Bills of Mortality. John Snow, the father of epidemiology, published "On the Mode of Communication of Cholera" in 1849. The first consideration of the importance of the social determinants of health and the inclusion of social justice as a pillar of public health was described in 1790 when Dr. Johan Peter Frank argued "... curative and preventive measures had little impact on populations where people lived in abject poverty and squalor."[1]

In the Canadian context, the first Board of Health was established in Lower Canada in 1832, with Upper Canada following suit in 1833. As these boards developed, they provided the infrastructure necessary for inspection and regulation that addressed issues as varied as pasteurization of milk, management of tuberculosis in humans, quarantine activities for various illnesses, and the control of sexually transmitted diseases. The early 20th century brought an increasing emphasis on maternal and child health and the immunization of children and youth.[2] In a parallel fashion, during the 18th and 19th centuries, public health practitioners investigated and advocated against nutritional (scurvy), occupational (mesothelioma - cancer of the scrotum) and environmental (lead poisoning) disease, and urged measures to overcome inequities of health.[1]

Through the 20th century, an expansion of focus from a principally communicable disease perspective to one combining communicable and non-communicable illnesses broadened public health practice. Similarly, there is an ongoing movement from an agentic* approach based on behaviour modification, to a population-based approach that focuses more on adjustment of societal structures, with an emphasis on support for populations at risk. The goal of these changes and this expansion has always been to foster the health of people and to develop a strong, resilient and just society. In striving for this goal, our actions have not always been correct, or may at times have been clouded by the beliefs of the day. These efforts continue, yet there are basic principles that have underlain public health practice since the beginning.

* The term *agentic* denotes self-directed actions aimed at personal development or personally chosen goals (The Free Dictionary by Farlex. Available at: www.medical-dictionary.thefreedictionary.com). This concept is based on a social cognition theory perspective in which people are producers as well as products of social systems (definition from: www.wordnik.com/words/agentic).

DEFINING PUBLIC HEALTH PRACTICE

Public health practice can be viewed as an approach to maintaining and improving the health of populations that is based on the principles of social justice, attention to human rights and equity, evidence-informed policy and practice, and addressing the underlying determinants of health. Such an approach places health promotion, health protection, population health surveillance, and the prevention of death, disease, injury and disability as the central tenets of all related initiatives. It also means basing those initiatives on evidence of what works or shows promise of working. It is an organized, comprehensive, and multi-sectoral effort.[3-5]

This definition and the practice of public health have developed over time, and will continue to develop to meet the evolving health requirements of the population. As these demands grow, there will be debates concerning the role and purpose of public health practice and the scope of practitioners' activities. Underlying these debates and developments, however, are an amalgam of concepts and practices that are the foundation and building blocks of public health.

FOUNDATION OF PUBLIC HEALTH

The foundation of, and lenses through which to view, all public health activities are the concepts of social justice[6] and health equity,[7] which relate to the social determinants of health. These lenses continually influence and inform each building block. All public health practice is built on the interconnectivity of five main building blocks (evidence base, risk assessment, policy, program and evaluation) that have been widely described in the literature, continue to evolve, and are the subject of the next section of this paper. Each component has many sub-components, and all the parts must function in a complex adaptive system* (see Figure 1) to meet the goals of public health.

Social Justice

The goal of social justice is to develop the ability of people to realize their potential in the society in which they live. Classically, "justice" refers to ensuring that individuals both fulfil their societal roles and receive their due from society,[8] while "social justice" generally refers to a set of institutions that enable people to lead fulfilling lives and be active contributors to their community. These institutions, among others, include education, health care, and social security.[9]

In Canada, social justice finds its root in Section 7 of the *Canadian Charter of Rights and Freedoms*, which provides for "...the right to life, liberty and security of the person and the right not to be deprived thereof except in accordance with the principles of fundamental justice."[10] This clause was used as the legal argument for the Supreme Court decision concerning *Insite*, the supervised consumption facility in Vancouver,[11] and for the decision that struck down three federal prostitution laws.[12] The *Canadian Charter of Rights and Freedoms* is further supported by various United Nations Conventions† that provide the social foundation on which to build a public health approach. In this context, social justice ensures that the population as a whole has equitable access to all public health initiatives implemented to minimize preventable death and disability.[3]

Health Equity

Health equity is defined as "... the absence of avoidable or remediable differences in health among groups of people, whether those groups are defined socially, economically, demographically, or geographically."[13] It is based on the principle of social justice and refers to the absence of disparities in controllable or remediable aspects of health. Underpinning this notion is the concept of the *social gradient* that notes

> *"...the poorest of the poor throughout the world have the worst health. Within countries, the evidence shows that in general the lower an individual's socioeconomic position the worse their health. There is a social gradient in health that runs from top to bottom of the socioeconomic spectrum".*[14]

In general, those who are healthier are at the top of the socioeconomic spectrum. The concept applies to every country. This notion is further shaped when the influences of *structural violence* and *intersectionality* are integrated into this consideration.‡

* Complex adaptive systems are systems composed of many interacting parts that evolve and adapt over time. Organized behaviour emerges from the simultaneous interaction of parts without a global plan (www.cognitern.psych.indiana.edu/rgoldsto/complex/intro.pdf). This approach has been applied to many complex issues, including economic, scientific and organizational design thinking.

† These include: the *International Convention on Civil and Political Rights*, the *International Convention on Economic, Social and Cultural Rights*, the *Convention Against Torture and Other Cruel, Inhuman and Degrading Treatment or Punishment*, the *Declaration of the Rights of Indigenous Peoples*, and the *International Convention on the Protection and Promotion of the Rights and Dignity of Persons with Disabilities*.

‡ *Structural violence* refers to the physical and psychological harms that can be caused by society's social, political and economic systems. As such, it is avoidable and preventable. The theory is described in Ho K. Structural violence as a human rights violation. *Essex Human Rights Review* 2007;4(2):1-17. *Intersectionality* refers to "... a tool for analysis, advocacy and policy that addresses multiple discriminations and helps us understand how different sets of identities affect access to rights and opportunities." Association for Women's Rights in Development. Intersectionality: A tool for gender and economic justice. *Women's Rights and Economic Change*. 2004;9(August):1-8.

One challenge is that the concepts of "equity" and "equality" are sometimes used interchangeably. They are related; however, there are important distinctions where:

> *Equity ... involves trying to understand and give people what they need to enjoy full, healthy lives. Equality, in contrast, aims to ensure that everyone gets the same things in order to enjoy full, healthy lives. Like equity, equality aims to promote fairness and justice but it can only work if everyone starts from the same place.*[15]

As such, consideration must be given to the **equitable** distribution of health services and the creation of culturally competent programming and policy to meet the requirements of the population that is at risk. Attention to that population is required such that the proposed change is supported through group empowerment and ownership.

Social Determinants of Health

The social determinants of health are defined as "the conditions in which people are born, grow, live, work and age".[16] They are shaped by the distribution of money, power and resources, which causes health inequities within populations. Although the list of social determinants of health may vary depending on the source of the information, there are some that are common to all sources and are generally viewed as having the greatest effect on population health. These include income, education, gender, physical environment, social environment, access to health services, and healthy childhood development. The intermingling of these factors creates the health situation specific to an individual or population.

Ecological Determinants of Health

There are many ecological processes and natural resources essential for health and well-being and that constitute Earth's life-support systems. These ecological determinants of health include adequate amounts of oxygen, water, and food. Other important ecological processes and natural resources include the ozone layer, nitrogen and phosphorus cycles, systems to detoxify wastes, and abundant fertile soil, fresh water and marine aquatic systems to grow food and other plants. For humans, three further requirements include materials to construct our shelters and tools, energy, and a stable global climate with temperatures conducive to human and other life forms.

THE BUILDING BLOCKS OF PUBLIC HEALTH

Public health, at its root, is the amalgamation of those activities that are taken to improve population-based health issues within the general domains of communicable and non-communicable disease. There is an internal tension between the domains; however, there are several activities (see Figure 1) that form the building blocks of all public health practice.

Evidence Base

Public health relies on the robustness, accuracy and validity of its evidence base. That base is composed of scientific research, population characteristics, needs, values and preferences, and professional expertise.[17] Research, surveillance and epidemiology, and community consultation are the vehicles through which that evidence is provided (see Figure 2). There is a strong connection between each component, such that research can be used to focus and strengthen surveillance activities. Surveillance can be conducted to inform research, while both surveillance and research can support or be directed by community consultation.

Research

Research is defined as those processes and activities that contribute to generalizable knowledge.[18] In this case, these activities inform public health practice

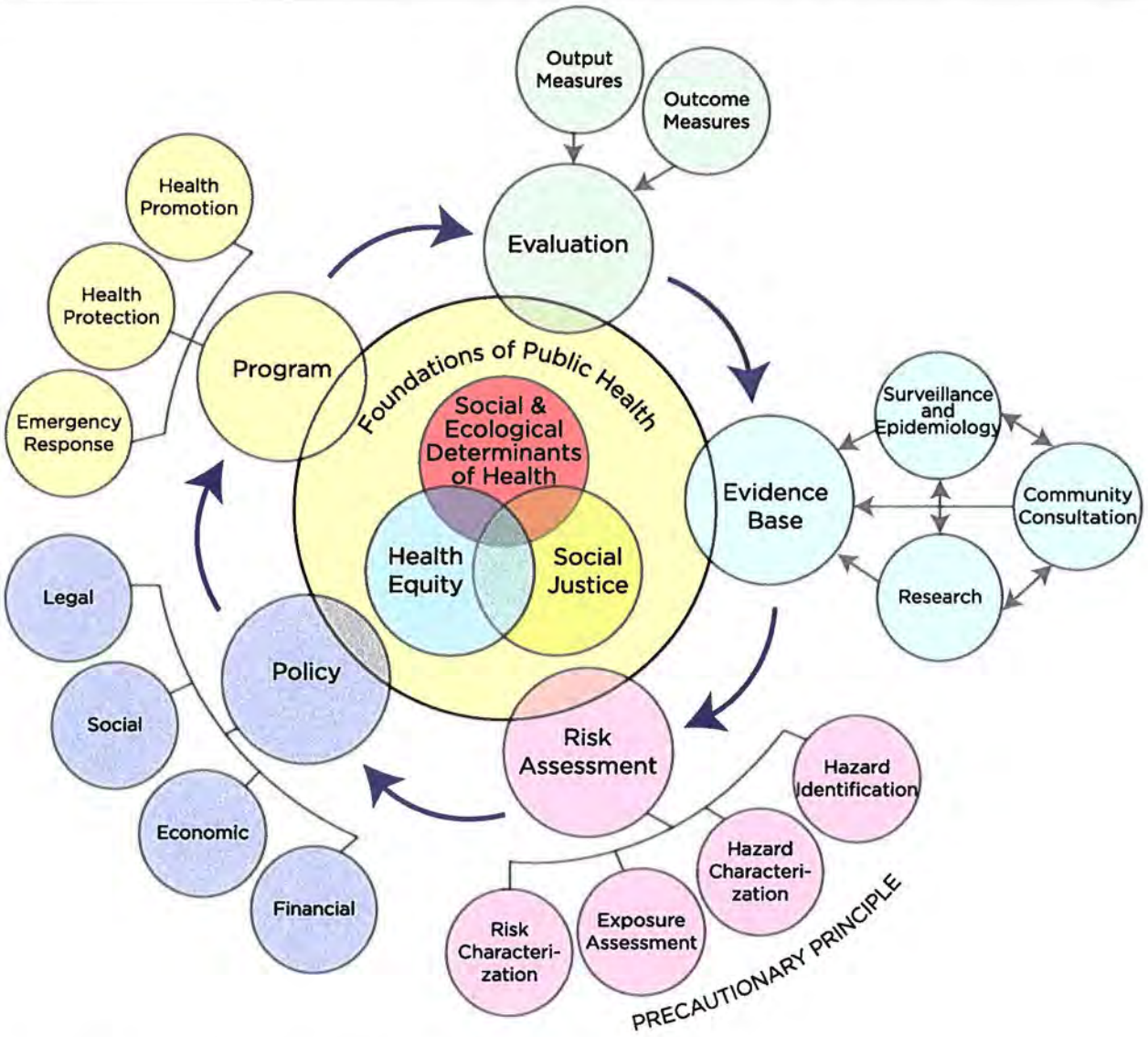


Figure 1: A conceptual framework for public health

and policy, and are targeted to develop, implement, and evaluate improved and more efficient ways of protecting and promoting health and preventing disease.[19] It can be divided into:

- *Quantitative research:* The use of data that can be counted or converted into numerical form.[20] It is primarily used to find statistical associations between variables, or when attempting to find variances in patterns of health between two populations, with an aim to minimize human bias.
- *Qualitative research:* The use of non-numerical observations to interpret phenomena.[20] It is used to gather insight as to how particular situations are interpreted by the study population. These results may come from clinical case studies,

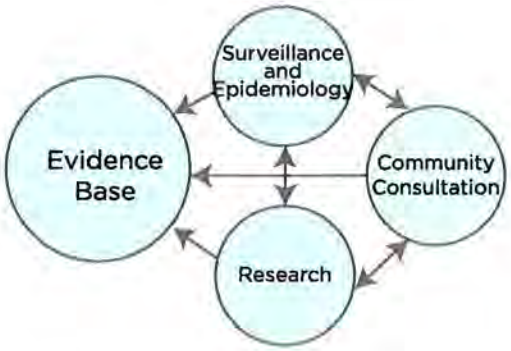


Figure 2: Interrelationship of the components of the evidence base

narratives of behaviour, ethnographies, and organizational or social studies, and can be used to develop theoretical pieces that are based on observable reality. Methods that may be used to gather this data include surveys, interviews, or focus groups to connect with the study population.

Both approaches can be combined to perform mixed methods or pragmatic research studies when seeking answers to complex research questions,[21] but there has to be a clear and strategic relationship between the methods used such that the data provides greater insight than can be obtained by using a single approach. Examples of mixed methods research are studies that link the social determinants of health with epidemiological data.

Surveillance and Epidemiology

Public health surveillance is defined as "the continuous, systematic collection, analysis, and interpretation of health-related data needed for planning, implementing, and evaluating public health practice." It can:

- serve as an early warning system for impending public health emergencies;
- document the impact of interventions, or track progress to specified goals; and
- monitor and clarify the epidemiology of health problems to allow priorities to be set and inform public health policies and strategies."[22]

Long-term or passive surveillance involves the monitoring of general health trends and health determinants[20] and provides information on, for example, current obesity or cancer trends in the population. Short-term, active or ongoing surveillance involves searching for emergent diseases or outbreaks, such as the surveillance conducted during the SARS or H1N1 outbreaks. Both types of surveillance target a specific health state, disease, or agent.

The distinction between surveillance and epidemiology should be noted. Epidemiology is defined as:

> *...the study of the distribution and determinants of health-related states or events (including diseases), and the application of this study to the control of diseases and other health problems. Various methods can be used to carry out epidemiological investigations: surveillance and descriptive studies can be used to study distribution; analytical studies are used to study determinants.*[23]

A fundamental concept for the application of epidemiological findings to preventive medicine is the distinction that separates the notion of a *high risk strategy*,* which is based on conventional medical approaches for resolving a health issue, from that of a *population strategy* that defines the public health approach for addressing preventive medicine.[24] Both concepts are developed from the *Rose Hypothesis*.†

* A *High Risk Strategy* focuses its efforts on individuals with the highest level of a risk factor and uses the established framework of medical practice to reduce that risk, while a *Population Strategy* predicts that shifting the population distribution of a risk factor prevents more burden of disease than targeting the people at high risk by providing a lower likelihood of an illness to the entire population.[22]

† The *Rose Hypothesis* notes that disease is a rare occurrence and that most people who adopt behaviour to lower a risk of disease will not benefit directly, but a few may benefit enormously. The challenge is that often a population-based approach must be applied so that those few who are at risk receive the benefits of preventive actions, or the necessary treatment. (Health Knowledge. Epidemiological basis for preventive strategies.

Research and surveillance/epidemiology may require the use of patient information, and could be subject to patient confidentiality requirements or review by organizational research ethics committees.

Community Consultation

Community consultation is a well-known methodology that can be viewed as a best practice for informed decision-making on complex issues within communities.[25] It is based on the following principles:

- Recognize the community as a unit of identity, with a shared sense of identification and emotional connection that influences common values, norms, and needs;
- Build on the strength and resources within a community to address local health concerns. Community consultation methodologies recognize and seek to expand social structures and processes that contribute to the ability of community members to work together to improve health; and
- Integrate knowledge and action for the mutual benefit of partners and stakeholders, as well as the reciprocal transfer of knowledge, skills, capacity and power.

This process enables community members to be active contributors, through collaboration and involvement, in an initiative that seeks to establish positive social change within the community.[26] The topic chosen must be of practical relevance to the community, and community members should be actively involved in the project's design, implementation, and dissemination. The design may involve aspects of quantitative and qualitative data collection methods, as well as information gathered through surveillance activities. At the completion of this process, results are transferable to community members to support positive social change. An example of where this process would prove, and has proven, useful is the development and implementation of a supervised consumption facility for illegal psychoactive substances.

Risk Assessment

Figure 3: Components of risk assessment

The evidence base in public health is constantly expanding as new information is uncovered through research, surveillance, and community consultation. Issues recurring within that base become priorities for public health attention. Prior to taking action on a specific issue, a risk assessment is necessary to estimate the nature and likelihood of negative health outcomes in individuals.[27] It can be applied to conventional public health issues as well as occupational, environmental, social and behavioural risks. A four-step process (see Figure 3) is used, and includes:

- *Hazard identification:* Identification of specific health effects or hazards. Information from surveillance and epidemiology activities can be used to identify them.
- *Hazard characterization:* Evaluation of the nature of the effects associated with a particular hazard. Qualitative and quantitative research may be

Available at: http://www.healthknowledge.org.uk/public-health-textbook/research-methods/1c-health-care-evaluation-health care-assessment/epidemiological-basis-pstrategies.)

Figure 4: Simplified model of a public health policy development process

used to characterize biological, physical, and chemical hazards.

- *Exposure assessment:* Evaluation of the possible effect of the hazard.
- *Risk characterization:* Integration of hazard identification, hazard characterization, and exposure assessment into a holistic estimate of adverse effect at the population level.

Following completion of the risk assessment, response options are identified and a risk management plan developed. Managers with the appropriate level of authority must decide on actions and take steps to implement them. The desired action could be undertaken directly when immediate action is required, for example during a response to an infectious disease outbreak, or through policy and program development processes.

Underlying this decision process is the *Precautionary Principle*, an approach to managing risk that has been developed to address circumstances of scientific uncertainty. It reflects the need to take prudent action without having to wait for completion of scientific research. This principle was applied by Krever during the inquiry into the Canadian tainted blood scandal,[28] and was enshrined in the 1992 *Declaration of the Rio Conference on Environment and Development*.

Policy

Policy is defined as the principles or protocols adopted or proposed by a government, party, business or individual that provide a definitive course or method of action, and guide or determine present or future decisions. Policies are generally not time limited, and provide the supportive environment, framework and anticipated outcomes to focus program activities and enable future decision-making. Policies are usually developed through a flexible, iterative process that

encompasses issue identification, policy instrument development, consultation, coordination, decision-making, implementation and evaluation. Partner and stakeholder collaboration is required. Within the Canadian context, federal policy development can find its starting point either in the political platform of the ruling party, or through a process that originates within the bureaucracy.

Within the public health domain, an ongoing challenge is to balance the role of science in policy-making, as the evidence base and risk assessment should inform and support policy development, while the policy decision could modify scientific activities. Complicating the process is the inclusion of economic, financial and social policy, and legal and jurisdictional considerations within the decision-making process.

It is essential to engage in the process those partners and stakeholders affected by a decision. The goal is to support development of a final approach that will be acceptable to the affected groups. Those engaged in the consultation must be at a level and have the authority necessary to speak for the organization. The role of a non-governmental organization such as CPHA is to participate in the policy development process through advocacy at the political and bureaucratic levels with the expressed positions reflecting the interests of Association members and based on the best available evidence.

A simplified model of these relationships is presented in Figure 4.

Intervention

As policy development provides the framework and anticipated outcomes for public health activities, programs or interventions are the specific actions that respond to the policy direction. They address health protection, health promotion and emergency response activities. The goal of any intervention is to limit the onset and progression of disease, injury or infection,[20]

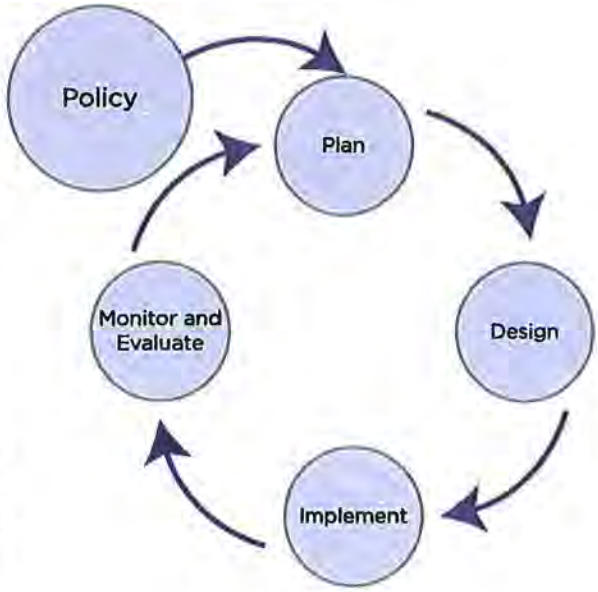


Figure 5: A generalized intervention development process

and may be implemented through collaboration with all levels of government, other government departments, non-governmental organizations, not-for-profit organizations, and private sector partners, as appropriate. In addition, all interventions must be evaluated to measure success in terms of the expected outputs (the desired product of the intervention), as well as the desired outcomes (improvement in the health of the population). Effective intervention development requires that those affected by the health issue addressed by the intervention be included in its development and implementation to improve its likelihood of success. A generalized program development process is presented in Figure 5.

Intervention activities generally address three broad categories of work and are listed below.

Health Protection

Health protection activities address the negative influences on health, and include interventions

as diverse as testing of food and water supplies, environmental testing, and surveillance to identify and track infectious disease outbreaks.[20] These activities rely on surveillance information to direct intervention activities, for example annual influenza vaccination programs, and can provide evidence for epidemiological investigations (food and water testing).

Health Promotion

Health promotion is the mix of activities that assist individuals and communities in taking charge of their personal health. It assists in developing healthy public policy, healthy environments, and personal resiliency, and "... involves any combination of health education and related organizational, economic, and political interventions designed to facilitate behavioural and environmental changes conducive to health."[20] This concept was first described as an entity in the *Ottawa Charter for Health Promotion.*[29]

Emergency Preparedness

Emergency preparedness interventions are those activities that provide the capacity to respond to acute harmful events that range from natural disasters to infectious disease outbreaks and chemical spills. They are founded on four building blocks:

- *Prevention:* those activities that reduce the likelihood of an event occurring
- *Preparedness:* planning, training and organizing to respond to harmful events and situations
- *Response:* the capacity to respond to acute, harmful events
- *Recovery:* the processes required to return to a "normal" state of existence

Evaluation

Each policy and program must be evaluated to determine whether it meets its agreed-to deliverables (output measures) and its desired effect in mediating the issue it was established to address (outcome measures). These can be described as implementation or process, and effectiveness or outcome evaluations.[30] Implementation evaluations assess whether a program is reaching its intended potential, and occur while the program is active. Qualitative and quantitative data are used to make informed judgements. Outcome evaluations measure progress in addressing the program's targeted public health challenge, and may include short-, intermediate-, and long-term results, that are also based on quantitative and qualitative data. The information gathered through evaluation can allow for further development of the program within the affected area of public health.

SUMMARY

Public health is a complex adaptive system which has evolved from providing clean water and managing human waste, to managing a broader cadre of communicable and non-communicable diseases, and continues to change as we address the influence of social determinants and the environment on health. Contributing to this challenge is the notion that the populations we serve are continually evolving, as are the related public health issues. Each public health practitioner must continually adjust his or her practise, but each adjustment must be based on the building blocks of evidence, risk assessment, policy, intervention and evaluation, which are supported by a foundation of health equity, social justice, and the social determinants of health. As such, this document should be considered a first attempt to define the basics of public health, and will continue to develop as the practice evolves.

REFERENCES

1. National Advisory Committee on SARS. Learning from SARS – Renewal of Public Health in Canada. Chapter 3A. What is Public Health? Ottawa, ON: Public Health Agency of Canada, 2003,43-68.
2. Canadian Public Health Association. This is Public Health: A Canadian History. CPHA, Ottawa: 2010.
3. Last J. *A Dictionary of Public Health*. Oxford University Press, 2007.
4. Frank J, Di Ruggiero E, Moloughney B. Proceedings of the "Think Tank on the future of public health in Canada" Calgary May 10 2003. *Can J Public Health* 2003;95(1):6-11.
5. Canadian Public Health Association. Enhancing the Public Health Human Resource Infrastructure in Canada. Ottawa: CPHA, 2010.
6. Canadian Charter of Rights and Freedoms, s 7, Part I of the Constitution Act, c 11. Ottawa: Government of Canada, 1982.
7. Commission on Social Determinants of Health. Closing the Gap in a Generation: Health Equity through Action on the Social Determinants of Health. Geneva, Switzerland: World Health Organization, 2008.
8. Rawls J. *A Theory of Justice*. Harvard University Press, 1971.
9. Swift A. *Political Philosophy*, 3rd ed. Cambridge, UK: Cambridge University Press, 2013.
10. Canadian Charter of Rights and Freedoms, s 2, Part I of the Constitution Act, c 11. Ottawa: Government of Canada, 1982.
11. Canada (Attorney General) v PHS Community Services Society Supreme Court Judgements 2011 SCC44 (2011) 3 SCR 134, September 30, 2011.
12. Canada (attorney General) v Bedford, Supreme Court Judgements 2013 SCC72, 3SCR1101, December 20, 2013.
13. World Health Organization. Health systems: Equity. Geneva, Switzerland: WHO, 2014.
14. World Health Organization. Social Determinants of Health: Key Concepts. Geneva, Switzerland: WHO, 2008.
15. Atlantic Centre of Excellence for Women's Health, British Columbia Centre of Excellence for Women's Health, and Prairie Women's Health Centre of Excellence. SGBA e-Learning Centre: Rising to the Challenge.
16. World Health Organization. What are social determinants of health? Geneva, Switzerland: WHO, 2013.
17. Brownson RC, Fielding JE, Maylahn CM. Evidence-based public health: A fundamental concept for public health practice. *Annu Rev Public Health* 2009;30:17-201.
18. Center for Disease Control and Prevention. Distinguishing public health research and public health non-research. Washington, DC: Department of Human and Health Services, 1999.
19. IJsselmuiden C, Matlin S 2006. Why health research? Geneva: Council on Health Research for Development and the Global Forum for Health Research, 2007.
20. The Association of Faculties of Medicine in Canada. AFMC primer on population health. Ottawa: AFMC, 2017.
21. Lingard L, Albert M, Levinson W. Grounded theory, mixed methods, and action research. The BMJ 2008;337.
22. World Health Organization. 2014. Public health surveillance. Geneva, Switzerland, 2014.
23. World Health Organization, 2014. Epidemiology. Geneva, Switzerland: WHO, 2014.
24. Rose G. *The Strategy of Preventive Medicine*. Oxford: Oxford University Press, 1992.
25. Israel BA, Schulz AJ, and Parker EA. A review of community-based research: Assessing partnership approaches to improve public health. *Ann Rev Public Health* 1998;19:173-202.
26. Centre for Community Based Research. What is community-based research? Waterloo, ON: Centre for Community Based Research, 2017.
27. United States Environmental Protection Agency. Human health risk assessment. Washington: EPA, 2012.
28. Picard A. The Krever Inquiry. Toronto, ON: Historica Canada, 2014.
29. World Health Organization. The Ottawa Charter for Health Promotion. First International Conference on Health Promotion, Ottawa, 17-21 November 1986. Geneva: WHO, 1986.
30. Centers for Disease Control and Prevention. Introduction to program evaluation for public health programs: A self-study guide. Atlanta, GA: CDC, 2012.

CANADIAN
PUBLIC HEALTH
ASSOCIATION

The Voice of Public Health

The Canadian Public Health Association is the independent national voice and trusted advocate for public health, speaking up for people and populations to all levels of government.

For more information, contact:
Canadian Public Health Association
404-1525 Carling Avenue, Ottawa, ON K1Z 8R9
T: 613-725-3769 | F: 613-725-9826 | info@cpha.ca

www.cpha.ca

Alberta Health

PANDEMIC INFLUENZA Alberta Prepares

THIS IS EXHIBIT " E " referred to in the Affidavit / Declaration of
Dr. Deena Hinshaw
affirmed
Sworn / Declared before me this 12th day
of July A.D., 2021
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public.
Heather L. Veale
Barrister & Solicitor

Alberta's Ethical Framework for Responding to Pandemic Influenza

January 2016

Alberta Government

Foreword

Alberta's Ethical Framework for Responding to Pandemic Influenza (AB Ethics Framework) is based on the extensive work completed by British Columbia, the UK, and Alberta. It has been reviewed by the three lead organizations, Alberta Health, Alberta Health Services (AHS) and Alberta Emergency Management Agency (AEMA). As Alberta's planning for pandemic influenza evolves, the AB Ethics Framework will be reviewed and updated regularly to reflect new learnings.

The AB Ethics Framework is based on a consistent set of well–recognized ethical principles and outlines a transparent and clear process to assess potential choices against. The purpose of this document is to assist in making public health decisions on pandemic influenza related ethical dilemmas. It may also assist Albertans in understanding the ethical implications of their own decisions during a pandemic influenza event. This framework is not intended for use in making clinical ethical decisions. For more information on clinical ethics see the following link http://www.albertahealthservices.ca/info/Page6671.aspx.

Table of Contents

Introduction

Public health ethics focus on the health and interests of a population and are distinct from clinical ethics which focus on the health and interests of the individual. For example, in public health ethics, decision-makers may have to decide which segment of the population should be prioritized for the pandemic influenza vaccine (e.g., seniors, pregnant women) when the initial batches are approved and available. In contrast, clinical ethics would be used to decide if vaccine is an appropriate intervention for an individual patient based on a number of factors including their condition and personal wishes. Alberta's Ethical Framework for Responding to Pandemic Influenza (AB Ethics Framework) does not replace clinical judgment nor is it a checklist for a single, clear conclusion. Ethics should be considered within a larger decision-making context[1] (e.g., scientific evidence, program considerations such as logistics or treatment strategies, legal considerations). For direction on clinical level ethics, health care providers should contact the AHS Clinical Ethics Service or refer to their professional body as appropriate.

The AB Ethics Framework is a resource to help planners and strategic policymakers from Alberta Health, Alberta Health Services (AHS) and Alberta Emergency Management Agency (AEMA) consider ethical implications of the choices they face. The framework provides a widely recognized, consistent set of principles to work through and outlines a transparent and understandable process to assess the potential choices. This framework can be used to assist in making decisions on common pandemic influenza-related ethical dilemmas such as vaccine priority decisions, compensation for health care workers, antiviral prioritization and many others.

History of Pandemic Influenza Ethics in Alberta

Pandemic influenza occurs when a novel influenza A virus, to which most humans have little or no immunity, acquires the ability to cause sustained human-to-human transmission that leads to a rapid worldwide spread. When exposed to the new virus, most people become ill as they have no immunity. This can lead to overwhelming demand on the health system and the need to make ethically challenging decisions surrounding the allocation of scarce resources (i.e., staff, equipment and supplies).

In 2003, the Alberta Clinical Subcommittee on Pandemic Influenza Planning recommended that Alberta Health form a committee to address ethical issues that could arise during a pandemic influenza in Alberta. In 2007, the committee completed "Pandemic Ethics: Navigating through Complexity: A Map for Decision Making" intended to provide core values and a systematic approach to guide policy makers. In response to 2009's pH1N1 event, AHS and Covenant Health published "Clinical Ethics and Pandemic Influenza: an ethics framework to guide clinicians' decision-making".

Post pH1N1 2009, the Minister of Health authorized the Health Quality Council of Alberta (HQCA) to conduct a formal review of the provincial response. Recommendation #17, "Alberta Health and AHS develop and maintain an ethical framework and strategies to guide operational and clinical decision-making that is understood by the public" was accepted by the Minister in principle, as some work had already been done in the province and it was felt that a public health ethical framework should be initiated at a national level.

In 2014, as part of the revision of Alberta's Pandemic Influenza Plan, this framework was developed to assist policymakers in the absence of a finalized national approach. A detailed literature review and environmental scan were conducted to identify the leading practices most applicable to Alberta. The review revealed that the principles found in British Columbia's ethical framework were based largely on the work done by the United

[1] Public Health Agency of Canada. *Canadian Pandemic Influenza Plan for the Health Sector.* (2011, September 13). Retrieved from http://www.phac-aspc.gc.ca/cpip-pclcpi/index-eng.php

Kingdom (UK) Department of Health. In addition, this framework aligns with the University of Toronto's Joint Centre for Bioethics' "Stand on Guard for Thee: Ethical Considerations in Preparedness Planning for Pandemic Influenza", which contributed to the Canadian Pandemic Influenza Plan (CPIP) and was significantly influential in the World Health Organization's global pandemic influenza ethics consultation, "Global Consultation on Addressing Ethical Issues in Pandemic Influenza Planning".

The AB Ethics Framework is based on the extensive work completed by British Columbia, the UK, and Alberta. It has been reviewed by three lead organizations, Alberta Health, AHS and AEMA, as well as a number of provincial groups with policy, ethics and technical expertise including the Alberta Pandemic Influenza Planning Joint Advisory Committee and the Alberta Health Pandemic Influenza Planning Task Group (Appendix 2).

This framework aligns with the current principles and model for ethical decision-making found in the CPIP. As this and other leading practice documents are revised, and as Alberta's planning for pandemic influenza evolves, AB Ethics Framework will be reviewed and updated to reflect new learnings.

Understanding Ethical Tensions in a Pandemic

When a risk like a pandemic influenza affects a population, the health system is obliged to respond to the needs of the affected individuals, society, and healthcare providers that put themselves at risk for the good of others. Ethical tensions are inevitable; in an effective health system these tensions are held in a dynamic balance. For example, individual freedoms might be affected through restricting access to certain locations or confining people through quarantine; the decision to temporarily implement these public health measures must be weighed against the social and economic functioning of the community. In cases where responsibilities to individuals and groups are held in tension, decision-makers can use the ethical principles to find the best possible solution.

Ethical Framework for Responding to Pandemic Influenza

This section is taken directly from British Columbia's "An Ethical Framework for Decision Making: Supporting British Columbia's Pandemic Influenza Planning and Response". Small adjustments have been made to the content for applicability to Alberta.

Ethical Principles

Equal concern and respect underpin this ethical framework. This means that:

- Everyone matters.
- Everyone matters equally - but this does not mean that everyone is treated the same.
- The interests of each person are the concern of all of us, and of society.
- The harm that might be suffered by every person matters, and so minimizing the harm that a pandemic influenza might cause is the central concern.

Equal concern and respect draws together a number of different ethical principles, each of which is outlined below. The individual principles are numbered for convenience but are not ranked in order of significance.

When a particular decision has to be made, using the list of principles can help in considering a range of ethical issues. It is not, however, a checklist for *the one right answer.*

In thinking about the principles, decision-makers will need to use the best information that is available to them at that time. Whether or not a decision was ethically sound has to be judged in relation to the situation that existed at the time it was made, rather than by reference to facts that became apparent at a later stage.

Often, there will be tension both within and between these principles - for example, in weighing different sorts of harm, and in trying to both minimize harm and to be fair.

There are often no absolute right answers. A judgement may have to be made on the priority to be given to each element of a principle and to the principles themselves in the context of particular circumstances. Sometimes, use of the first seven principles may indicate that more than one possible decision would be ethically justifiable and would be in accordance with the fundamental principle of equal concern and respect. In such a case, the principle of "good decision-making" (#8, below) should be used to decide which one to take.

Individual Principles

1. *Respect*

This principle means that:

- People should be kept as informed as possible.
- Whenever possible, people should have the chance to express their views on health care decisions that affect them.
- People's personal choices about their treatment and care should be considered as much as possible.
- When people are unable to make their own health care decisions and have not provided any written expressed wishes to refuse or consent to future health care (such as identification of goals of care), then those who must decide for them should do so in consideration of what the person may have wanted and supported by the standards and duties of the health care providers involved in the decision at the time.

Respect applies to all individuals including patients, health care workers and the general public. There should be the widest possible involvement of people in planning for a pandemic influenza. The urgency of the situation may mean that it is not possible to consult widely (or indeed at all); However, treating people with respect means keeping them informed of the situation, what is happening and what is going to happen, as much as possible.

People's choices about their treatment and care are very important. Respect means balancing people's personal choices with the reality of the situation. For example, this may not mean that people are entitled to have the treatment of their choice if those caring for them would not consider it effective or is not suitable for them or if treatment resources were limited.

2. *Minimizing the harm caused by pandemic influenza*

During a pandemic influenza, some harm is likely to be unavoidable. This principle means that there is a need to:

- Try to minimize the spread of a pandemic influenza if it reaches Alberta.
- Minimize the risk of complications for the ill, for example, through the appropriate use of antivirals.
- Learn from experience, both at home and abroad, about the best way to fight the pandemic influenza and to treat people who are ill.
- Minimize the disruption to society caused by pandemic influenza.

This principle is intended to cover the physical, psychological, social and economic harm that pandemic influenza might cause. Examples of actions relevant to minimizing harm include those that save lives, support the health service in saving lives, and are designed to help society cope with and recover from pandemic influenza.

3. *Fairness*

The principle of fairness means that:

- Everyone matters equally but may not be treated the same.
- People with an equal chance of benefiting from health resources should have an equal chance of receiving them; however, it may be considered fair to tell people who could get the same benefit from an intervention at a later date to wait.

The implications of the principles of minimizing harm and fairness often arise together in many planning and policy decisions. So, in considering a particular decision, a first question might be: How could harm be minimized? Then it is necessary to ask: Would it be fair to do this? Could the same outcome be achieved in a fairer way? This involves thinking about the interests of everyone who may be affected by the decision. There needs to be good reasons to treat some people differently from others, which the decision-makers should be prepared to explain. The decision-making process also needs to be fair, which is considered part of the principle of good decision-making (#8 below).

4. *Working together*

This principle means:

- Working together to plan for, respond to, and recover from pandemic influenza.
- Helping one another.
- Being prepared to share information that will help others, without compromising the privacy and dignity of the individuals involved.

Because pandemic influenza will affect the whole of society, it is important that different agencies collaborate and coordinate at provincial, regional and local levels.

Working together also implies strong links at the international, national and inter-provincial levels. This includes both providing and seeking timely information from partners across Canada.

5. *Reciprocity*

The principle of reciprocity is based on the concept of mutual exchange. Therefore:

- If people are asked to take increased risks, or face increased burdens during a pandemic influenza, they should be supported in doing so, and the risks and burdens should be minimized as far as possible.

Some people, such as healthcare workers, may face very heavy burdens in trying to help us through pandemic influenza; it is important to think about how to minimize those burdens. An example of this could be providing those with the highest risk of contracting influenza at work with priority access to a vaccine.

6. *Keeping things in proportion*

This principle means that:

- Those responsible for providing information should neither exaggerate nor minimize the situation and should give people the most accurate information that they can.
- Decisions on actions that may affect people's daily lives, which are taken to protect the public from harm, should be proportionate to the relevant risk and benefits that can be gained from the proposed action. Proportionality requires that the least restrictive means possible is used when limiting liberty and freedom in the face of a pandemic influenza. For example, hospitals or long term care centres may restrict visitations to prevent patients from exposure to pandemic influenza.

At the start of a pandemic influenza, much will remain unknown about how it is going to affect people and the country as a whole. The media and other people responsible for communication will have an important role to play in helping people understand what the real situation is and what they need to do, without exaggerating or minimizing the situation.

7. *Flexibility*

This principle means that:

- Plans should be adapted to take into account new information and changing circumstances.
- People should have as much opportunity as possible to express concerns about or disagreement with decisions that affect them.

8. *Good decision-making*

Respect for this principle involves the following components:

i. Openness and transparency

This means that those making decisions should:

- Consult those concerned as much as possible in the time available.
- Be open about what decisions need to be made and who is responsible for making them.
- Be as open as possible about what decisions have been made and why they were made.

ii. Inclusiveness

This means that those making decisions should:

- Involve people to the greatest extent possible in aspects of planning that affect them.
- Decision makers should take into account all relevant views expressed.
- Work to make sure that particular groups are not excluded from becoming involved. Some people may find it harder to access communications or services than others, and decision-makers should consider how they can express their views and have a fair opportunity to get their needs for treatment or care met.
- Take into account any disproportionate impact of the decision on particular groups of people.

iii. Accountability

This means that those responsible for making decisions may have to justify the decisions that they do or do not make.

iv. Reasonableness

This means that decisions should be:

- Rational.
- Not arbitrary.
- Based on appropriate evidence, available at the time.
- The result of an appropriate process, taking into account how quickly a decision has to be made and the circumstances in which a decision is made.
- Practical- what is decided should have a reasonable chance of working.

Ethical Decision-Making Tools

Ethical decision-making tools are designed to encourage a systematic process for exploring in what way the ethical principles are reflected in a difficult decision. Depending on the context of the decision, these tools can be used by an individual or to facilitate a group discussion. The ethical principles contribute to but do not represent the entire decision-making process and should be used within a broader context when dealing with complex problems. When considering options, the goal should be to find a solution based on all information available and consider all relevant factors (scientific evidence, program considerations, policy considerations).

Generally, planners and policymakers will already be considering the ethical components of their recommended actions, even if not done so explicitly. Therefore, another key function of this kind of tool is to demonstrate in what manner the ethical principles were considered.

Many factors impact how decisions are made, such as familiarity with ethical issues, time constraints and the expertise of the group. Different tools are available to satisfy different needs. Two are outlined here; however, there are many tools which can be used in different contexts.

- **Ethical Considerations Assessment Worksheet** (Appendix 1)
  Designed to assess already identified potential courses of action against the eight ethical principles and provide rationale for the recommended decision.

- **Good Decisions: A map to the best decision, all things considered**
  Developed in BC and used in conjunction with their ethical framework. This is a longer, more complete guide that takes users from the first step of articulating the issue to identifying ethical concerns and finally a recommendation. This tool includes a step to determine who needs to be involved in a decision. It can also help users define the "key question" and identify which ethical issues are most important (http://www2.gov.bc.ca/assets/gov/health/about-bc-s-health-care-system/office-of-the-provincial-health-officer/reports-publications/bc-pandemic-influenza-ethics-framework-2012.pdf , p. 13-29).

Formal Decision-Making Mechanism(s)

Ethical decision making is a component of the established emergency management structures used during a response, as outlined in the Alberta Pandemic Influenza Plan (http://www.health.alberta.ca/health-info/pandemic-influenza.html).

Although we can and should identify potential situations ahead of time, planning scenarios cannot incorporate all potential factors that can affect the impact of a pandemic influenza. Some factors are population-wide and could affect all scenarios, such as seasonality, pre-existing immunity or antiviral resistance, whereas others may be setting-specific, such as the effects on a remote community. Because these impacts are hard to predict, some decisions will have to be made rapidly at the time of a pandemic influenza.

In order to assist the ethical decision-making process, mechanisms such as pre-established relationships and committees should be in place to bring the right expertise and decision-making capability to the table (e.g., Pandemic Influenza Planning Joint Advisory Committee, Alberta Health Pandemic Influenza Planning Task Group, Appendix 2). Membership should be determined by the group leading the pandemic influenza response so that the most relevant program area expertise is included.

Appendix 1 – Ethical Considerations Assessment Worksheet

Purpose:
To compare/weigh potential options against the eight ethical principles identified in Alberta's Ethical Framework for Responding to Pandemic Influenza (AB Ethics Framework).

To use this tool effectively, it will be necessary to review the Ethical Principles found on pages 5-9 of the AB Ethics Framework. This tool is intended to be used in conjunction with scientific, policy and program considerations and assumes some potential courses of action have been produced.

Instructions:

- Write each of the potential courses of action in the Option boxes along the top row.
- For each of the Ethical Principles, identify how each Option will or will not fulfill the responsibilities of that Ethical Principle.
    - If the Option does not fulfill the Ethical Principle, you may also wish to provide justification for why this Option may still be appropriate.
- Once all of the Options have been evaluated against the Ethical Principles, the table can be used to determine which Option(s) best addresses the ethical dilemma.
- The *Summary of Decision* then makes explicit the Option that is recommended based on the information in this table.

The following example is for illustrative purposes only and does not necessarily reflect corporate human resource policies.

Example: You witness a co-worker who has worked with the organization a long time taking stationary supplies out of the office.

Ethical Principles:	**Option 1:** Report this to your supervisor immediately.	**Option 2:** Confront the co-worker about what you saw.	**Option 3:** Do nothing.
Respect	This respects the workplace and your supervisor, as they will be informed of the incident. It doesn't necessarily respect the employee as he was not informed before the report.	This option incorporates respect, as it addresses the issue but gives the employee a chance to express their side of the story. Your supervisor may not be informed, but since inappropriate actions may be corrected, it may not be necessary.	This option does not reflect respect, as you have made no effort to understand what you saw or let your supervisor know if there is in fact an issue.
Keeping things in proportion	This option seems out of proportion. Without taking the time to understand the situation, one might actually report inaccurate information that could jeopardize the reputation of the employee.	This option is in proportion. It addresses the issue, but allows the employee to share their side of the story and possibly correct the inappropriate actions without losing face, especially since the supplies are not worth much money.	It could be argued that this option is proportional as the supplies are not worth much, and their loss won't greatly affect the business. Not reporting it will ensure that the employee's reputation is not duly or unduly affected.

Ethical Considerations Assessment

Ethical Principles:	Option 1:	Option 2:	Option 3:
Respect			
Minimizing the harm			
Fairness			
Working together			
Reciprocity			
Keeping things in proportion			
Flexibility			
Good Decision-Making			

Summary of Decision

For the question...	
We recommend that...	
This allows us to best...	
This solution does not...	
We argue that this is justified because...	

Appendix 2 – Pandemic Influenza Planning Joint Advisory Committee and Alberta Health Pandemic Influenza Group

Alberta Pandemic Influenza Planning Joint Advisory Committee

The Joint Advisory Committee (JAC) is made up of senior-level decision-makers from each of the three pandemic influenza lead organizations, Alberta Health, Alberta Health Services (AHS) and the Alberta Emergency Management Agency (AEMA). The JAC provides ongoing advice and coordination for pandemic influenza preparedness in Alberta.

Current members include:

Alberta Health

- Executive Director, Health Protection (Chair)
- Director, Emergency Planning and Preparedness
- Deputy Chief Medical Officer of Health

AHS

- Executive Director, Emergency/Disaster Management
- Special Project Lead, Emergency/ Disaster Management
- Senior Medical Officer of Health

AEMA

- Director, Central Operations

Alberta Health Pandemic Influenza Planning Task Group

The Task Group provides content expertise for the *Alberta's Pandemic Influenza Plan* (APIP) and related organizational / operational planning as required, and aligns the work across divisions and work units of Alberta Health.

The Task Group is made up of technical expertise from the following areas:

- Public Health Emergency Planning
- Clinical Advisory and Research
- Communicable Disease
- Communications
- Drug Program Operations and Policy
- Emergency Preparedness and Response
- Enterprise Risk Management
- Epidemiology and Surveillance
- Immunization
- Intergovernmental Relations
- Infection Prevention and Control
- Legal & Legislative Services
- Addiction and Mental Health
- Office of the Chief Medical Officer of Health
- Workforce Policy and Planning

References

Alberta Health Services Ethics Advisory Committee. (2009, October). Clinical Ethics and Pandemic Influenza. Edmonton, Alberta: Alberta Health Services and Covenant Health.

British Columbia Ministry of Health. (2012). *British Columbia's Pandemic Influenza Response Plan (2012): An Ethical Framework for Decision MakingL Supporting British Columbia's Pandemic Influenza Planning and Response.* Victoria: Government of British Columbia.

Pandemic Influenza Working Group, University of Toronto Joint Centre for Bioethics. (2005). *Stand On Guard for Thee: Ethical Considerations in Preparedness Planning for Pandemic Influenza.* Toronto: University of Toronto Joint Centre for Bioethics.

Public Health Agency of Canada. (2011, September 13). *Canadian Pandemic Influenza Plan for the Health Sector.* Retrieved August 15, 2014, from Public Health Agency of Canada: http://www.phac-aspc.gc.ca/cpip-pclcpi/index-eng.php.

United Kingdom Department of Health. (2007). *Responding to Pandemic Influenza: The Ethical Framework for Policy and Planning.* London: United Kingdom Cabinet Office.

Wasylenko, E. (2007). *Navigating Through Complexity: A Map for Decision Making.* Edmonton: Alberta Influenza Pandemic Preparedness Ethics Working Group.

World Health Organization. (2007). *Ethical Considerations in Developing a Public Health Response to Pandemic Influenza.* Geneva: WHO Press.

Government of Canada / Gouvernement du Canada

COVID-19: Main modes of transmission

On this page

THIS IS EXHIBIT " F " referred to in the Affidavit / Declaration of Dr. Deena Hinshaw affirmed / ~~Declared~~ before me this 12th day of July A.D., 2021

A Commissioner for Oaths in and for the Province of Alberta. A Notary Public.

Heather L. Veale Barrister & Solicitor

How COVID-19 spreads

SARS-CoV-2, the virus that causes COVID-19, spreads from an infected person to others through respiratory droplets and aerosols when an infected person breathes, coughs, sneezes, sings, shouts, or talks. The droplets vary in size, from large droplets that fall to the ground rapidly (within seconds or minutes) near the infected person, to smaller droplets, sometimes called aerosols, which linger in the air, especially in indoor spaces.

The relative infectiousness of droplets of different sizes is not clear. Infectious droplets or aerosols may come into direct contact with the mucous membranes of another person's nose, mouth or eyes, or they may be inhaled into their nose, mouth, airways and lungs. The virus may also spread when a person touches another person (i.e., a handshake) or a surface or an object (also referred to as a fomite) that has the virus on it, and then touches their mouth, nose or eyes with unwashed hands.

Settings with higher risk of transmission

Outbreak investigations and scientific studies are revealing more about COVID-19 and this new knowledge is being applied to reduce its spread. We know that the virus is most frequently transmitted when people are in close contact with others who are infected with the virus (either with or without symptoms). We also know that most transmission occurs indoors.

Reports of outbreaks in settings with poor ventilation suggest that infectious aerosols were suspended in the air and that people inhaled the virus at distances beyond 2 metres. Such settings have included choir practice, fitness classes, and restaurants, as well as other settings. Transmission can be facilitated by certain environmental conditions, such as re-circulated air. Activities that increase generation of respiratory droplets and aerosols may increase risk in these settings (such as singing, shouting, or exercising).

It is still unclear how easily the virus spreads through contact with surfaces or objects.

Follow public health measures

While we do not yet fully understand all modes of transmission and their relative importance, it is likely that multiple modes of transmission occur.

The public health measures that we have been practising continue to be effective in preventing the spread of the virus that causes COVID-19. To protect yourself and others, use multiple personal preventive practices at once in a layered approach. With the increased circulation of some variants of concern, it is even more important that you strictly follow recommended personal preventive practices.

Ventilation

Maximize ventilation by ensuring that heating, ventilation and air conditioning (HVAC) systems are in good working order. Drawing as much fresh air as possible from outside will decrease the concentration of aerosols that may be suspended in the air, and reduce the chances of SARS-CoV-2 spread if those aerosols happen to contain the virus. If the weather permits, open a window. Reduce the noise level in public spaces, for example turn off or reduce the music volume, so people can speak quietly.

Related links

- COVID-19: Improving indoor ventilation

Date modified:
2021-06-29

www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

Aerosol emission and superemission during human speech increase with voice loudness

Received: 14 June 2018
Accepted: 10 January 2019
Published online: 20 February 2019

Sima Asadi[1], Anthony S. Wexler[2,3,4,5], Christopher D. Cappa[4], Santiago Barreda[6], Nicole M. Bouvier[7,8] & William D. Ristenpart[1]

Mechanistic hypotheses about airborne infectious disease transmission have traditionally emphasized the role of coughing and sneezing, which are dramatic expiratory events that yield both easily visible droplets and large quantities of particles too small to see by eye. Nonetheless, it has long been known that normal speech also yields large quantities of particles that are too small to see by eye, but are large enough to carry a variety of communicable respiratory pathogens. Here we show that the rate of particle emission during normal human speech is positively correlated with the loudness (amplitude) of vocalization, ranging from approximately 1 to 50 particles per second (0.06 to 3 particles per cm^3) for low to high amplitudes, regardless of the language spoken (English, Spanish, Mandarin, or Arabic). Furthermore, a small fraction of individuals behaves as "speech superemitters," consistently releasing an order of magnitude more particles than their peers. Our data demonstrate that the phenomenon of speech superemission cannot be fully explained either by the phonic structures or the amplitude of the speech. These results suggest that other unknown physiological factors, varying dramatically among individuals, could affect the probability of respiratory infectious disease transmission, and also help explain the existence of superspreaders who are disproportionately responsible for outbreaks of airborne infectious disease.

It has long been recognized that particles expelled during human expiratory events, such as sneezing, coughing, talking, and breathing, serve as vehicles for respiratory pathogen transmission[1–9]. The relative contribution of each expiratory activity in transmitting infectious microorganisms, however, remains unclear[1]. Much previous research has focused on coughing[7–10] and sneezing[11,13,14] activities that yield relatively large droplets (approximately 50 μm or larger) easily visible to the naked eye. Less noticeable, but arguably more infectious for some diseases, are the smaller particles emitted during sneezing and coughing as well as during breathing[15–17] and talking[16,18,19]. These small particles are believed to be generated during breathing and talking from the mucosal layers coating the respiratory tract via a combination of a "fluid-film burst" mechanism within the bronchioles and from vocal folds adduction and vibration within the larynx[6,20,21]. The particles emitted during breathing and typical speech predominantly average only 1 μm in diameter[15–17] and are thus too small to see without specialized equipment; most people outside of the community of bioaerosol researchers are less aware of them.

Despite their small size, however, these micron-scale particles are sufficiently large to carry a variety of respiratory pathogens such as measles virus (50–500 nm)[22], influenza virus (100 nm–1 μm)[23], and *Mycobacterium tuberculosis* (1–3 μm)[24]. Indeed, recent work by Yan *et al.* has confirmed that significant amounts of influenza viral RNA are present in small particles (<5 μm) emitted by influenza-infected individuals during natural breathing, without coughing or sneezing[25]. These small particles are potentially more infectious than larger sneeze- or

[1]Department of Chemical Engineering, University of California Davis, 1 Shields Ave, Davis, CA, 95616, USA. [2]Department of Mechanical and Aerospace Engineering, University of California Davis, 1 Shields Ave, Davis, CA, 95616, USA. [3]Air Quality Research Center, University of California Davis, 1 Shields Ave, Davis, CA, 95616, USA. [4]Department of Civil and Environmental Engineering, University of California Davis, 1 Shields Ave, Davis, CA, 95616, USA. [5]Department of Land, Air and Water Resources, University of California Davis, 1 Shields Ave, Davis, CA, 95616, USA. [6]Department of Linguistics, University of California Davis, 1 Shields Ave, Davis, CA, 95616, USA. [7]Department of Medicine, Div. of Infectious Diseases, Icahn School of Medicine at Mount Sinai, 1 Gustave Levy Place, New York, NY, 10029, USA. [8]Department of Microbiology, Icahn School of Medicine at Mount Sinai, 1 Gustave Levy Place, New York, NY, 10029, USA. Correspondence and requests for materials should be addressed to W.D.R. (email: wdristenpart@ucdavis.edu)

cough-generated droplets for several reasons. First, smaller particles persist in the air for longer time periods before setting by gravity, thus increasing the probability of inhalation by susceptible individuals[26]. Second, smaller particles have a larger probability of penetrating further into the respiratory tract of a susceptible individual to initiate a lower respiratory tract infection[4]. Third, and perhaps most importantly, speech can release dramatically larger numbers of particles compared to coughing. Early work by Papineni and Rosenthal[19] and Loudon and Roberts[19] reported that speaking (as exemplified by counting aloud) releases about 2–10 times as many total particles as a single cough. Similarly, Loudon and Roberts investigated the role of singing in the spread of tuberculosis and showed that the percentage of airborne droplet nuclei generated by singing is 6 times more than that emitted during normal talking and approximately equivalent to that released by coughing[27]. More recent work using advanced particle characterization techniques have yielded similar results[21,28–30]. Chao *et al.*[28] used an interferometric imaging technique to obtain the size distribution of particles larger than 2 μm and found that counting aloud from 1 to 100 releases at least 6 times as many particles as an individual cough. Likewise, Morawska and coworkers[21,29] reported that counting aloud for 10 seconds followed by 10 seconds of breathing, repeated over two minutes, releases half as many particles as 30 seconds of continual coughing, which in turn releases half as many particles as saying "aah" for 30 seconds. They also reported that more particles are released when speech is voiced, which involves vocal folds vibration, rather than whispered, which does not.

Despite the clear evidence that speech emits large quantities of potentially infectious particles, to date little is known about how particle emission is modulated by different types of speech. Notably, the above work measured neither the total duration nor the loudness of the vocalizations; it is also unclear whether counting aloud will have a distribution of phones (phonemes) that is representative of typical conversational speech. Many important questions remain unanswered. For example, does raising your voice cause an increase in particle emission, or alter the particle size distribution? Does it matter what language you speak? Do all individuals emit particles at similar rates?

To address these questions, we used an aerodynamic particle sizer (APS) placed in a laminar flow hood to characterize the number and size distribution of particles emitted by individual human volunteers while they performed various vocalizations and breathing activities. Using this approach, we find three key results:

(1) The particle emission rate during speech is linearly correlated with the amplitude (loudness) of vocalization, for four different languages tested.
(2) The particle size distribution is independent of vocalization loudness or language spoken.
(3) Some individuals emit particles at a rate more than an order of magnitude larger than their peers, i.e., they behave as "speech superemitters."

Taken together, the results strongly suggest that individual human speech patterns and speech-associated particle emissions are highly heterogeneous and thus might play a role in the transmission of some respiratory pathogens. Furthermore, the results suggest a new hypothesis: that speech superemitters might contribute to the phenomenon of superspreading, in which a relative few contagious individuals infect a disproportionately large number of secondary cases during infectious disease outbreaks[31].

Results

Four separate types of experiments were performed. In the first experiment, participants said /ɑ/ (the vowel sound in 'saw') for five seconds, followed by 15 seconds of nose breathing, repeated six times in succession. This procedure mimics previous experimental measurements of particle emission during vocalization[21], but here the participants also systematically repeated the experiment at different voice amplitudes. Representative raw data for a single participant performing a series of six successive /ɑ/ vocalizations, at approximately the same loudness, are shown in Fig. 1. The simultaneous microphone recording (Fig. 1A) and APS measurements (Fig. 1B) demonstrate that the dynamics of particle release are highly correlated with the vocalization. Prior to and between vocalizations, during nose breathing in which exhaled air is directed away from the APS, the particle count is negligible, as is expected for the HEPA filtered air inside the laminar flow hood. Shortly after the vocalization commences, the number of particles rapidly increases and peaks, then decreases back to zero as the participant resumes nose breathing; the process then repeats at the next five-second vocalization. The approximately two-second lag between onset of vocalization and the observed increase in particle count is due to the time necessary for the released particles to reach the sensor in the APS. We emphasize that by design an APS does not measure 100% of the particles drawn into it, so the particle emission rates reported here do not represent the absolute number of particles emitted by the participant; the emission rates are best understood in relative terms, or in terms of the equivalent instantaneous concentrations of particles sampled from the funnel. As shown in the secondary axis of Fig. 1B, the instantaneous concentration of particles for this particular experiment was approximately 2 per cm^3 of sampled air.

The six vocalizations shown in Fig. 1A were made, to the best of the participant's ability, at the same loudness. Each participant then repeated a similar series of /ɑ/ vocalizations at different self-regulated voice amplitudes. Representative results for a single participant (F4) show that the particle emission rate (N), defined as the total number of particles emitted during a single vocalization divided by the measured duration (in seconds) of that vocalization, also correlates with the root mean square amplitude (A_{rms}) of the vocalization (Fig. 2A). In our set-up $A_{rms} = 0.45$ corresponds to an extremely loud conversational voice, as loud as comfortable without yelling (~98 decibels measured 6.5 cm from the participant's mouth, measured over background noise of approximately 65 decibels), while $A_{rms} = 0.02$ corresponds to a quiet vocalization just above whispering (~70 decibels; cf. Supplementary Fig. S1). As shown in Fig. 2A, the particle emission rate is linearly correlated with A_{rms} over this entire range of vocalization amplitudes, with the particle emission rate increasing from 6 to 53 particles per second at the quietest and loudest vocalizations respectively.

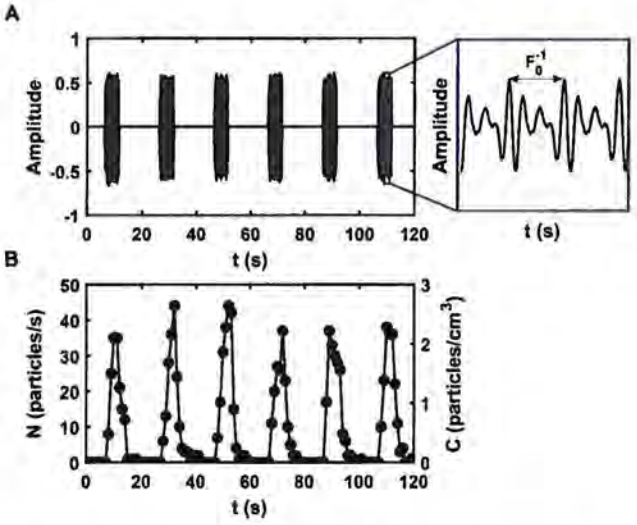


Figure 1. Representative raw data in which a participant (F4) said /ɑ/ for 5 seconds, followed by 15 seconds of nose breathing, repeated 6 times at approximately the same loudness. (**A**) The amplitude (arb. units) recorded by the microphone versus time. Magnification shows 13 ms of the waveform with fundamental frequency of F_0. (**B**) The corresponding number/concentration of particles measured by the APS versus time.

Although the particle emission rate increased with amplitude, the size distribution of the particles was not affected significantly (Fig. 2B), with the geometric mean particle diameter remaining near 1 μm regardless of voice amplitude (Supplementary Fig. S2A). Because the particle size remains similar regardless of amplitude, the increased particle counts shown in Fig. 2 indicate that the total volume of emitted respiratory fluid (i.e., the proteinaceous liquid droplets aerosolized from the serous and mucoid layers lining the respiratory tract) increases considerably with the vocalization loudness. Note that the characteristic time scale for evaporative drying of 1-micron diameter droplets is on the order of 100 milliseconds[14], which is much less than the time required for the particles to move from the participant's mouth into the detection module within the APS, suggesting that the particles measured here had fully dried into droplet nuclei prior to measurement (see methods and Supplementary Fig. S3).

Experiments with multiple participants indicated that these trends are conserved over a larger sample size (Fig. 2C). The particle emission rate increased approximately linearly with A_{rms} for each of the study participants, although the absolute magnitude varied between individuals. One participant (F3) released as many as 200 particles per second at higher amplitudes; another (F2) released as few as 1 particle per second at lower amplitudes. Notably, the data with this cohort of non-elderly adults reveal no obvious trends with gender or age (Supplementary Figs S4A, B). Similarly, no clear correlation was observed with the body mass index (BMI) of the participants (Supplementary Figs S4C, D).

To more closely represent normal conversational speech, the participants read aloud a short passage of text in English at varied loudness (quiet, intermediate, or loud). Representative raw data for a single participant (F4) indicate that the particle emission rate also correlates with voice amplitude for normal speech (Fig. 3A,B). To quantify the loudness, we take A_{rms} here as the average over the entire approximately two-minute duration of the vocalization, excluding pauses between words. Aggregated data for 10 participants confirms that the particle emission rate for normal English speech correlates linearly with A_{rms} (Fig. 3C); speaking loudly yielded on average a 10-fold increase in the emission rate compared to speaking the same series of words quietly. Again, the size distributions (Fig. 3D) and geometric mean diameter of particles (Supplementary Fig. S2B) were insensitive to voice amplitude. The reading experiment also was repeated in different languages to test whether choice of language matters; the results (Supplementary Fig. S5) confirmed the increasing trend between particle emission rate and amplitude, but exhibited no significant difference in the particle emission rate among the languages tested (Supplementary Fig. S6). Likewise, we measured the temperature and humidity during the experiments, and found no significant impact of temperature or humidity on either the particle emission rate or the mean particle size (Supplementary Figs S7 and S8).

A key recurring feature of the data is that some individual participants emitted many more particles than others. Because all participants spoke at slightly different amplitudes, we used linear regressions of the particle emission rate versus amplitude for each individual (cf. Fig. 2A) to calculate a normalized particle emission rate at the loudness amplitude of 0.1 (approximately 85 dB). Using this approach, the results for 40 people show that the particle emission rate for different individuals follows a long-tailed distribution for both vocalization of /ɑ/ (Fig. 4A) and reading of English text aloud (Fig. 4B). At this loudness, the normalized particle emission rates ranged from approximately 1 to 14 particles per second between different individuals, with an average of approximately 4 particles per second. Notably, the rates have a sizeable standard deviation well approximated by a lognormal fit (red curves in Fig. 4). In other words, although half of the participants emitted fewer than 3 particles per second, a small fraction of individuals (8 out of 40) emitted considerably more. These "speech superemitters,"

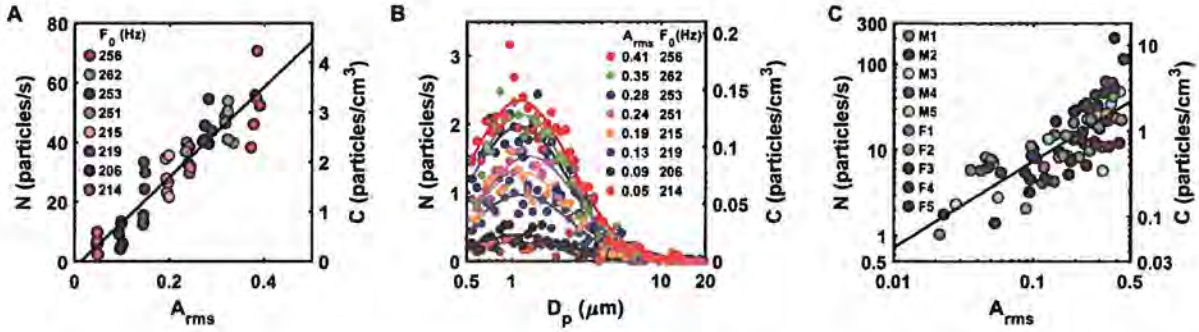


Figure 2. Particle emission rate/concentration while saying /ɑ/ at 8 different amplitudes, repeated 6 times at each amplitude. (**A**) Particle emission rate/concentration versus root mean square amplitude, A_{rms} (arb. units) for a representative participant (F4). Solid line is the best linear fit, with correlation coefficient $\rho = 0.932$ and Pearson's p value $= 5.9 \times 10^{-22}$. (**B**) Corresponding particle size distribution for the data presented in (**A**). (**C**) Aggregated particle emission rate/concentration versus root mean square amplitude, A_{rms} (arb. units) for 10 participants, 5 males (denoted as M1 to M5) and 5 females (denoted as F1 to F5). There are 8 data points for each participant, each representing the average of repeating /ɑ/ six times at approximately the same voice amplitude (cf. Fig. 1). Solid line is a power law fit with exponent 1.004, correlation coefficient $\rho = 0.774$ and Pearson's p value $= 3.8 \times 10^{-17}$.

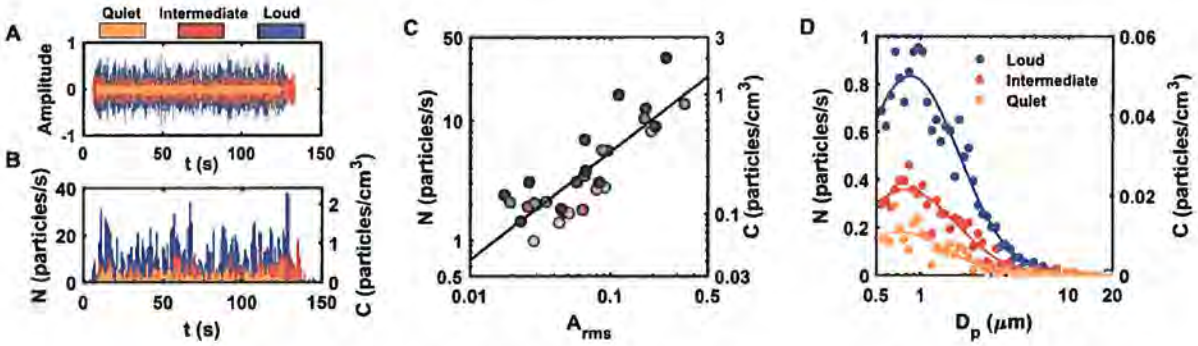


Figure 3. Particle emission rate/concentration while reading a passage of text aloud (the "Rainbow" passage), at three different loudness levels. (**A**) Superimposed representative recordings of amplitude (arb. units) for an individual (F4) reading the passage at three different voice amplitudes, and (**B**) the corresponding number/concentration of particles measured by the APS versus time. Color code same as in (**A**). (**C**) Particle emission rate/concentration as a function of root mean square amplitude, A_{rms}, for 10 participants. There are 3 points for each person, representing 3 voice amplitudes, color code same as Fig. 2C. Solid line is a power law fit with exponent 0.96, correlation coefficient $\rho = 0.865$ and Pearson's p value $= 6.8 \times 10^{-10}$. (**D**) Representative particle size distribution for the one individual (F4).

whose individual particle emission rate exceeded the group mean by one standard deviation or more, consistently released an order of magnitude more particles than their peers. For vocalizing /ɑ/, Fig. 4A shows that 15% of the participants emitted 32% of the total particles, while Fig. 4B shows that, for reading aloud in English, 12.5% of the participants emitted 40% of the total particles. Supplementary Fig. S9A shows that 4 out of these 8 individuals are superemitters for both saying /ɑ/ and passage reading activities, while 2 of them are only superemitters while saying /ɑ/, and 2 of them are superemitters while reading a text passage. We repeated the passage reading experiment for two of the participants (M5 and F4) on three different days separated by several months (Supplementary Fig. S9B), and the results show that the particle emission rates remained almost unchanged for at least these two individuals (F4, a superemitter, and M5, a non-superemitter) despite the long time period between measurements.

To help interpret our findings we also compared the particle emission rates of four different types of breathing with speech at three levels of loudness using the same experimental set-up. The breathing experiments included nose breathing, mouth breathing, a "deep-fast" mode, and a "fast-deep" mode (see methods for details). The results show that the particle emission rate for speech is significantly higher than all types of breathing tested here (Fig. 5A). Furthermore, the corresponding geometric mean diameters of the particles generated during speech are slightly larger on average than those generated during breathing (Fig. 5B), consistent with prior work and the hypothesis that vocalization activates laryngeal particle generation[21]. Note that in Fig. 5A the speech outliers correspond to a single participant who is a speech superemitter (F4), but this individual was not also responsible

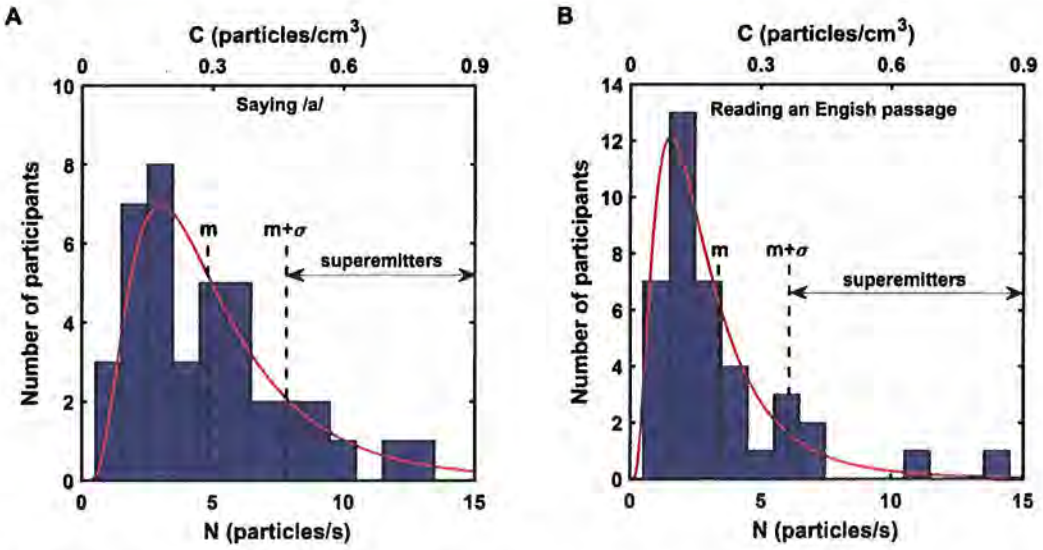


Figure 4. Histogram of particle emission rate/concentration at voice amplitude of 0.1 (approximately 85 dB). (**A**) For saying /ɑ/, with median of M = 4.3 particles/s, mean of m = 4.8 particles/s and standard deviation of σ = 3.0 particles/s. (**B**) For reading an English passage (10 people read the "Rainbow" passage and 30 people read chapter 24 of "The Little Prince") with median of M = 2.5 particles/s, mean of m = 3.4 particles/s and standard deviation of σ = 2.7 particles/s. Particle emission rates larger than m + σ are labeled superemitters. Red curves are lognormal fits found via nonlinear regression.

for the observed outliers of "fast-deep" and "nose" breathing activities. In other words, the "breathing high producers" as defined by Edwards *et al.*[18] are not necessarily also speech superemitters.

Discussion

Given that the results clearly indicate that particle emission rate is correlated with vocalization amplitude, a natural question is: why? The particles emitted during breathing and speech are hypothesized to be formed primarily by a "fluid-film burst" mechanism inside the small airways of the lungs and/or via vocal folds vibration and adduction at the larynx[6,30,31]. During exhalation the elastic walls of the respiratory bronchioles contract, and the mucosal fluid on the lumen surface forms a continuous film that can completely fill the airway. During the subsequent inhalation, the bronchioles expand and the film ruptures, yielding particles that are drawn into the alveoli and subsequently exhaled. A similar mechanism is believed to occur in the larynx, as the vocal folds repeatedly close and open during vocalization[21]; when the vocal folds come into contact during adduction, fluid films that form between them can then rupture during their subsequent abduction. Our direct comparison of particles emitted during various types of breathing versus speech demonstrates that even quiet speech yields significantly more particles than normal breathing (Fig. 5A). Coupled with the observation that the particles generated during speech on average are slightly larger (Fig. 5B), the results suggest that laryngeal particle generation, which presumably does not occur during normal breathing, is at least partially responsible for the observed larger rates of particle emission. Indeed, the fundamental frequency or "pitch" of vocalization (i.e., the frequency at which the vocal folds open and close) increases slightly with amplitude (cf. Supplementary Fig. S11 and Gramming *et al.*[32]), so the increased amplitude could reflect an increased opportunity for particles to form at the larynx.

Complicating matters, however, vocalization at a larger voice amplitude requires a larger exhalation flow rate[33,34]. A possible interpretation of our observations is that the underlying physical mechanism of particle release hinges on the combination of laryngeal particle generation rate and the time integral of the exhalation flow rate during vocalization[35]. If the volume of exhaled air is larger when the voice amplitude is higher, a larger fraction of particles formed in bronchiolar film rupture may escape from the lungs, with consequently more emitted particles, thus increasing the particle concentration in the exhaled air. Since our measurements only gauge the particle emission rate (and equivalent concentration), it is difficult to decouple the relative contributions of these two mechanisms. Fitting our particle size distributions to constrained bimodal lognormal distributions provides some evidence consistent with the interpretation presented by Johnson *et al.*[21] that there are two modes, presumably due to bronchiolar versus laryngeal generation, but we do not find any significant difference in particle emission rates for the two modes as a function of vocalization amplitude (Supplementary Fig. S10 and cf. Fig. 5B). Furthermore, it is less understood how particles originating in the respiratory tract might deposit in more proximal regions instead of being emitted during exhalation. Particle deposition efficiency during nasal exhalation is known to depend on exhalation flow rate in a convoluted fashion, with Brownian diffusion, sedimentation, and inertial impaction all playing roles at different length and time scales within the respiratory tract[36]. Nonetheless, our results strongly suggest that, in general, more particles escape the respiratory tract if the vocalization is louder.

Our results also clearly show that some participants release many more particles than others, for as-yet unclear reasons. It is known that the Rayleigh-Plateau instability that gives rise to small droplets during the "film burst" is

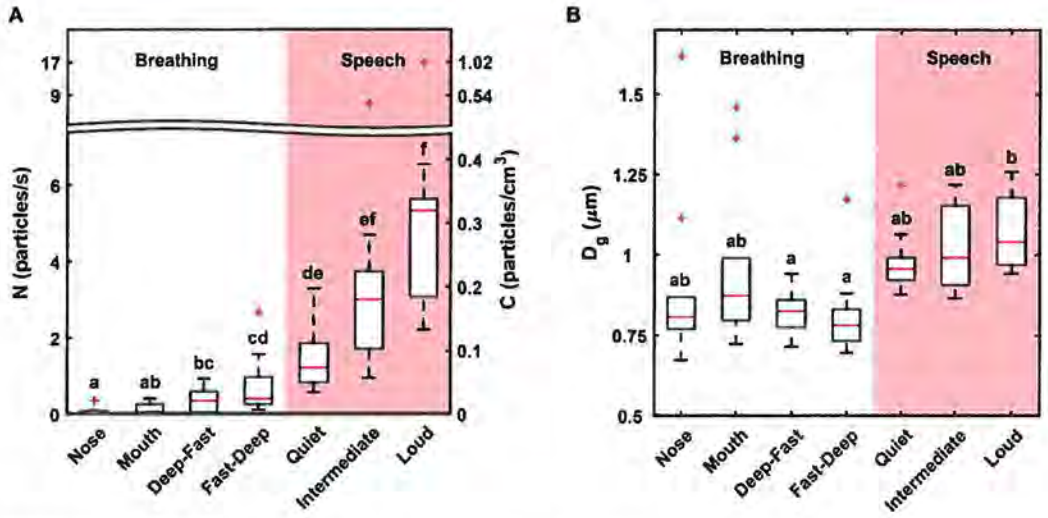


Figure 5. Comparison of (**A**) emission rate/concentration and (**B**) corresponding geometric mean diameters of particles emitted during various modes of breathing versus speech at different loudness levels. "Nose" denotes normal nasal breathing; "Mouth" denotes normal mouth breathing; "Deep-Fast" denotes deep, slow nasal inhalation followed by fast mouth exhalation; "Fast-Deep" denotes fast nasal inhalation followed by deep (i.e., slow and prolonged) mouth exhalation. "Quiet", "Intermediate", and "Loud" denote loudness levels while reading aloud a passage of text ("Rainbow" passage) at respective amplitudes. Red lines indicate medians, while bottom and top of blue boxes indicate the 25th and 75th percentiles respectively; sample size is n = 10. Outliers (defined as values that exceed 2.7 standard deviations) are indicated with red plus signs. Note that the 2 outliers for speech in (**A**) are a different individual (F4) than the two outliers observed for nose and fast-deep breathing (M24 and M5 respectively). Scheffe groups are indicated with letters; groups with no common letter are considered significantly different with $p < 0.05$, cf. Supplementary Table S1. Note that (**A**) has different scales above and below the break.

sensitive to the interfacial tension, density, and viscosity of the fluid[37], so one possible explanation is that the mucosal fluids in different people have different material properties and correspondingly generate more or fewer drops. Notably, different disease states are known to alter the physicochemical properties of the mucosal fluid lining the respiratory tract[38], so it is possible that infected individuals might generate markedly different quantities of particles than those emitted by the healthy individuals tested here. Intriguingly, Edwards *et al.*[15] found that delivering nebulized isotonic saline to individuals decreased the number of particles exhaled during normal breathing for a few hours after inhalation of the saline; further tests are warranted with speech. Alternatively, it is possible that individual manners of articulation affect the amount of internal deposition of the particles before they manage to escape the mouth. Our tests of different languages yielded no significant differences, at odds with previous speculation that language spoken might have played a role in the epidemiology of SARS coronavirus transmission[39], and suggesting that some as yet unknown physiological factor causes the dramatic variation among individuals.

Regardless of the underlying physical mechanism, from an epidemiological perspective the existence of speech superemitters motivates consideration of a new hypothesis: that speech superemitters contribute to "superspreading" of infectious diseases transmitted by emitted airborne particles. A superspreader is a contagious individual who infects a disproportionately large number of susceptible contacts[31,40,41]. To date, several airborne superspreading events have been documented, such as the MERS-CoV outbreak in South Korea in 2015 and the SARS-CoV outbreak in 2003, the latter being initiated in Hong Kong and spreading to Canada, Vietnam, and Singapore through travel[40–43]. In the case of respiratory infectious diseases in particular, the underlying physiological and immunological factors that contribute to heterogeneity in individual infectiousness remain poorly understood, despite the epidemiological importance of respiratory superspreaders. Quantifying infectious pathogen loads in exhaled air is technically challenging, relative to other contagious substances like blood, urine, and feces. Many factors presumably affect the secondary attack rate attributable to any infectious individual, including the herd immunity status of others in proximity. Nonetheless, our results suggest that, for respiratory infections transmitted from person to person via airborne particles, the existence of speech superemitters might help explain the existence of superspreaders. A similar hypothesis was advanced by Edwards *et al.*[15] in response to their observation of variability between individuals in the number of particles emitted during mouth breathing. Interestingly, our data show that speech superemitters are not necessarily breathing superemitters as well (Fig. 5A), suggesting that respiratory superemission during vocalized speech has a different underlying physiology than superemission during tidal breathing.

Our results indicate that speech is potentially of much greater concern than breathing for two reasons: the particles on average are larger, and thus could potentially carry a larger number of pathogens, and much greater quantities of particles are emitted compared to breathing, thus increasing the odds of infecting nearby susceptible individuals. Laryngeal particle generation during speech is also potentially important since some studies suggest that human influenza viruses attach more abundantly to the large airways of the upper respiratory tract than to

the bronchiolar and alveolar cells in the lower respiratory tract, while MERS-CoV and avian influenza viruses mainly cause lower respiratory tract infections due to the greater presence of these virus receptors deeper within the lung[44–47]; likewise there is evidence that laryngeal tuberculosis is potentially more contagious than typical pulmonary tuberculosis[48].

A second key epidemiological implication of our results is that simply talking in a loud voice would increase the rate at which an infected individual releases pathogen-laden particles into the air, which in turn would increase the probability of transmission to susceptible individuals nearby[18]. For example, an airborne infectious disease might spread more efficiently in a school cafeteria than a library, or in a noisy hospital waiting room than a quiet ward. Moreover, our data suggest a related hypothesis, that infected individuals could be transmitting significant numbers of respiratory pathogens via speech in the absence of overt clinical signs of illness like coughing or sneezing. More research is needed; however, the presence of asymptomatic or paucisymptomatic superspreaders would have important public health implications in the surveillance for and mitigation of infectious disease epidemics that are spread by airborne respiratory particles. The data presented here strongly suggest that further efforts to test these hypotheses are warranted.

Methods

Human subjects. The University of California Davis Institutional Review Board approved this study and all research was performed in accordance with relevant guidelines and regulations of the Institutional Review Board. We recruited 48 healthy volunteers (26 males and 22 females, ranging in age from 18 to 45 years old) by posting flyers at the University of California Davis campus over the time period May 2016 to March 2018. Informed consent was obtained from all participants prior to study participation. All participants completed a brief questionnaire including age, gender, weight, height, general health status, and smoking history. Only participants who self-reported as healthy non-smokers were included in the study. The subject in Supplementary Fig. S12 provided her written informed consent for the publication of identifying information/images in an online open-access publication.

Experimental set-up. A photograph of the experimental set-up is provided as Supplementary Fig. S12. An aerodynamic particle sizer (APS, TSI model 3321) operating at a total flow rate of 5 L/min (sheath flow rate $\cong$ 4 L/min, sample flow rate $\cong$ 1 L/min) was placed inside a HEPA filtered laminar flow hood that provided class 10 air. A plastic funnel (diameter = 10 cm) was connected to the APS sampling inlet via a conductive silicon tube (distance between funnel hole to APS inlet = 7.5 cm, tube inner diameter = 1.2 cm). During each experiment, participants sat at the laminar flow hood, in front of the APS, and spoke into the funnel. For the majority of speaking and breathing experiments, a nose rest across the funnel opening was used to position participants' mouths approximately 7.5 cm away from the funnel inlet (hole) and also to divert nasal exhalations away from the APS. During "nose-breathing" experiments, the nose rest was removed to allow nasal exhalations to be drawn into the APS. Note that participants' faces did not touch the funnel, so that air was free to move around the side of their faces; in this sense the cone was a semi-confined environment and not all expired particles were necessarily sampled by the APS. Also note that the sheath flow inside of an APS is filtered, so the particle emission rates sampled by the APS automatically remove 80% of the particles sampled from the funnel. Equivalent concentrations reported on the secondary axes in Figs 1 through 5 are determined from the raw particle counts using the sample flow rate, i.e., $C = \frac{\text{particles}}{5} \times \frac{5}{\text{cm}^3} = \frac{\text{particles}}{\text{cm}^3}$. Also note that the APS measures the size distribution of particles larger than 0.5 μm, but only detects the presence of particles between 0.37 μm and 0.5 μm without providing precise size measurements. For this reason Figs 1–5 exclude the counts of particles smaller than 0.5 μm; including them has little impact on the results since the vast majority of particles were larger than 0.5 microns.

A microphone (audio-technica PRO 37) and a decibel meter (Extech, 407760) were placed immediately on either side of the funnel to record the vocalizations. A computer screen with word prompts and a timer was placed behind the APS to guide participants in making requested vocalizations for the specified duration. The timing, duration, repetition, and order of vocalization and breathing experiments were coordinated by customized code written in LabVIEW (National Instruments). A digital hygrometer was used to measure the ambient temperature and relative humidity inside the laminar flow hood during all experiments. The participants were not allowed to drink or eat during the experiment, but they were free to rest between experiments for a few minutes as needed; data from each individual participant was gathered over an approximately 1-hour time period. We performed the experiments in an indoor (controlled) environment, so the ambient temperature varied only from approximately 20 to 25 °C, while the ambient relative humidity measured inside the laminar flow hood varied from a low of approximately 45% to a high of 80%. Control experiments indicate that the particle size distribution was independent of whether the particles were expired early or late during a sustained vocalization (Supplementary Fig. S3), indicating that transient fluctuations in the humidity inside the funnel due to exhalation had no impact on the final measured size distribution. Particles with initial diameter of less than 20 μm dry to approximately half of their initial diameter in less than 1 second[49,50]. Different correction factors have been suggested in the literature that one can use to estimate the initial size of the particles[49,51]; here we focus on the final size distribution because epidemiologically it is the final size distribution governs the deposition efficiency of the particles in the respiratory tract of nearby susceptible individuals[52].

Vocalization experiments. *"/ɑ/" experiments.* Participants (n = 10, 5 males, M1 to M5, and 5 females, F1 to F5) voiced /ɑ/ (the vowel sound in 'saw') for five seconds, followed by 15 seconds of nose breathing, repeated six times in succession. The participant repeated the series of six /ɑ/ vocalizations, to the best of the participant's ability, at the same amplitude. Each participant completed eight sets of /ɑ/ experiments, each set performed at different, self-regulated voice amplitude. Timed prompts with directions for the requested vocalization appeared on the computer screen, which displayed a timer and an amplitude (loudness) gauge to help the participants regulate their voice amplitude. The requested amplitudes were presented to participants in a random order.

"Rainbow passage" experiments. Participants (n = 10, 5 males, M1 to M5, and 5 females, F1 to F5) read aloud a 330-word excerpt of text in English, known in linguistics research as the Rainbow passage[51]. Participants were asked to read the Rainbow passage aloud three times, at a comfortable pace, over approximately 2 minutes per reading. Each of the three readings was performed at a different self-regulated amplitude: quiet, intermediate, and loud. Quiet was defined for participants as "just louder than a whisper," intermediate as a "normal conversational voice," and loud as "giving a loud lecture".

"The Little Prince" experiments. Bilingual participants (n = 30) fluent in both English and either Spanish (n = 10, 5 males, M6 to M10, and 5 females, F6 to F10), Mandarin (n = 10, 5 males, M11 to M15, and 5 females, F11 to F15), or Arabic (n = 10, 6 males, M16 to M21, and 4 females, F16 to F19) read Chapter 24 of "The Little Prince[51]" aloud six times, three times in English translation, each time at a different amplitude (quiet, intermediate, and loud) and three times in their respective language, again at three loudness levels.

Breathing/speaking experiments. Participants (n = 10, 6 males, M5 and M22 to M26, and 4 females, F4 and F20 to F22) alternated four silent breathing patterns with vocalized speech at three amplitudes. For breathing measurements, the breathing patterns were designated as "nose" (both inhalation and exhalation through the nose), "mouth" (both inhalation and exhalation through the mouth), "deep-fast" (deep, slow inhalation for ~3 seconds through the nose, holding it for ~1 second, followed by fast exhalation through the mouth (~1 second)), and "fast-deep" (rapid inhalation through the nose (~1 second), holding it for ~1 second, followed by slow exhalation through the mouth for ~3 seconds). Each breathing experiment was performed over 2 minutes, and at a comfortable pace for the participants. Between performing different breathing patterns, participants were asked to read the Rainbow passage in a "quiet," "intermediate," or "loud" voice, as prompted by the computer in random order.

Statistical analysis. Data analysis was performed in MATLAB (MathWorks), with data fits performed as noted in figure legends. Pearson's linear correlation coefficients and p values were calculated for linear fits. Lognormal fits were made via nonlinear regression, and median, mean, and standard deviation were calculated. Box-and-whisker plots show the median (red line), interquartile range (blue box), and range (black whiskers). To analyze the breathing/speaking experiments data presented in Fig. 5, Stata/SE 15.1 was used to perform general linear mixed model (GLMM) analysis to account for person-level correlations, and post hoc pairwise comparisons were performed and adjusted for multiple comparisons using Scheffe's method.

Data Availability

All relevant data are available from the corresponding authors upon request.

References

1. Tellier, R. Review of aerosol transmission of influenza A virus. *Emerg. Infect. Dis* **12**, 1657–1662, https://doi.org/10.3201/eid1211.060426 (2006).
2. Weber, T. P. & Stilianakis, N. I. Inactivation of influenza A viruses in the environment and modes of transmission: A critical review. *Journal of Infection* **57**, 361–373, https://doi.org/10.1016/j.jinf.2008.08.013 (2008).
3. Tellier, R. Aerosol transmission of influenza A virus: a review of new studies. *Journal of the Royal Society Interface* **6**, S783–S790, https://doi.org/10.1098/rsif.2009.0302.focus (2009).
4. Gralton, J., Tovey, E., McLaws, M. L. & Rawlinson, W. D. The role of particle size in aerosolised pathogen transmission: a review. *Journal of Infection* **62**, 1–13, https://doi.org/10.1016/j.jinf.2010.11.010 (2011).
5. Tang, J. W. Investigating the airborne transmission pathway - different approaches with the same objectives. *Indoor Air* **25**, 119–124, https://doi.org/10.1111/ina.12175 (2015).
6. Wei, J. J. & Li, Y. G. Airborne spread of infectious agents in the indoor environment. *Am. J. Infect. Control* **44**, S102–S108, https://doi.org/10.1016/j.ajic.2016.06.003 (2016).
7. Yang, S. H., Lee, G. W. M., Chen, C. M., Wu, C. C. & Yu, K. P. The size and concentration of droplets generated by coughing in human subjects. *Journal of Aerosol Medicine-Deposition Clearance and Effects in the Lung* **20**, 484–494, https://doi.org/10.1089/jam.2007.0610 (2007).
8. Lindsley, W. G. *et al.* Quantity and size distribution of cough-generated aerosol particles produced by influenza patients during and after illness. *Journal of Occupational and Environmental Hygiene* **9**, 443–449, https://doi.org/10.1080/15459624.2012.684582 (2012).
9. Lindsley, W. G., Reynolds, J. S., Szalajda, J. V., Noti, J. D. & Beezhold, D. H. A cough aerosol simulator for the study of disease transmission by human cough-generated aerosols. *Aerosol Sci. Technol.* **47**, 937–944, https://doi.org/10.1080/02786826.2013.803019 (2013).
10. Lindsley, W. G. *et al.* Viable influenza A virus in airborne particles expelled during coughs versus exhalations. Influenza and Other Respiratory. *Viruses* **10**, 404–413, https://doi.org/10.1111/irv.12390 (2016).
11. Bourouiba, L., Dehandschoewercker, E. & Bush, J. W. M. Violent expiratory events: on coughing and sneezing. *Journal of Fluid Mechanics* **745**, 537–563, https://doi.org/10.1017/jfm.2014.88 (2014).
12. Zayas, G. *et al.* Cough aerosol in healthy participants: fundamental knowledge to optimize droplet-spread infectious respiratory disease management. *Bmc Pulmonary Medicine* **12**, https://doi.org/10.1186/1471-2466-12-11 (2012).
13. Scharfman, B. E., Techet, A. H., Bush, J. W. M. & Bourouiba, L. Visualization of sneeze ejecta: steps of fluid fragmentation leading to respiratory droplets. *Experiments in Fluids* **57**, 9, https://doi.org/10.1007/s00348-015-2078-4 (2016).
14. Han, Z. Y., Weng, W. G. & Huang, Q. Y. Characterizations of particle size distribution of the droplets exhaled by sneeze. *Journal of the Royal Society Interface* **10**, 1–11, https://doi.org/10.1098/rsif.2013.0560 (2013).
15. Edwards, D. A. *et al.* Inhaling to mitigate exhaled bioaerosols. *Proceedings of the National Academy of Sciences of the United States of America* **101**, 17383–17388, https://doi.org/10.1073/pnas.0408159101 (2004).
16. Papineni, R. S. & Rosenthal, F. S. The size distribution of droplets in the exhaled breath of healthy human subjects. *Journal of Aerosol Medicine and Pulmonary Drug Delivery* **10**, 105–116, https://doi.org/10.1089/jam.1997.10.105 (1997).
17. Fabian, P. *et al.* Influenza virus in human exhaled breath: an observational study. *Plos One* **3**, https://doi.org/10.1371/journal.pone.0002691 (2008).
18. Duguid, J. P. The size and the duration of air-carriage of respiratory droplets and droplet-nuclei. *Journal of Hygiene* **44**, 471–479 (1946).
19. Loudon, R. G. & Roberts, R. M. Droplet expulsion from the respiratory tract. *American Review of Respiratory Disease* **95**, 435–442, https://doi.org/10.1164/arrd.1967.95.3.435 (1967).

20. Johnson, G. R. & Morawska, L. The mechanism of breath aerosol formation. *Journal of Aerosol Medicine and Pulmonary Drug Delivery* **22**, 229–237, https://doi.org/10.1089/jamp.2008.0720 (2009).
21. Johnson, G. R. *et al.* Modality of human expired aerosol size distributions. *Journal of Aerosol Science* **42**, 839–851, https://doi.org/10.1016/j.jaerosci.2011.07.009 (2011).
22. Liljeroos, L., Huiskonen, J. T., Ora, A., Susi, P. & Butcher, S. J. Electron cryotomography of measles virus reveals how matrix protein coats the ribonucleocapsid within intact virions. *Proceedings of the National Academy of Sciences of the United States of America* **108**, 18085–18090, https://doi.org/10.1073/pnas.1105770108 (2011).
23. Rossman, J. S. & Lamb, R. A. Influenza virus assembly and budding. *Virology* **411**, 229–236, https://doi.org/10.1016/j.virol.2010.12.003 (2011).
24. Fennelly, K. P. *et al.* Variability of infectious aerosols produced during coughing by patients with pulmonary tuberculosis. *American Journal of Respiratory and Critical Care Medicine* **186**, 450–457, https://doi.org/10.1164/rccm.201203-0444OC (2012).
25. Yan, J. *et al.* Infectious virus in exhaled breath of symptomatic seasonal influenza cases from a college community. *Proceedings of the National Academy of Sciences of the United States of America* **115**, 1081–1086, https://doi.org/10.1073/pnas.1716561115 (2018).
26. Shaman, J. & Kohn, M. Absolute humidity modulates influenza survival, transmission, and seasonality. *Proceedings of the National Academy of Sciences of the United States of America* **106**, 3243–3248, https://doi.org/10.1073/pnas.0806852106 (2009).
27. Loudon, R. G. & Roberts, M. R. Singing and the dissemination of tuberculosis. *American Review of Respiratory Disease* **98**, 297–300 (1968).
28. Chao, C. Y. H. *et al.* Characterization of expiration air jets and droplet size distributions immediately at the mouth opening. *Journal of Aerosol Science* **40**, 122–133, https://doi.org/10.1016/j.jaerosci.2008.10.003 (2009).
29. Morawska, L. *et al.* Size distribution and sites of origin of droplets expelled from the human respiratory tract during expiratory activities. *Journal of Aerosol Science* **40**, 256–269, https://doi.org/10.1016/j.jaerosci.2008.11.002 (2009).
30. Xie, X. J., Li, Y. G., Sun, H. Q. & Liu, L. Exhaled droplets due to talking and coughing. *Journal of the Royal Society Interface* **6**, S703–S714, https://doi.org/10.1098/rsif.2009.0388.focus (2009).
31. Lloyd-Smith, J. O., Schreiber, S. J., Kopp, P. E. & Getz, W. M. Superspreading and the effect of individual variation on disease emergence. *Nature* **438**, 355–359, https://doi.org/10.1038/nature04153 (2005).
32. Gramming, P., Sundberg, J., Ternström, S., Leanderson, R. & Perkins, W. H. Relationship between changes in voice pitch and loudness. *Journal of Voice* **2**, 118–126, https://doi.org/10.1016/S0892-1997(88)80067-5 (1988).
33. Titze, I. R. Phonation threshold pressure: A missing link in glottal aerodynamics. *J. Acoust. Soc. Am.* **91**, 2926–2935, https://doi.org/10.1121/1.402928 (1992).
34. Titze, I. R. & Sundberg, J. Vocal intensity in speakers and singers. *J. Acoust. Soc. Am.* **91**, 2936–2946, https://doi.org/10.1121/1.402929 (1992).
35. Gupta, J. K., Lin, C. H. & Chen, Q. Y. Characterizing exhaled airflow from breathing and talking. *Indoor Air* **20**, 31–39, https://doi.org/10.1111/j.1600-0668.2009.00623.x (2010).
36. Xi, J. X. & Longest, P. W. Characterization of submicrometer aerosol deposition in extrathoracic airways during nasal exhalation. *Aerosol Sci. Technol.* **43**, 808–827, https://doi.org/10.1080/02786820902950887 (2009).
37. Eggers, J. Nonlinear dynamics and breakup of free-surface flows. *Reviews of Modern Physics* **69**, 865–929, https://doi.org/10.1103/RevModPhys.69.865 (1997).
38. Girod, S., Zahm, J. M., Plotkowski, C., Beck, G. & Puchelle, E. Role of the physiochemical properties of mucus in the protection of the respiratory epithelium. *European Respiratory Journal* **5**, 477–487 (1992).
39. Inouye, S. SARS transmission: language and droplet production. *Lancet* **362**, 170–170, https://doi.org/10.1016/s0140-6736(03)13874-3 (2003).
40. Wong, G. *et al.* MERS, SARS, and Ebola: The role of super-spreaders in infectious disease. *Cell Host & Microbe* **18**, 398–401, https://doi.org/10.1016/j.chom.2015.09.013 (2015).
41. Lau, M. S. Y. *et al.* Spatial and temporal dynamics of superspreading events in the 2014–2015 West Africa Ebola epidemic. *Proceedings of the National Academy of Sciences of the United States of America* **114**, 2337–2342, https://doi.org/10.1073/pnas.1614595114 (2017).
42. Stein, R. A. Super-spreaders in infectious diseases. *International Journal of Infectious Diseases* **15**, E510–E513, https://doi.org/10.1016/j.ijid.2010.06.020 (2011).
43. Chun, B. C. Understanding and modeling the super-spreading events of the Middle East respiratory syndrome outbreak in Korea. *Infection and Chemotherapy* **48**, 147–149, https://doi.org/10.3947/ic.2016.48.2.147 (2016).
44. van Riel, D. *et al.* Seasonal and pandemic human influenza viruses attach better to human upper respiratory tract epithelium than avian influenza viruses. *American Journal of Pathology* **176**, 1614–1618, https://doi.org/10.2353/ajpath.2010.090949 (2010).
45. van Riel, D. *et al.* Human and avian influenza viruses target different cells in the lower respiratory tract of humans and other mammals. *American Journal of Pathology* **171**, 1215–1223, https://doi.org/10.2353/ajpath.2007.070248 (2007).
46. Widagdo, W., Okba, N. M. A., Raj, V. S. & Haagmans, B. L. MERS-coronavirus: From discovery to intervention. *One Health* **3**, 11–16, https://doi.org/10.1016/j.onehlt.2016.12.001 (2017).
47. Shinya, K. *et al.* Influenza virus receptors in the human airway. *Nature* **440**, 435, https://doi.org/10.1038/440435a (2006).
48. Sepkowitz, K. A. How contagious is tuberculosis? *Clinical Infectious Diseases* **23**, 954–962, https://doi.org/10.1093/clinids/23.5.954 (1996).
49. Nicas, M., Nazaroff, W. W. & Hubbard, A. Toward understanding the risk of secondary airborne infection: Emission of respirable pathogens. *Journal of Occupational and Environmental Hygiene* **2**, 143–154, https://doi.org/10.1080/15459620590918466 (2005).
50. Xie, X., Li, Y., Chwang, A. T. Y., Ho, P. L. & Seto, W. H. How far droplets can move in indoor environments – revisiting the Wells evaporation-falling curve. *Indoor Air* **17**, 211–225, https://doi.org/10.1111/j.1600-0668.2006.00469.x (2007).
51. Liu, L., Wei, J., Li, Y. & Ooi, A. Evaporation and dispersion of respiratory droplets from coughing. *Indoor Air* **27**, 179–190, https://doi.org/10.1111/ina.12297 (2017).
52. Heyder, J., Gebhart, J., Rudolf, G., Schiller, C. F. & Stahlhofen, W. Deposition of particles in the human respiratory tract in the size range 0.005–15 MU-M. *Journal of Aerosol Science* **17**, 811–825, https://doi.org/10.1016/0021-8502(86)90035-2 (1986).
53. Fairbanks, G. *Voice and articulation drillbook*. (Harper, 1960).
54. Saint-Exupêry, A. Le Petit Prince, trans Woods K (Harcourt, Brace & World, New York) 1st ed., Chapter 24 (1943).

Acknowledgements

We thank the National Institute of Allergy and Infectious Diseases of the National Institutes of Health (NIAID/NIH), grant R01 AI110703, and the NIEHS UC Davis Core Centre, grant P30-ES023513, for supporting this research, and P. Dayal for assistance with statistical analysis.

Author Contributions

S.A., A.S.W., C.D.C., S. B., N.M.B. and W.D.R. designed research; S.A. performed experiments; S.A. and W.D.R. analysed the data; S.A. and W.D.R. wrote the manuscript, and all co-authors reviewed the manuscript.

Additional Information

Supplementary information accompanies this paper at https://doi.org/10.1038/s41598-019-38808-z.

Competing Interests: The authors declare no competing interests.

Publisher's note: Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

An analysis of SARS-CoV-2 viral load by patient age

Terry C. Jones[1,2], Barbara Mühlemann[1,3], Talitha Veith[1,3], Marta Zuchowski[1], Jörg Hofmann[4], Angela Stein[4], Anke Edelmann[4], Victor Max Corman[1,3], Christian Drosten[1,3]

Affiliations:

1: Institute of Virology, Charité-Universitätsmedizin Berlin, corporate member of Freie Universität Berlin, Humboldt-Universität zu Berlin, and Berlin Institute of Health, 10117 Berlin, Germany

2: Center for Pathogen Evolution, Department of Zoology, University of Cambridge, Downing St., Cambridge, CB2 3EJ, U.K.

3: German Centre for Infection Research (DZIF), partner site Charité, 10117 Berlin, Germany

4: Labor Berlin - Charité Vivantes GmbH, Sylter Straße 2, 13353 Berlin, Germany

Address for correspondence:

Professor Christian Drosten
Charité - Universitätsmedizin Berlin
Campus Charité Mitte
Chariteplatz 1
D-10117 Berlin
Germany
E-Mail: christian.drosten@charite.de

Revision history:

30/4/2020, 6pm

Table 1: We added a column with the percentage of positively tested individuals with a viral load higher than one million viral copies and changed the table legend accordingly. We also made changes to the formatting of table A1.

Discussion, paragraph 2: In the second paragraph of the discussion, we changed the sentence *"An estimate based on the number of symptomatic admissions in a specialist pediatric hospital assumes that thousands of pediatric cases were missed during the early phase of the Wuhan outbreak, at a time at which only ca. 10,0000 adult patients were registered (13)."* to *"Further, an estimate based on the number of symptomatic admissions in a specialist pediatric hospital suggested approximately 1105 (95% CI: 592-1829) cumulative pediatric COVID-19 hospitalizations prior to the lockdown in Wuhan starting January 23rd, at which point only 425 confirmed cases had been reported across all age groups, none of which were under age 15 (13)."*

Abstract

Data on viral load, as estimated by real-time RT-PCR threshold cycle values from 3,712 COVID-19 patients were analysed to examine the relationship between patient age and SARS-CoV-2 viral load. Analysis of variance of viral loads in patients of different age categories found no significant difference between any pair of age categories including children. In particular, these data indicate that viral loads in the very young do not differ significantly from those of adults. Based on these results, we have to caution against an unlimited re-opening of schools and kindergartens in the present situation. Children may be as infectious as adults.

Introduction

The present measures to curb the spread of SARS-CoV-2 by non-pharmaceutical interventions are beginning to show effects in many countries. Along with the gradual lifting of measures of physical distancing, there is a growing discussion regarding the contribution of school- and kindergarten closures to the reduction of transmission rate (*1*) and to the expected rebound upon reopening. Studies to determine the contribution of children as sources of infection are complicated by the fact that non-pharmaceutical interventions including school- and kindergarten closures were in place before observational trials could begin. A household study in China and observations in a limited number of contact investigations in Germany suggest that children are infected by SARS-CoV-2 at a rate that may not be different from that of adults (*2*, *3*). However, the extent to which children can act as sources of infection remains unclear. A challenge when trying to address this question by epidemiological observation is posed by the present situation of physical distancing. Because kindergartens and schools are closed, it becomes less likely that children become index cases in households. During the early phase of the SARS-CoV-2 epidemic in many European countries, the seeding of cases by adult-aged travelers who visited early epidemic foci was an additional reason why children were under-represented in age-related incidence (*4*). It is therefore unlikely that epidemiological investigations undertaken under the present conditions can identify the actual risk of acquisition of infection from children by subjects of any age group.

An alternative way to achieve a correlate of infectivity is to directly analyze the virus concentration in the respiratory tract. We have previously shown that viral loads under a concentration of ca. 10^6 copies per mL of sputum or per entire throat swab are unlikely to yield infectious virus growth in cell culture (*5*). We also found that virus could not be isolated from respiratory samples after the first week of symptoms, which is highly concordant with transmission analyses based on actual transmission pairs, suggesting that infectivity ends by the end of the first week of symptoms (*6*). To enable an estimate of infectivity in children, we analyzed viral loads observed during routine testing at a large laboratory testing centre in Berlin (Charité Institute of Virology and Labor Berlin). Charité Institute of Virology was the first laboratory qualified to test for SARS-CoV-2 in Germany and until early February 2020 was the only SARS-CoV-2 testing facility in Berlin, a city of ca. 3.8 million inhabitants. Labor Berlin is a

large medical laboratory services provider in Berlin, owned by the senate of Berlin and serving Charité as well as other large hospitals in Berlin and beyond. Labor Berlin serves public testing centres that mainly see adult outpatients. It also tests out- and inpatients from several hospitals, and serves practitioners and public health agencies submitting samples taken during household-based contact tracing.

Results

From January to 26th April, 2020, virology laboratories at Charité and Labor Berlin screened 59,831 patients for COVID-19 infection, 3,712 (6.2%) with a positive real-time RT-PCR result. We divided patients according to two categorizations to investigate whether there is a relationship between patient age and viral load. The first categorization is based on ten-year brackets, ages 1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90, and 91-100. The second categorization is based on broad social strata: kindergarten (ages 0-6), grade school (ages 7-11), high school (ages 12-19), university (ages 20-25), adult (26-45 years), and mature (age over 45). Patient counts in each age group, and number and percentage of PCR positive patients are shown in **Table 1**. A comparison of age stratification in tested cases versus the Berlin population is shown in **Figure A1.** Of note, whereas younger age groups have lower detection rates (**Table 1**), this does not imply an age-based estimate of infection prevalence because of mostly symptoms-directed testing.

Due to the small sample sizes in the pediatric age groups, we examined diagnostic indications for 47 cases (1-11 years of age) for whom this information was available. Fifteen cases had indications pointing toward underlying disease or hospitalization. Average viral loads in these cases were lower than in children tested in outpatient departments, practices, or households **(Figure A2)**. This corresponds to the observation that hospitalization occurs after some days of symptoms, a time when viral loads in throat swabs are beginning to decline (*5*).

Viral load

The distribution of observed viral loads in a total of 3,712 cases are shown in **Figure 1**. The viral loads are not normally distributed but are skewed towards a mean (logarithm base 10) value of 5.19 (i.e., $10^{5.19}$ viral copies) per sample, with a median of 4.80, corresponding to threshold cycle (Ct) values of 30.01 and 31.23, respectively. The sharp drop on the left side of the distribution is due to the assay sensitivity limit. The viral load projection derived in our study is semi-quantitative, and projects viral load per mL of sputum or per entire swab sample, while only a fraction of the volume of both types of sample can actually reach the test tube. Also, quantification is based on a standard preparation tested once in multiple diluted replicates to generate a standard curve and derive a formula upon which Ct values are transformed into viral loads. This approach does not reflect inter-run variability or the variability between different RT-PCR setups and chemistries. However, these variabilities apply to all age groups and do not affect the interpretation of data for the purpose of the present study.

Analysis of variation in viral load between age groups

Viral loads are plotted according to categorization in **Figure 2** with per-group descriptive statistics shown in **Table 2**. Two key prior conditions for an analysis of variance are a) that the dependent variable is approximately normally distributed within each category and b) that the variance within each category is approximately equal. A Shapiro test for normal distribution in the first categorization (C1) has a value of 0.96 (p value 2.71^{-31}), and in the second categorization (C2) a value of 0.96 (p value 8.56^{-32}) (**Table A1**), strongly indicating that the $\log_{10}$ viral load numbers in both categories are not normally distributed, as is clear from **Figures A3** and **A4**. Regarding equality of variance, Levene's statistic (*7*) (using median values) in categorization C1 has value 1.80 (p value 0.063) while in categorization C2, the same statistic has value 2.30 (p value 0.042) (**Table A2**). Thus in C2 there is evidence that the viral load variance between the categories cannot be considered approximately equal. Given these results, we used the non-parametric Kruskal-Wallis H test (*8*), since it does not have pre-conditions of normality or equality of variance. The Kruskal-Wallis H statistic had value 22.39 (p value 0.008) for C1 and 14.97 (p value 0.011) for C2 (**Table A3**). Although the significant Kruskal-Wallis test indicates at least one significant pairwise difference exists between subgroups in both categorizations, due care must be exercised in the post hoc interpretation due to the influence of highly skewed distributions.

We performed pairwise post hoc analyses on both categorizations using three methods: the Tukey honestly significant difference (HSD) test (*9*) (**Table A4**), Bonferroni-adjusted pairwise T-test (*10*) (**Table A5**), and Dunn's test (**Table A6**) (*11*). For categorization C1, none of the three post hoc methods indicated a significant difference between any pair of the ten subgroups. For categorization C2 the situation was identical, apart from Dunn's test indicating a difference (p value 0.045) between the very youngest (kindergarten) and very oldest (Mature) subgroups. Thus the overwhelming conclusion from the three post hoc testing methods is that no significant differences in viral load exists between any subgroups in either categorization.

Discussion

Because of difficulties in conducting observational trials to investigate the infectivity of children as opposed to other age groups with SARS-CoV-2 infection, in this short study we attempt the provision of a direct measure of virus concentration from which one can extrapolate to infectivity.

Whereas the attack rate in children seems to correspond to that in adults (*2*), it is obvious that children are under-represented in clinical studies and less frequently diagnosed due to mild or absent symptoms. For instance, a recent systematic review identified only 1,065 pediatric SARS-CoV-2 cases in the medical literature as of April 2020 (*12*). Further, an estimate based on the number of symptomatic admissions in a specialist pediatric hospital suggested approximately 1105 (95% CI: 592-1829) cumulative pediatric COVID-19 hospitalizations prior to the

lockdown in Wuhan starting January 23rd, at which point only 425 confirmed cases had been reported across all age groups, none of which were under age 15 (*13*). Because they are mostly asymptomatic, children may not be presented at testing centers even if they belong to households with a confirmed index case. There are many other factors that complicate the determination of infection rates in, and transmission rates from children. For instance, the age profile during the early phase of the outbreak in many European countries makes it difficult to derive transmission rates from household contact studies. Early transmission clusters were started by travellers of adult age, making children less likely to be index cases in households (*4*). Another circumstance making children less likely to carry the virus into households is that kindergartens and schools were closed early in the outbreak in Germany. These combined effects will cause children to be more likely to receive rather than spread infections in households for purely circumstantial reasons. This observation may be misunderstood as an indication of children being less infectious. The determination of viral loads seems to provide an interesting means to achieve an indirect but robust estimate of infectivity in the present epidemiological circumstances. The correlation of RNA-based viral load in the respiratory tract with infectivity, as measured in cell culture, has been established (*5*, *14*).
In our study, the virus detection rate increased steadily with age of patients tested. As testing was predominantly directed by symptoms, this suggests that children with respiratory symptoms and fever are less likely than adults to suffer from acute SARS-CoV-2 infection. Many other respiratory viruses cause symptomatic disease in children, but less so in adults where endemic respiratory viruses often present as mild upper respiratory tract infection without fever. Our results should clearly not be taken as an indicator of age-specific prevalence in Germany. Rather, the low rate of SARS-CoV-2 detection in the tested children suggests that symptoms are not a good predictor of infection. At the same time, the absence of symptoms does not imply absence of virus excretion. In a study of people living in the Italian village of Vó, in which ca. 80% of the population were tested by RT-PCR twice within two weeks, about half the population were found to be asymptomatically infected, showing no symptoms over the observation period of two weeks, while viral loads were equivalent in symptomatic and asymptomatic patients (*15*).

It is a limitation that we have not generally discriminated the studied patients into sub-cohorts based on symptomatic status, underlying diseases, or other indications for diagnostic test application. At least for the children in the present study, we can say that hospitalized children with underlying disease were not found to have higher viral loads than children without known underlying disease tested in outpatient departments, practices, or households. The latter would represent children attending schools and kindergartens.

The viral loads observed in the present study, combined with earlier findings of similar attack rate between children and adults (*2*), suggest that transmission potential in schools and kindergartens should be evaluated using the same assumptions of infectivity as for adults. There are reasons to argue against the notion of adult-like infectivity in children, such as the fact that asymptomatic children do not spread the virus by coughing, and have smaller exhaled air volume than adults. However, there are other arguments that speak in favour of transmission, such as the greater physical activity and closer social engagement of children. We recommend

collecting and evaluating more viral load data from testing laboratories to achieve more robust statistical assessments and independent confirmation of the present results. Based on the absence of any statistical evidence for a different viral load profile in children found in the present study, we have to caution against an unlimited re-opening of schools and kindergartens in the present situation, with a widely susceptible population and the necessity to keep transmission rates low via non-pharmaceutical interventions. Children may be as infectious as adults.

Acknowledgements

Work at Charité virology is funded by European Commission via project ReCoVer, the German Ministry of Research and Education via Deutsches Zentrum für Infektionsforschung, and the German Ministry of Health via the Konsiliarlabor für Coronaviren.

Categorization C1				
Group	**Count**	**+ve**	**% +ve**	**% +ve load >1M**
1-10	2,181	49	2.25	0.50
11-20	1,991	78	3.92	1.05
21-30	9,710	536	5.52	1.87
31-40	12,737	630	4.95	1.59
41-50	9,572	575	6.01	1.59
51-60	10,586	662	6.25	2.08
61-70	5,529	431	7.80	2.66
71-80	4,064	420	10.33	3.03
81-90	3,302	314	9.51	3.30
91-100	159	17	10.69	5.03

Categorization C2				
Group	**Count**	**+ve**	**% +ve**	**% +ve load >1M**
KG	1,759	37	2.10	0.40
GS	623	16	2.57	0.80
HS	1,790	74	4.13	1.12
Uni	4,587	267	5.82	2.05
Adult	23,665	1,247	5.27	1.63
Mature	27,407	2,071	7.56	2.42

Table 1: Categorization breakdown and positive PCR counts and percentages. The 'Count' column in each categorization gives the total number of patients tested. '+ve' indicates a total number of positive RT-PCR results for the subgroup. '% +ve load >1M' indicates the percentage of positively tested individuals with over one million viral copies. KG: kindergarten; GS: grade school; HS: high school; Uni: University, +ve: positive.

A) Category C1	N	Mean	SD	SE	95% Conf.	Interval
1	49	4.637858	1.826493	0.260928	4.121141	5.154576
2	78	4.798684	1.790027	0.202681	4.398859	5.198509
3	536	5.261825	1.93962	0.083779	5.097465	5.426185
4	630	5.213623	2.020657	0.080505	5.055708	5.371538
5	575	4.985018	1.87101	0.078027	4.831953	5.138083
6	662	5.258317	1.905385	0.074055	5.11306	5.403575
7	431	5.278967	1.872932	0.090216	5.101938	5.455996
8	420	5.174407	1.78352	0.087027	5.003631	5.345183
9	314	5.344452	1.899481	0.107194	5.134016	5.554887
10	17	5.609229	2.047993	0.496711	4.605712	6.612745
B) Category C2	**N**	**Mean**	**SD**	**SE**	**95% Conf.**	**Interval**
Adult	1247	5.15923	1.970687	0.055806	5.049806	5.268655
GS	16	5.364652	2.214843	0.553711	4.243786	6.485517
HS	74	4.783514	1.776356	0.206497	4.376017	5.191012
KG	37	4.371295	1.601139	0.263226	3.848256	4.894334
Mature	2071	5.229369	1.867447	0.041035	5.148921	5.309818
Uni	267	5.283627	1.946236	0.119108	5.049738	5.517517

Table 2: Statistics describing the viral load distributions in C1 and C2. The mean, standard deviation (SD), standard error (SE), 95% Confidence Interval (95% Conf.), and the interval are shown for the base-10 logarithm of viral load for **A)** categorization C1 (by age class), and **B)** categorization C2 (by schooling/social). KG: kindergarten; GS: grade school; HS: high school; Uni: University.

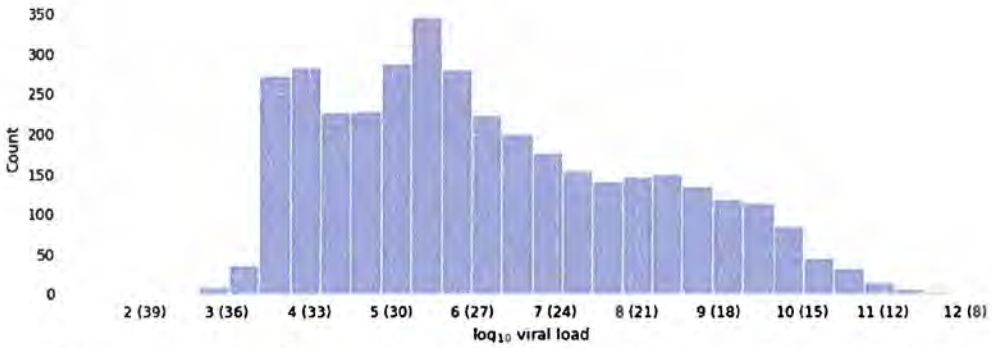


Figure 1: Histogram of viral loads: The plot shows the frequency distribution of 3,712 values of patient SARS-CoV-2 (logarithm base 10) viral load, estimated from real-time RT-PCR Ct values. The RT-PCR cycle corresponding to the logarithmic viral load is given in parentheses. The sharp drop on the left side of the distribution is due to RT-PCR sensitivity and the limit on cycles.

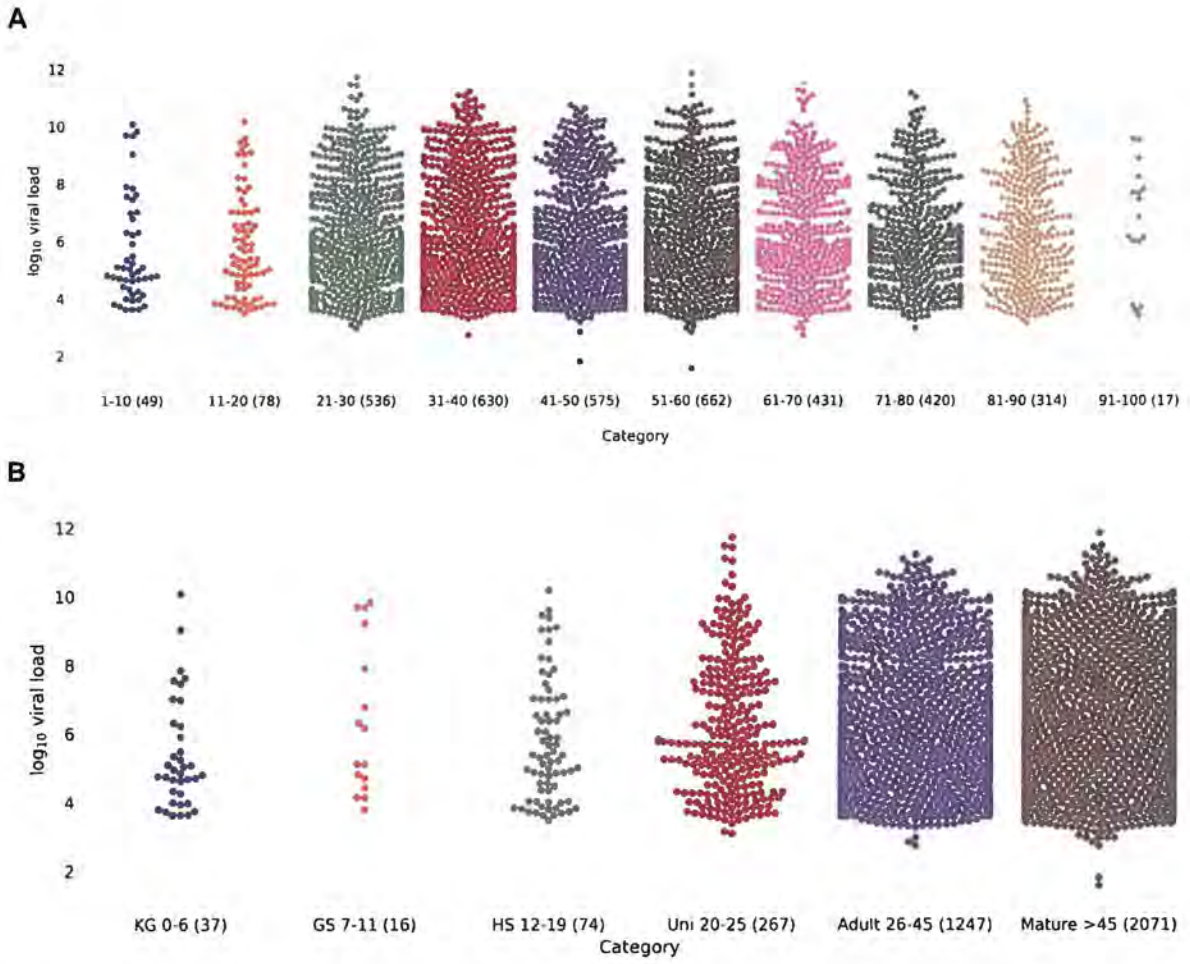


Figure 2: Viral load by patient category. A: categorization by 10-year age strata (C1): Patients were divided into categories based on age. The base 10 logarithm of viral load is estimated from the real-time PCR Ct value. Category counts are given in parentheses in the x-axis labels. **B: Categorization by schooling/social (C2):** Patients were divided into categories based schooling level, estimated on the basis of age. X-axis labels show the category (KG: kindergarten; GS: grade school; HS: high school; Uni: University), the age range in years, then the category count in parentheses.

Methods

Due to testing of some but not all positive cases by two RT-PCR targets, 3,712 of 59,831 (6.2%) patients had 5,285 positive results overall. In cases with more than one result, we selected the PCR result with the lowest Ct value. Results based on Light Cycler 480 PCR, as opposed to Roche 8800 or 6800, were chosen preferentially when results from more than one PCR system per patient was available (the latter systems were introduced in the laboratory during the observation period).

The following Python (version 3.8) software packages were used in the analysis and production of images: Scipy (version 1.4.1) (*16*), pandas (version 1.0.3) (*17*), researchpy (version 08/28/2018) (https://researchpy.readthedocs.io/en/latest/), statsmodels (version 0.11.1) (*18*), matplotlib (version 3.2.1) (*19*), numpy (1.18.3) (*20*), and seaborn (version 0.10.1) (*21*).

Viral load is estimated from Ct value based on the empirical formula $\log_{10}(8 * 10^{14} * e^{-0.745 * Ct})$. The formula is derived from testing a standard curve.

References

1. N. M. Ferguson, D. Laydon, G. Nedjati-Gilani, N. Imai, K. Ainslie, M. Baguelin, S. Bhatia, A. Boonyasiri, Z. Cucunubá, G. Cuomo-Dannenburg, A. Dighe, I. Dorigatti, H. Fu, K. Gaythorpe, W. Green, A. Hamlet, W. Hinsley, L. C. Okell, S. van Elsland, H. Thompson, R. Verity, E. Volz, H. Wang, Y. Wang, P. G. T. Walker, C. Walters, P. Winskill, C. Whittaker, C. A. Donnelly, S. Riley, A. C. Ghani, Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand (2020), (available at https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College-COVID19-NPI-modelling-16-03-2020.pdf).

2. Q. Bi, Y. Wu, S. Mei, C. Ye, X. Zou, Z. Zhang, X. Liu, L. Wei, S. A. Truelove, T. Zhang, W. Gao, C. Cheng, X. Tang, X. Wu, Y. Wu, B. Sun, S. Huang, Y. Sun, J. Zhang, T. Ma, J. Lessler, T. Feng, Epidemiology and transmission of COVID-19 in 391 cases and 1286 of their close contacts in Shenzhen, China: a retrospective cohort study. *The Lancet Infectious Diseases* (2020), , doi:10.1016/s1473-3099(20)30287-5.

3. M. M. Böhmer, U. Buchholz, V. M. Corman, M. Hoch, K. Katz, D. V. Marosevic, S. Böhm, T. Woudenberg, N. Ackermann, R. Konrad, U. Eberle, B. Treis, A. Dangel, K. Bengs, V. Fingerle, A. Berger, S. Hörmansdorfer, S. Ippisch, B. Wicklein, A. Grahl, K. Pörtner, N. Muller, N. Zeitlmann, T. Sonia Boender, W. Cai, A. Reich, M. an der Heiden, U. Rexroth, O. Hamouda, J. Schneider, T. Veith, B. Mühlemann, R. Wölfel, M. Antwerpen, M. Walter, U. Protzer, B. Liebl, W. Haas, A. Sing, C. Drosten, A. Zapf, Outbreak of COVID-19 in Germany Resulting from a Single Travel-Associated Primary Case. *SSRN Electronic Journal*, , doi:10.2139/ssrn.3551335.

4. D. F. Gudbjartsson, A. Helgason, H. Jonsson, O. T. Magnusson, P. Melsted, G. L. Norddahl, J. Saemundsdottir, A. Sigurdsson, P. Sulem, A. B. Agustsdottir, B. Eiriksdottir, R. Fridriksdottir, E. E. Gardarsdottir, G. Georgsson, O. S. Gretarsdottir, K. R. Gudmundsson, T. R. Gunnarsdottir, A. Gylfason, H. Holm, B. O. Jensson, A. Jonasdottir, F. Jonsson, K. S. Josefsdottir, T. Kristjansson, D. N. Magnusdottir, L. le Roux, G. Sigmundsdottir, G. Sveinbjornsson, K. E. Sveinsdottir, M. Sveinsdottir, E. A. Thorarensen, B. Thorbjornsson, A. Löve, G. Masson, I. Jonsdottir, A. D. Möller, T. Gudnason, K. G. Kristinsson, U. Thorsteinsdottir, K. Stefansson, Spread of SARS-CoV-2 in the Icelandic Population. *N. Engl. J. Med.* (2020), doi:10.1056/NEJMoa2006100.

5. R. Wölfel, V. M. Corman, W. Guggemos, M. Seilmaier, S. Zange, M. A. Müller, D.

Niemeyer, T. C. Jones, P. Vollmar, C. Rothe, M. Hoelscher, T. Bleicker, S. Brünink, J. Schneider, R. Ehmann, K. Zwirglmaier, C. Drosten, C. Wendtner, Virological assessment of hospitalized patients with COVID-2019. *Nature* (2020), doi:10.1038/s41586-020-2196-x.

6. X. He, E. H. Y. Lau, P. Wu, X. Deng, J. Wang, X. Hao, Y. C. Lau, J. Y. Wong, Y. Guan, X. Tan, X. Mo, Y. Chen, B. Liao, W. Chen, F. Hu, Q. Zhang, M. Zhong, Y. Wu, L. Zhao, F. Zhang, B. J. Cowling, F. Li, G. M. Leung, Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nat. Med.* (2020), doi:10.1038/s41591-020-0869-5.

7. C. R. Rao, I. Olkin, S. G. Ghurye, W. Hoeffding, W. G. Madow, H. B. Mann, Contributions to Probability and Statistics. Essays in Honor of Harold Hotelling. *Revue de l'Institut International de Statistique / Review of the International Statistical Institute*. **29** (1961), p. 83.

8. W. H. Kruskal, W. Allen Wallis, Use of Ranks in One-Criterion Variance Analysis. *Journal of the American Statistical Association*. **47** (1952), pp. 583–621.

9. J. W. Tukey, Comparing Individual Means in the Analysis of Variance. *Biometrics*. **5** (1949), p. 99.

10. O. J. Dunn, Estimation of the Means of Dependent Variables. *The Annals of Mathematical Statistics*. **29** (1958), pp. 1095–1111.

11. O. J. Dunn, Multiple Comparisons Using Rank Sums. *Technometrics*. **6** (1964), pp. 241–252.

12. R. Castagnoli, M. Votto, A. Licari, I. Brambilla, R. Bruno, S. Perlini, F. Rovida, F. Baldanti, G. L. Marseglia, Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Infection in Children and Adolescents: A Systematic Review. *JAMA Pediatr.* (2020), doi:10.1001/jamapediatrics.2020.1467.

13. Z. Du, C. Nugent, B. J. Cowling, L. A. Meyers, Hundreds of severe pediatric COVID-19 infections in Wuhan prior to the lockdown, , doi:10.1101/2020.03.16.20037176.

14. N. C. Institute, National Cancer Institute, Skilled Nursing Facility with Medicare Certification in Anticipation of Covered Skilled Care. *Definitions* (2020), , doi:10.32388/tgnx82.

15. E. Lavezzo, E. Franchin, C. Ciavarella, G. Cuomo-Dannenburg, L. Barzon, C. Del Vecchio, L. Rossi, R. Manganelli, A. Loregian, N. Navarin, D. Abate, M. Sciro, S. Merigliano, E. Decanale, M. C. Vanuzzo, F. Saluzzo, F. Onelia, M. Pacenti, S. Parisi, G. Carretta, D. Donato, L. Flor, S. Cocchio, G. Masi, A. Sperduti, L. Cattarino, R. Salvador, K. A. M. Gaythorpe, A. R. Brazzale, S. Toppo, M. Trevisan, V. Baldo, C. A. Donnelly, N. M. Ferguson, I. Dorigatti, A. Crisanti, Imperial College London COVID-19 Response Team, Suppression of COVID-19 outbreak in the municipality of Vo, Italy, , doi:10.1101/2020.04.17.20053157.

16. P. Virtanen, R. Gommers, T. E. Oliphant, M. Haberland, T. Reddy, D. Cournapeau, E. Burovski, P. Peterson, W. Weckesser, J. Bright, S. J. van der Walt, M. Brett, J. Wilson, K. J. Millman, N. Mayorov, A. R. J. Nelson, E. Jones, R. Kern, E. Larson, C. J. Carey, İ. Polat, Y. Feng, E. W. Moore, J. VanderPlas, D. Laxalde, J. Perktold, R. Cimrman, I. Henriksen, E. A.

Quintero, C. R. Harris, A. M. Archibald, A. H. Ribeiro, F. Pedregosa, P. van Mulbregt, SciPy 1.0 Contributors, SciPy 1.0: fundamental algorithms for scientific computing in Python. *Nat. Methods.* **17**, 261–272 (2020).

17. W. McKinney, Data Structures for Statistical Computing in Python. *Proceedings of the 9th Python in Science Conference* (2010), , doi:10.25080/majora-92bf1922-00a.

18. S. Seabold, J. Perktold, Statsmodels: Econometric and Statistical Modeling with Python. *Proceedings of the 9th Python in Science Conference* (2010), , doi:10.25080/majora-92bf1922-011.

19. J. D. Hunter, Matplotlib: A 2D Graphics Environment. *Computing in Science & Engineering.* **9** (2007), pp. 90–95.

20. T. Oliphant, *Guide to NumPy: 2nd Edition* (CreateSpace, 2015).

21. M. Waskom, O. Botvinnik, P. Hobson, J. B. Cole, Y. Halchenko, S. Hoyer, A. Miles, T. Augspurger, T. Yarkoni, T. Megies, L. P. Coelho, D. Wehner, cynddl, E. Ziegler, diego, Y. V. Zaytsev, T. Hoppe, S. Seabold, P. Cloud, M. Koskinen, K. Meyer, A. Qalieh, D. Allan, seaborn: v0.5.0 (November 2014) (2014), doi:10.5281/zenodo.12710.

Appendix

Categorization	Statistic	p value	Result
C1	0.959	2.713e-31	significant, not normally distributed
C2	0.957	8.563e-32	significant, not normally distributed

Table A1: Shapiro test for normal distribution.

Categorization	Statistic	p value	Result
C1	1.800	0.063	Not significant, equal variance
C2	2.302	0.042	Significant, unequal variance

Table A2: Levene's test for equality of variance.

Categorization	Statistic	p value	Result
C1	22.390	0.008	significant, a differing pair may exist
C2	14.969	0.010	significant, a differing pair may exist

Table A3: Kruskal-Wallis H test.

Categorization	Group 1	Group 2	Mean diff	p-adjusted	lower	upper	reject
C1	1	2	0.1608	0.9	-0.9385	1.2601	FALSE
	1	3	0.624	0.4633	-0.2761	1.524	FALSE
	1	4	0.5758	0.5617	-0.3186	1.4702	FALSE
	1	5	0.3472	0.9	-0.5503	1.2446	FALSE
	1	6	0.6205	0.4598	-0.2724	1.5133	FALSE
	1	7	0.6411	0.4379	-0.2681	1.5503	FALSE
	1	8	0.5365	0.6675	-0.3738	1.4469	FALSE
	1	9	0.7066	0.3171	-0.2197	1.6329	FALSE
	1	10	0.9714	0.7008	-0.7261	2.6689	FALSE

2	3	0.4631	0.5812	-0.2677	1.194	FALSE
2	4	0.4149	0.6989	-0.3089	1.1388	FALSE
2	5	0.1863	0.9	-0.5413	0.914	FALSE
2	6	0.4596	0.5755	-0.2623	1.1816	FALSE
2	7	0.4803	0.5549	-0.2618	1.2223	FALSE
2	8	0.3757	0.8309	-0.3678	1.1193	FALSE
2	9	0.5458	0.4159	-0.2172	1.3087	FALSE
2	10	0.8105	0.8371	-0.8036	2.4247	FALSE
3	4	-0.0482	0.9	-0.4026	0.3062	FALSE
3	5	-0.2768	0.314	-0.6389	0.0853	FALSE
3	6	-0.0035	0.9	-0.3539	0.3469	FALSE
3	7	0.0171	0.9	-0.373	0.4073	FALSE
3	8	-0.0874	0.9	-0.4804	0.3056	FALSE
3	9	0.0826	0.9	-0.3459	0.5112	FALSE
3	10	0.3474	0.9	-1.1382	1.833	FALSE
4	5	-0.2286	0.5354	-0.5764	0.1192	FALSE
4	6	0.0447	0.9	-0.291	0.3803	FALSE
4	7	0.0653	0.9	-0.3116	0.4423	FALSE
4	8	-0.0392	0.9	-0.4191	0.3407	FALSE
4	9	0.1308	0.9	-0.2858	0.5474	FALSE
4	10	0.3956	0.9	-1.0866	1.8778	FALSE
5	6	0.2733	0.2597	-0.0705	0.6171	FALSE
5	7	0.2939	0.313	-0.0903	0.6782	FALSE
5	8	0.1894	0.8622	-0.1977	0.5765	FALSE
5	9	0.3594	0.1781	-0.0637	0.7826	FALSE
5	10	0.6242	0.9	-0.8599	2.1083	FALSE
6	7	0.0206	0.9	-0.3526	0.3939	FALSE
6	8	-0.0839	0.9	-0.4601	0.2923	FALSE
6	9	0.0861	0.9	-0.3271	0.4994	FALSE
6	10	0.3509	0.9	-1.1304	1.8322	FALSE
7	8	-0.1046	0.9	-0.518	0.3089	FALSE
7	9	0.0655	0.9	-0.382	0.5129	FALSE

	7	10	0.3303	0.9	-1.1609	1.8215	FALSE
	8	9	0.17	0.9	-0.2799	0.6199	FALSE
	8	10	0.4348	0.9	-1.0571	1.9268	FALSE
	9	10	0.2648	0.9	-1.2369	1.7665	FALSE
C2	Adult	GS	0.2054	0.9	-1.1618	1.5726	FALSE
	Adult	HS	-0.3757	0.5574	-1.0259	0.2744	FALSE
	Adult	KG	-0.7879	0.1304	-1.6944	0.1186	FALSE
	Adult	Mature	0.0701	0.9	-0.1246	0.2649	FALSE
	Adult	Uni	0.1244	0.9	-0.242	0.4908	FALSE
	GS	HS	-0.5811	0.8701	-2.0793	0.917	FALSE
	GS	KG	-0.9934	0.503	-2.6193	0.6325	FALSE
	GS	Mature	-0.1353	0.9	-1.499	1.2285	FALSE
	GS	Uni	-0.081	0.9	-1.4796	1.3176	FALSE
	HS	KG	-0.4122	0.8885	-1.5063	0.6819	FALSE
	HS	Mature	0.4459	0.3561	-0.197	1.0887	FALSE
	HS	Uni	0.5001	0.3441	-0.2138	1.214	FALSE
	KG	Mature	0.8581	0.0728	-0.0432	1.7594	FALSE
	KG	Uni	0.9123	0.0701	-0.0409	1.8656	FALSE
	Mature	Uni	0.0543	0.9	-0.2991	0.4076	FALSE

Table A4: Tukey HSD post hoc analysis. No significant difference is found between any pair of subgroups in either of the two categorizations. KG: kindergarten; GS: grade school; HS: high school; Uni: University.

Categorization	Critical value	Result
C1	0.0011	No significant pairs
C2	0.0033	No significant pairs

Table A5: Bonferroni-adjusted pairwise post hoc T-tests. No significant difference is found between any pair of subgroups in either of the two categorizations.

	1	2	3	4	5	6	7	8	9	10
1	-1	1	0.588	1	1	0.499	0.425	0.829	0.301	1
2		-1	1	1	1	1	1	1	0.738	1
3			-1	1	0.589	1	1	1	1	1
4				-1	1	1	1	1	1	1
5					-1	0.322	0.335	1	0.216	1
6						-1	1	1	1	1
7							-1	1	1	1
8								-1	1	1
9									-1	1
10										-1

Table A6a: Dunn's post hoc test for categorization C1. No significant difference is found between any pair of subgroups in either of the two categorizations.

	Adult	GS	HS	KG	Mature	Uni
Adult	-1	1	0.996	0.128	0.847	1
GS		-1	1	0.847	1	1
HS			-1	1	0.455	0.549
KG				-1	0.045	0.056
Mature					-1	1
Uni						-1

Table A6b: Dunn's post hoc test for categorization C2. Just one inter-group comparison, Kindergarten vs Mature has a p value (0.045) less that the traditional 0.05 significance threshold. KG: kindergarten; GS: grade school; HS: high school; Uni: University.

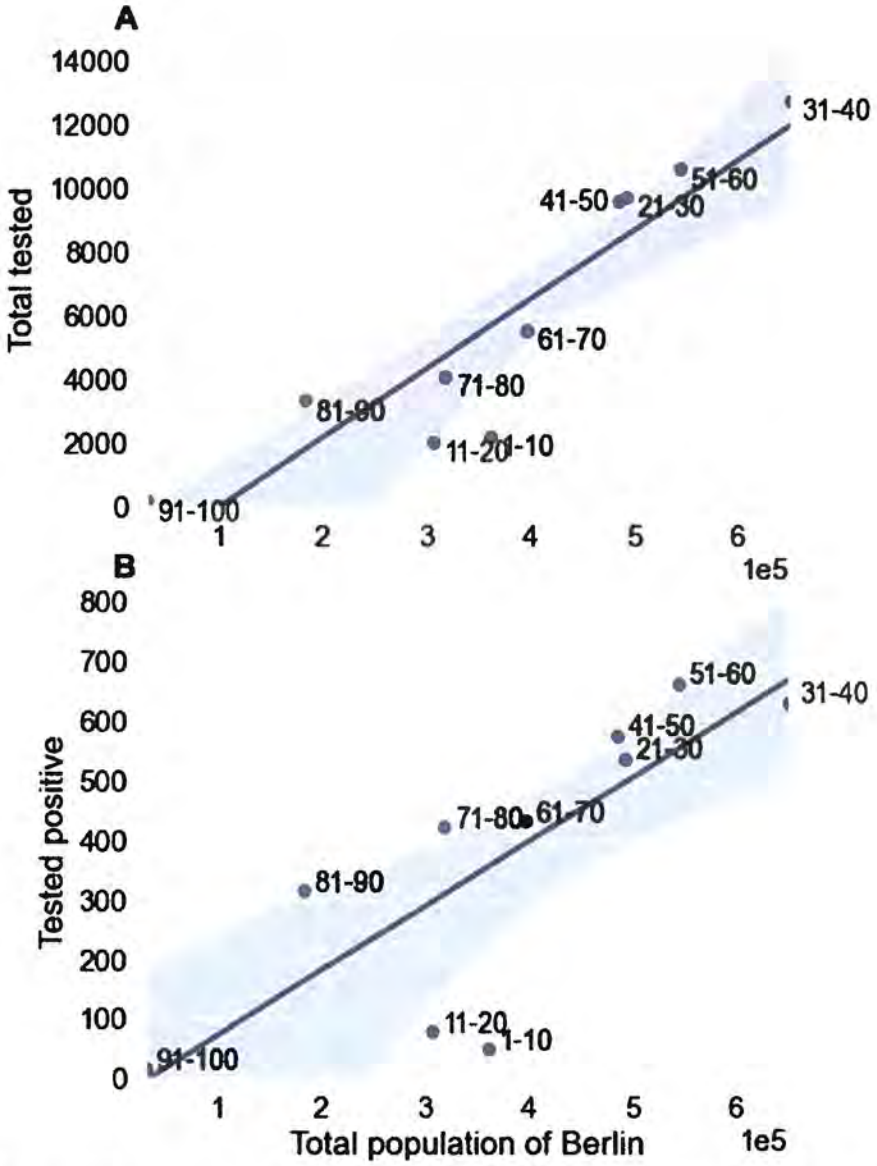


Figure A1: Positive age group counts versus population count. A) Total number of people tested for SARS-CoV-2 in each age group plotted against the total number of people in the corresponding age group in Berlin (acquired from Amt für Statistik Berlin-Brandenburg, https://www.statistik-berlin-brandenburg.de/, as of December 31, 2019). B) Number of people tested positive for SARS-CoV-2 plotted against the number of people in each age group in Berlin. Age categories 1-10 and 11-20 years have a relatively lower number of tested and positive cases. A linear regression is shown with the shaded area indicating the 95% confidence interval.

Figure A2: Differences in viral load in patients aged 1-11 years with and without a pre-existing condition. Wilcoxon rank-sum test indicates a significant difference between the two groups (p value 0.02).

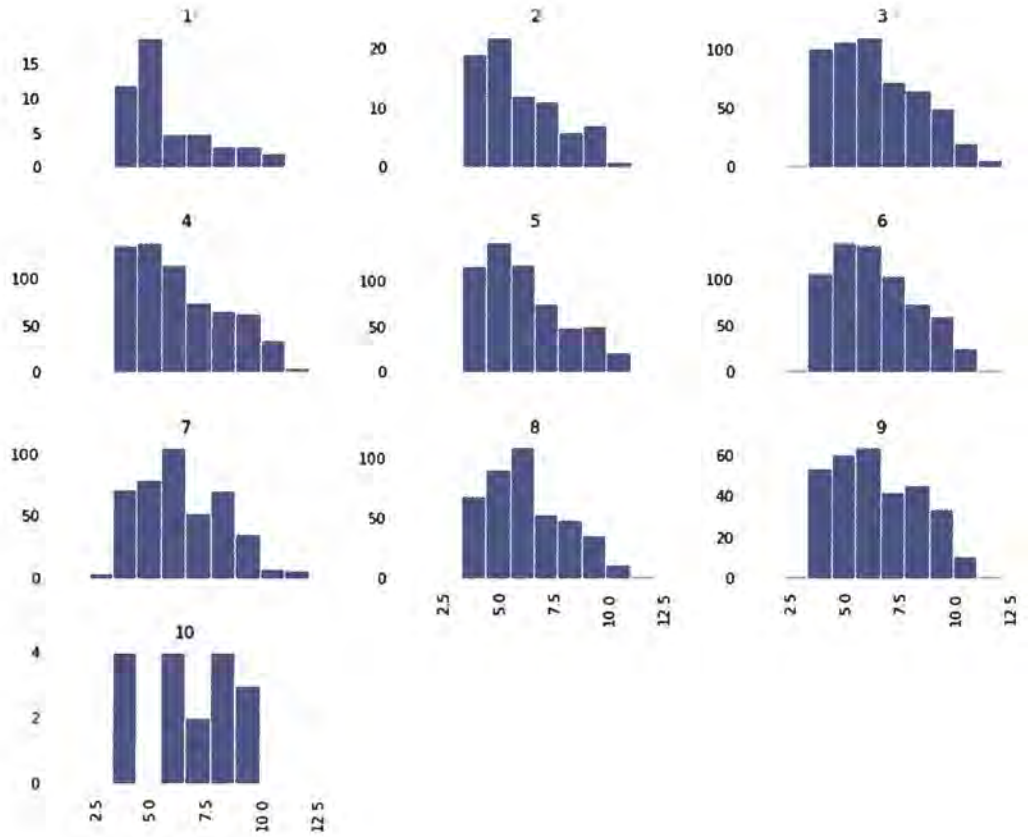


Figure A3: Per-group viral load histograms for categorization C1: The individual histograms for the ten groups of categorization C1 make it immediately clear that the underlying distribution of viral load for group 10 (91-100 years) is far from normal, and several other groups are clearly also not normally distributed. Note that the data above are also presented in Figure 2A, although there presented with viral load on the y-axis, with the distribution spreading horizontally in two directions, with added jitter for the spread visualization.

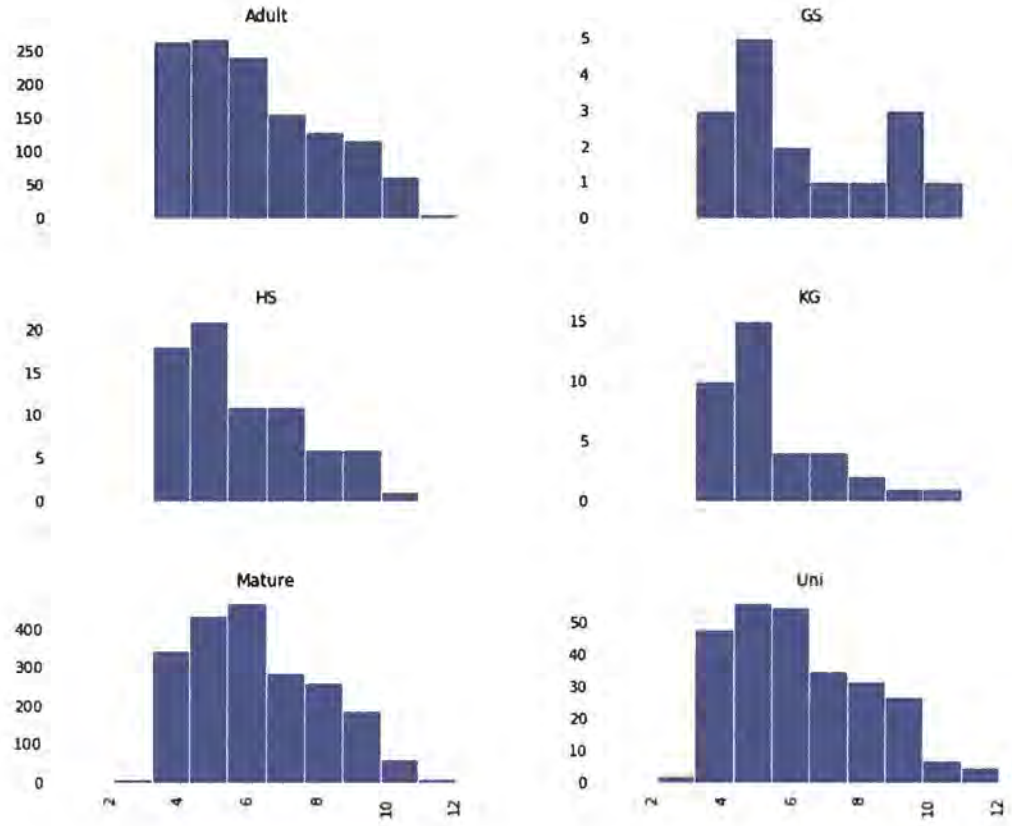


Figure A4: Per-group viral load histograms for categorization C2: The individual histograms for the six groups of categorization C2 make it immediately clear that the underlying distributions are not normal. Note that the data above are also presented in Figure 2B, although there presented with viral load on the y-axis, with the distribution spreading horizontally in two directions, with added jitter for the spread visualization.

Wrong person, place and time: viral load and contact network structure predict SARS-CoV-2 transmission and super-spreading events

Ashish Goyal[1], Daniel B. Reeves[1], E. Fabian Cardozo-Ojeda[1], Joshua T. Schiffer[1,2,3*†], Bryan T. Mayer [1†]

[1] Vaccine and Infectious Diseases Division, Fred Hutchinson Cancer Research Center

[2] Department of Medicine, University of Washington, Seattle

[3] Clinical Research Division, Fred Hutchinson Cancer Research Center

† These authors contributed equally to the work.

Corresponding author: Joshua T. Schiffer, jschiffe@fredhutch.org

One Sentence Summary: We developed a coupled within-host and between-host mathematical model to identify viral shedding levels required for transmission of SARS-CoV-2 and influenza, and to explain why super-spreading events occur more commonly during SARS-CoV-2 infection.

Abstract

SARS-CoV-2 is difficult to contain because many transmissions occur during the pre-symptomatic phase of infection. Moreover, in contrast to influenza, while most SARS-CoV-2 infected people do not transmit the virus to anybody, a small percentage secondarily infect large numbers of people. We designed mathematical models of SARS-CoV-2 and influenza which link observed viral shedding patterns with key epidemiologic features of each virus, including distributions of the number of secondary cases attributed to each infected person (individual R_0) and the duration between symptom onset in the transmitter and secondarily infected person (serial interval). We identify that people with SARS-CoV-2 or influenza infections are usually contagious for fewer than one day congruent with peak viral load several days after infection, and that transmission is unlikely below a certain viral load. SARS-CoV-2 super-spreader events with over 10 secondary infections occur when an infected person is briefly shedding at a very high viral load and has a high concurrent number of exposed contacts. The higher predisposition of SARS-CoV-2 towards super-spreading events is not due to its 1-2 additional weeks of viral shedding relative to influenza. Rather, a person infected with SARS-CoV-2 exposes more people within equivalent physical contact networks than a person infected with influenza, likely due to aerosolization of virus. Our results support policies that limit crowd size in indoor spaces and provide viral load benchmarks for infection control and therapeutic interventions intended to prevent secondary transmission.

Introduction

The SARS-CoV-2 pandemic is an ongoing tragedy that has caused 700,000 deaths and massively disrupted the global economy. The pandemic is rapidly expanding in the United States and is re-emerging focally in many countries that had previous success in limiting its spread.[1]

Two features have proven challenging in containing outbreaks. First, most transmissions occur during the pre-symptomatic phase of infection.[2] Underlying this observation is a highly variable incubation period, defined as time between infection and symptom onset, which often extends beyond an infected person's peak viral shedding.[3]

Second, there is substantial over-dispersion of the basic reproduction number (R0) for an individual infected with SARS-CoV-2,[4] meaning that most infected people do not transmit at all, while a minority may transmit to dozens of people, with the average, population R0 achieving a high enough level (>1) to allow exponential growth of cases in the absence of an effective intervention.[5] Approximately 10-20% of infected people account for 80% of SARS-CoV-2 transmissions.[4,6] Super-spreader events, in which the duration of contact between a single transmitter and large number of secondarily infected people is often limited to hours, are well documented.[7,8] This pattern is not evident for influenza which has more homogeneous individual transmissions numbers.[9,10] Differing shedding kinetics between the two viruses might explain this distinction; SARS-CoV-2 is often present intermittently in the upper airways for many weeks,[11,12] while influenza is rarely shed for more than a week.[13] Alternatively, SARS-CoV-2 aerosolization may predispose to wider exposure networks given the presence of an infected person in a crowded indoor space.

Viral load is recognized as a strong determinant of transmission risk. For influenza, the dose of viral exposure is related to the probability of infection in human challenge studies,[14] and early treatment reduces household transmission.[15,16] Household shedding of human herpesvirus-6 is closely linked to subsequent infection in newborns,[17] and infants shedding high levels of cytomegalovirus in the oropharynx predictably transmit the virus back to their mothers.[18]

The epidemiology of viral infections can also be perturbed by biomedical interventions that lower viral load at mucosal transmission surfaces. Reduction of genital herpes simplex virus-2 shedding with antiviral treatments decreases probability of transmission.[19] Suppressive antiretroviral therapy (ART) for HIV virtually eliminates the possibility of partner-to-partner sexual transmission and has limited community transmission dramatically.[20,21]

These concepts are relevant for SARS-CoV-2 infection and require urgent attention as the pandemic continues to wreak havoc. Early therapies that lower peak viral load may reduce the severity of COVID-19 but may also decrease the probability of transmission and of super-spreader events.[22] Similarly, the effectiveness of policies such as limiting mass gatherings, and enforcing mask use can be directly evaluated by their ability to reduce exposure viral load and transmission risk.[23] Here we developed a transmission simulation framework to capture the contribution of viral load to observed epidemiologic transmission metrics for influenza and SARS-CoV-2 and used this approach to explain why SARS-CoV-2 is predisposed to super-spreading events.

Results

Overall approach. We designed a series of steps to estimate the viral load required for SARS-CoV-2 and influenza transmission, as well as conditions required to explain the observed over-dispersion of secondary infections (*individual R0*) and frequent super-spreader events associated with SARS-CoV-2 but not influenza. This process included within-host modeling of viral loads, simulations of exposures and possible transmissions based on various transmission dose response curves, testing of various parameter sets against epidemiologic data and exploratory analyses with the best fitting model **(Fig S1)**.

Within-host mathematical model of SARS CoV-2 shedding. First, we used our previously developed within-host mathematical model (equations in the **Methods**),[24] to generate plausible viral load patterns in the upper airway of an infected person or *transmitter* who could potentially transmit the virus to others **(Fig 1, Fig S2a)**. Briefly, the model captures observed upper airway viral kinetics from 25 people from four different countries.[25-28] Key observed features include an early viral peak followed by a decelerating viral clearance phase, which in turn leads to a temporary plateau at a lower viral load, ultimately followed by rapid viral elimination. Our model captures these patterns by including a density dependent term for early infected cell elimination and a nonspecific acquired immune term for late infected cell elimination.

One limitation of our model is that only half of study participants provided longitudinal viral load data from the very early days of infection when COVID-19 is often pre-symptomatic. Therefore, the model's output is most reliable for later time points. In particular, we have somewhat limited information on viral expansion rate and duration of peak shedding. To impute possible

variability, we generated a set of heterogeneous shedding curves in which the viral upslope, the downslope of viral load after peak and the viral load during plateau phase were varied **(Fig S2b)**. Overall, the model generated several distinct patterns of infection: rapid elimination after the initial peak, a prolonged plateau phase with a low viral load, and a prolonged plateau phase with higher viral load. We simulated the transmission model with and without imputed heterogeneity.

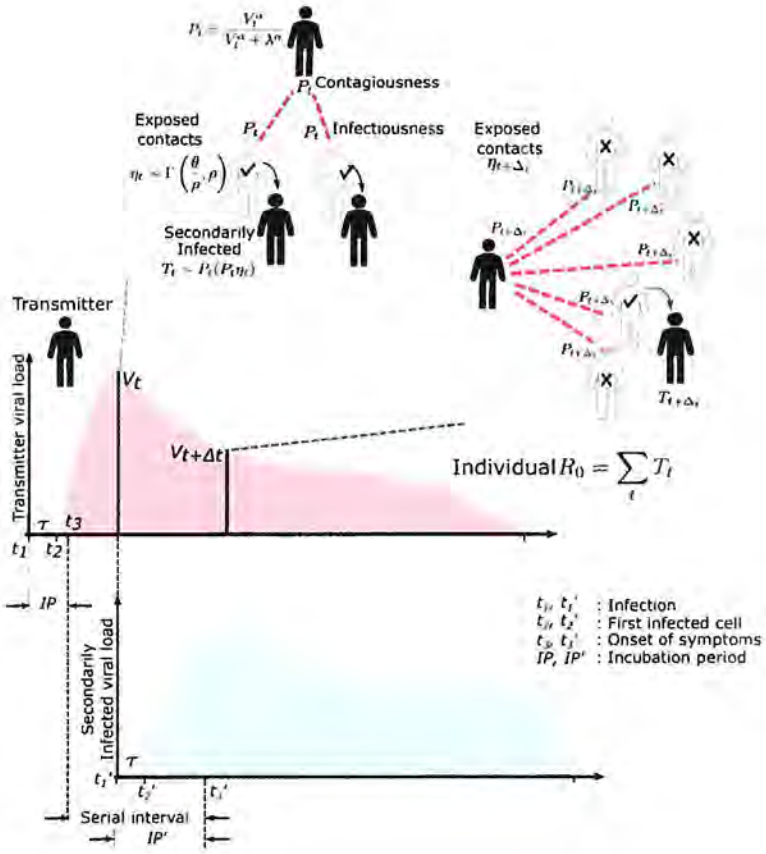


Fig 1. SARS-CoV-2 and influenza transmission model schematic. In the above cartoon, the transmitter has 2 exposure events at discrete timepoints resulting in 7 total exposure contacts and 3 secondary infections. Transmission is more likely at the first exposure event due to higher exposure viral load. To model this process, the timing of exposure events and number of exposed contacts is governed by a random draw from a gamma distribution which allows for heterogeneity in number of exposed contacts per day (**Fig S3**). Viral load is sampled at the precise time of each

exposure event. Probability of transmission is identified based on the product of two dose curves (**Fig S2C, D**) which capture contagiousness (probability of viral passage to an exposure contact's airway) and infectiousness (probability of transmission given viral presence in the airway). Incubation period (**Fig S4**) of the transmitter and secondarily infected person is an input into each simulation and is depicted graphically. Individual R0 is an output of each simulation and is defined as the number of secondary infections generated by an infected individual. Serial interval is an output of each simulated transmission and is depicted graphically.

Transmission dose response curves. We defined an *exposure event* in very specific biologic terms as a discrete event consisting of sufficient contact in time and space between a transmitter and one or more uninfected persons (*exposure contacts*) to allow for the possibility of a successful transmission. We next designed hundreds of dose response curves which separately predict contagiousness (CD curves) and infectiousness (ID curves) at a certain viral dose given an exposure contact. *Contagiousness* is defined as the viral load dependent probability of passage of virus-laden droplets or airborne particles from the airways of a potential transmitter to the airway of an exposure contact. *Infectiousness* is defined as the viral load dependent probability of transmission given direct airway exposure to virus in an exposure contact. *Transmission risk* is the product of these two mechanistic probabilities derived from the ID and CD curves and results is a transmission dose (TD) response curve. Each CD or ID curve is defined by its ID50 (λ) or viral load at which contagion or infection probability is 50% **(Fig S2c)**, as well as its slope (α) **(Fig S2d)**.[29] The TD50 is defined as viral load at which there is 50% transmission probability. We assumed equivalent curves for contagiousness and infectiousness for model fitting purposes. We also considered a simpler model with only a single TD curve (for *infectiousness*) and obtained qualitatively similar results (**Supplement and Methods**). Our model is inclusive of the hypothesis that viral load is not a key determinant of transmission when $\alpha << 1$ **(Fig S2d)**.

Exposure contact rate simulations. We introduced heterogeneity of exposure contact rates among possible transmitters by randomly selecting from a gamma distribution defined by mean number of exposure contacts per day (θ) and a scaling factor (ρ) that controls daily variability **(Fig S3)**.

Transmission simulations. For each defined exposure contact, viral load in the transmitter was sampled and transmission risk was then identified based on the product of the CD and ID curves, or the TD curve **(Fig S2e, f; Fig 1)**. Based on these probabilities, we stochastically modeled whether a transmission occurred for each exposure contact. This process was repeated when there were multiple possible exposure events within a given discretized time interval and the total number of exposures and transmissions within that interval was calculated.

For each successful transmission, we assumed that it takes τ days for the first infected cell to produce virus. To inform simulated values of *serial interval* (SI or time between symptom onset in the secondarily infected and transmitter), we randomly selected the *incubation period* (IP), for both the transmitter and the newly infected person, from a gamma distribution based on existing data **(Fig S4a)**.[3,30] Incubation period was defined as time from infection to the time of the onset of symptoms, where the mean incubation for SARS-CoV-2 is 5.2 days compared to 2 days for influenza.[3,9,30]

Model fitting. In order to identify the parameter set that best recapitulated the observed data, we then simulated several hundred thousands of parameter sets with ~250 possible TD curves defined by ID50 and CD50 (λ) and slope (α), along with ~180 combinations of the mean exposed contact rate per day (θ) and associated variance parameter (ρ), and values of $\tau \in [0.5, 1, 2, 3]$ days. We aimed to identify the parameter set that best recapitulated the following

features of the observed epidemiologic and individual-level data for SARS-CoV-2: mean R0 across individuals ($R0 \in [1.4, 2.5]$),[3,4,6,31,32] mean serial interval across individuals ($SI \in [4.0, 4.5]$),[3,31,33] cumulative distribution functions of individual R0,[4,6,34-36] and cumulative distribution functions of serial intervals derived from SARS-CoV-2 transmission pair studies that were conducted early during the pandemic,[31] prior to any confounding influence of social distancing measures. Here, we define *individual R0* as the total number of secondary transmissions from the transmitter in a fully susceptible population (**Methods**). Given that viral RNA is composed mostly of non-infectious material, we further checked the closeness of the solved ID curve with the observed relationship between viral RNA and probability of positive viral culture from a longitudinal cohort of infected people.[37]

Influenza modeling. Next, we performed equivalent analyses for influenza to explain the lower frequency of observed super-spreader events with this infection. Influenza viral kinetics were modelled using a previously data-validated model.[38] Incubation periods for influenza are lower and less variable than for SARS-CoV-2 and were randomly selected for each simulation of the model using a gamma distribution (**Fig S4b**).[39] We again fit the model to: mean R0 across individuals ($R0 \in [1.1, 1.5]$),[40-42] mean serial interval ($SI \in [2.9, 4.3]$),[9] cumulative distribution functions of individual R0 corresponding to the 2008-2009 influenza A H1N1 pandemic with mean R0=1.26 and dispersion parameter=2.36 in the negative binomial distribution, and cumulative distribution functions of serial intervals.[9,10,40]

Model-predicted individual R0 and serial intervals for SARS-CoV-2 infection. A single model parameter set ($[\alpha, \lambda, \tau, \theta, \rho] = [0.8, 10^7, 0.5, 4, 40]$) most closely reproduced empirically

observed individual R0 and serial interval histograms **(Fig 2a, c)** and cumulative distribution functions **(Fig 2b, d)**. We re-ran the model to fit to a higher population R0 of 2.8 and arrived at a similar set of parameter values but with a higher daily rate of exposure contacts ($[\alpha, \lambda, \tau, \theta, \rho] = [0.8, 10^{7.5}, 0.5, 20, 30]$). Despite assuming that each infected person sheds at a high viral load for a period of time **(Fig 1, Fig S2b)**, the model captured the fact that ~75% of 10,000 simulated transmitters do not infect any other people and that each increase in the number of possible transmissions is associated with a decreasing probability **(Fig. 2a)**.

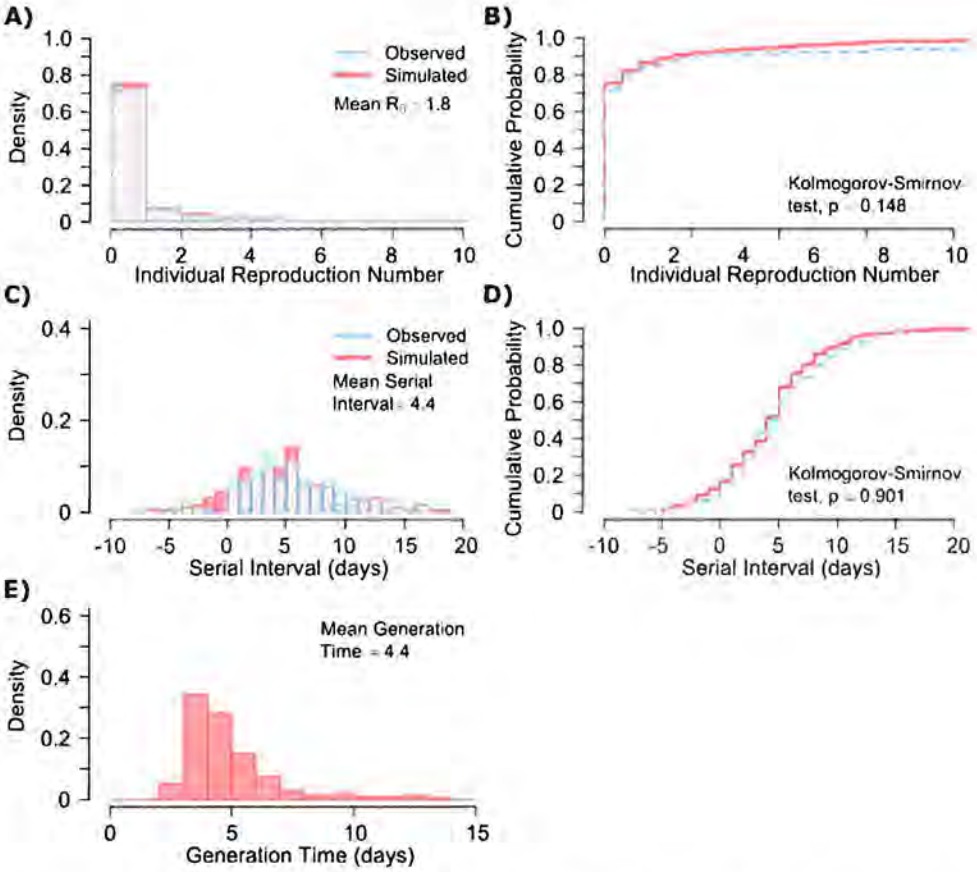


Fig 2. SARS-CoV-2 transmission model fit. A. Simulated and actual frequency histograms of individual R0 values, **B.** Simulated and actual cumulative distribution of individual R0 values. **C.** Simulated and actual frequency histograms of individual serial intervals, **D.** Simulated and actual cumulative distribution of individual serial intervals. **E.** Frequency distribution of simulated generation times.

194

195 SARS-CoV-2 viral load was recently measured with viral RNA levels and mapped to
196 concurrent probability of positive viral culture in a Dutch cohort.[37] Our model output
197 demonstrated a nearly equivalent infectious dose response curve if we multiplied modeled viral
198 RNA levels by 25 **(Fig S5):** this adjustment was likely necessary because viral loads in the Dutch
199 study participants were notably higher than those in German, Singaporean, Korean and French
200 participants used in our intra-host model fitting.[25-28,37]

201 The model also generated super-spreader events with 10,000 simulated transmissions
202 **(Fig. 2b).** If super-spreaders are defined as those who produce at least 5 secondary infections, we
203 estimate that ~10% of all infected people and ~35% of all transmitters are super-spreaders. If
204 super-spreaders are defined as those who produce at least 10 secondary infections, we estimate
205 that ~6% of all infected people and ~25% of all transmitters are super-spreaders. If super-
206 spreaders are defined as those who produce at least 20 secondary infections, we estimate that
207 ~2.5% of all infected people and ~10% of all transmitters are super-spreaders. If super-spreaders
208 are defined as those producing $\geq$5, $\geq$10, or $\geq$20 secondary infections, the contribution to all
209 secondary infections is estimated at ~85%, ~70%, or ~44%, respectively **(Table 1)**.

210 The model also recapitulated the high variance of the serial interval observed within
211 SARS-CoV-2 transmission pairs, including negative values observed in the data **(Fig 2c, d).** We
212 next projected *generation time*, defined as the period between when an individual becomes
213 infected and when they transmit the virus, for all transmission pairs and identified that the mean
214 serial interval (4.4 days) provides an accurate approximation of mean generation time. However,
215 the variance of generation time was considerably lower and by definition does not include

negative values. A majority of generation times fell between 4 and 7 days, compared to -5 to 12 days for the serial interval **(Fig 2e)**.

Super-spreader definitions	SARS-CoV-2			Influenza		
	All infected people	All transmitters	Contribution of super-spreaders to transmissions	All infected people	All transmitters	Contribution of super-spreaders to transmissions
Individual R0≥5	~10%	~35%	~85%	~2%	~3%	~10%
Individual R0≥10	~6%	~25%	~70%	~0%	~0%	~0%
Individual R0≥20	~2.5%	~10%	~44%	~0%	~0%	~0%

Table 1: Prevalence of super-spreaders among transmitters, and contribution of super-spreading events to all SARS-CoV-2 and influenza transmissions. Estimates are from 10,000 simulations.

Viral load thresholds for SARS-CoV-2 transmission. The optimized ID curve has an ID50 of 10^7 viral RNA copies and a moderately steep slope **(Fig 3a)**. The TD50 for SARS-CoV-2 was slightly higher at $10^{7.5}$ viral RNA copies **(Fig 3a)**. To assess the impact of these parameters on transmission, we performed simulations with 10,000 transmitters and concluded that transmission is very unlikely (~0.00005%) given an exposure to an infected person with an upper airway viral load of $<10^4$ SARS-CoV-2 RNA copies, and unlikely (~0.002%) given an exposure to an infected person with a viral load of $<10^5$ SARS-CoV-2 RNA copies. On the other hand, transmission is much more likely (39%) given an exposure to an infected person who is shedding $>10^7$ SARS-CoV-2 RNA copies, and 75% given an exposure to an infected person with a viral

load of $>10^8$ SARS-CoV-2 RNA copies. We obtain similar results (not shown) when we solve our model using the assumption of homogeneous viral load trajectories as in **Fig S2a.**

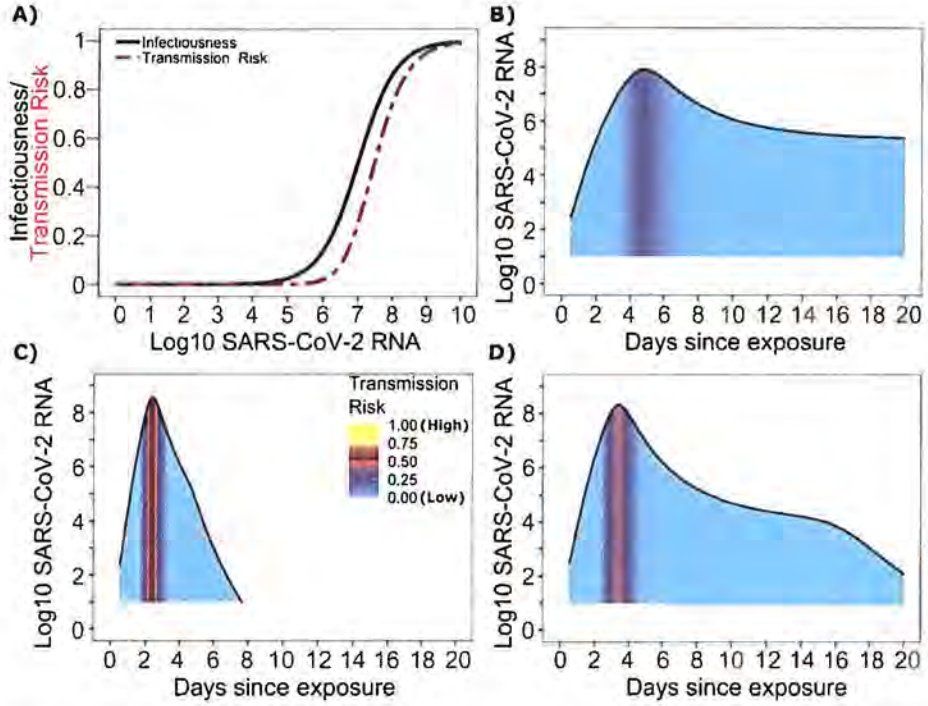
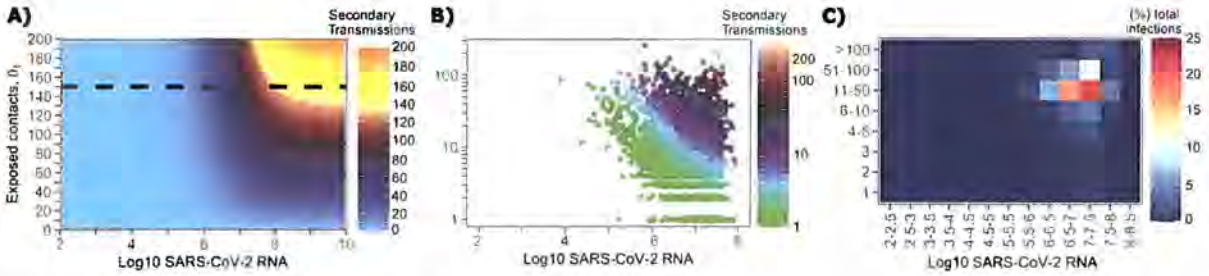


Fig 3. SARS-CoV-2 transmission probability as a function of shedding. A. Optimal infectious dose (ID) response curve (infection risk = P_I) and transmission dose (TD) response curve (transmission risk = $P_I * P_I$) curves for SARS-CoV-2. Transmission probability is a product of two probabilities, contagiousness and infectiousness (**Fig 1**). **B-D.** Three simulated viral shedding curves. Heat maps represent risk of transmission at each shedding timepoint given an exposed contact with an uninfected person at that time.

Narrow duration of high infectivity during SARS-CoV-2 infection. We next plotted the probability of infection given an exposure to a transmitter. Under multiple shedding scenarios, the window of high probability transmission is limited to time points around peak viral load, and some heterogeneity in regard to peak infectivity is noted between people **(Fig 3b-d)**. In general, infected persons are likely to be most infectious (i.e., above TD50) for a ~0.5-1.0-day period

252 between days 2 and 6 after infection. We therefore conclude that the observed wide variance in
253 serial interval **(Fig 2c)** results primarily from the possibility of highly discrepant incubation
254 periods between the transmitter and infected person, rather than wide variability in shedding
255 patterns across transmitters.
256



257
258
259 **Fig 4. Conditional requirements for SARS-CoV-2 superspreading events. A.** Heatmap
260 demonstrating the maximum number of feasible secondary infections per day from a transmitter
261 given an exposure viral load on log10 scale (x-axis) and number of exposed contacts per day (y-
262 axis). The exposed contact network allows a maximum of 150 exposed contacts per day (black
263 dotted line) which is sufficient for multiple transmissions from a single person per day. **B.** 10,000
264 simulated transmitters followed for 30 days. The white space is a parameter space with no
265 transmissions. Each dot represents the number of secondary transmissions from a transmitter per
266 day. Input variables are log10 SARS-CoV-2 on the start of that day and number of contact
267 exposures per day for the transmitter. There are 1,154,001 total exposure contacts and 15,992
268 total infections. **C.** 10,000 simulated infections with percent of infections due to exposure viral
269 load binned in intervals of 0.5 intervals on log10 scale (x-axis) and number of exposed contacts
270 (y-axis).
271

272

273 ***Requirements for SARS CoV-2 super-spreader events.*** The solved value for exposed contact
274 network heterogeneity (ρ) is 40 indicating high variability in day-to-day exposure contact rates
275 **(Fig S3d)** with a high average number of exposed contacts per day (θ=4). We generated a heat
276 map from our TD curve to identify conditions required for super-spreader events which included
277 viral load exceeding 10^7 SARS CoV-2 RNA copies and a high number of exposure contacts on
278 that day. We observed an inflection point between 10^6 and 10^7 SARS CoV-2 RNA copies where

large increases in the number of daily exposure contacts had a more limited impact on increasing the number of transmissions from a single person **(Fig 4a).** The exposure contact network occasionally resulted in days with ≥150 exposure contacts per day, which may allow an extremely high number of secondary infections from a single person **(Fig 4a).**

We next plotted transmission events simulated on a daily basis over 30 days since infection, from 10,000 transmitters, according to viral load at exposure and number of exposure contacts on that day **(Fig 4b)**. Secondary transmissions to only 1-3 people occurred almost exclusively with daily numbers of exposure contacts below 10 with any exposure viral load exceeding 10^6 RNA copies or with higher numbers of exposure contacts per day and viral loads exceeding 10^5 RNA copies. Massive super-spreader events with over 50 infected people almost always occurred at viral loads exceeding 10^7 RNA copies with high levels of concurrent exposure contacts **(Fig 4b).**

We next identified that over 50% of secondary infections were associated with a transmitter who has a high number of exposed contacts (11-100 per day) and a viral load exceeding 10^6 RNA copies **(Fig 4c)**, which is the mechanistic underpinning of why ~70% of all secondary infections arose from transmitters who produced more than 10 secondary infections **(Table 1).**

Model predicted individual R0 and serial intervals for influenza infection. A single model parameter set most closely reproduced empirically observed histograms and cumulative distribution functions for individual R0 and serial intervals for influenza: $(\alpha, \lambda, \tau, \theta, \rho) = (0.7, 10^{5.5}, 0\text{-}0.5, 4, 1)$. ID50 values for influenza were lower than SARS CoV-2, but a direct comparison cannot be made because tissue culture infectious dose (TCID) has been more

commonly used for measurements of influenza viral load, whereas viral RNA is used for SARS-CoV-2. Nevertheless, TCID is a closer measure of infectious virus and it is thus reasonable that ID50 based on TCID for influenza would be ~30-fold lower than ID50 based on total viral RNA (infectious and non-infectious virus) for SARS-CoV-2.[37]

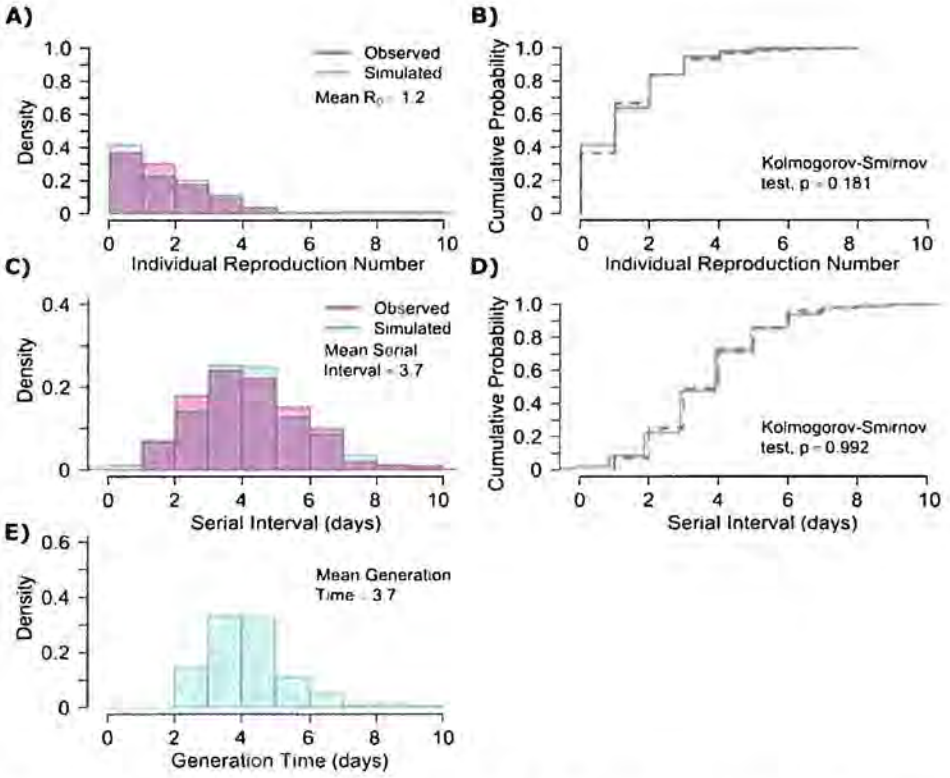


Fig 5. Influenza transmission model fit. A. Simulated and actual frequency histograms of individual R0 values, **B.** Simulated and actual cumulative distribution of individual R0 values. **C.** Simulated and actual frequency histograms of individual serial intervals, **D.** Simulated and actual cumulative distribution of individual serial intervals. **E.** Frequency distribution of simulated generation times.

The other notable difference was a considerably lower ρ value for influenza **(Fig S3b)**, denoting much less heterogeneity in the number of exposure contacts per person while the average daily exposure contact was the same for both viruses (4 per day). The model captures the

fact that 40% of influenza infected people do not transmit to anyone else and that each increase in the number of individual transmissions is associated with a lower probability **(Fig. 5a)**. Relative to SARS-CoV-2, super-spreader events involving 5 or more people were predicted to be 5-fold less common overall and 10-fold less common among transmitters (~2% of all infected people and ~3% of transmitters) **(Fig. 5b, Table 1).** Super-spreaders defined as those infecting ≥5 individuals contributed to only ~10% to all transmissions **(Table 1)**.

The model also recapitulated the lower variance of serial interval for influenza relative to SARS-CoV-2 **(Fig 5c, d).** We next identified that the mean and variance of the serial interval provide good approximations of the mean and variance for generation time. A majority of generation times fell between 2 and 6 days **(Fig 5e)**.

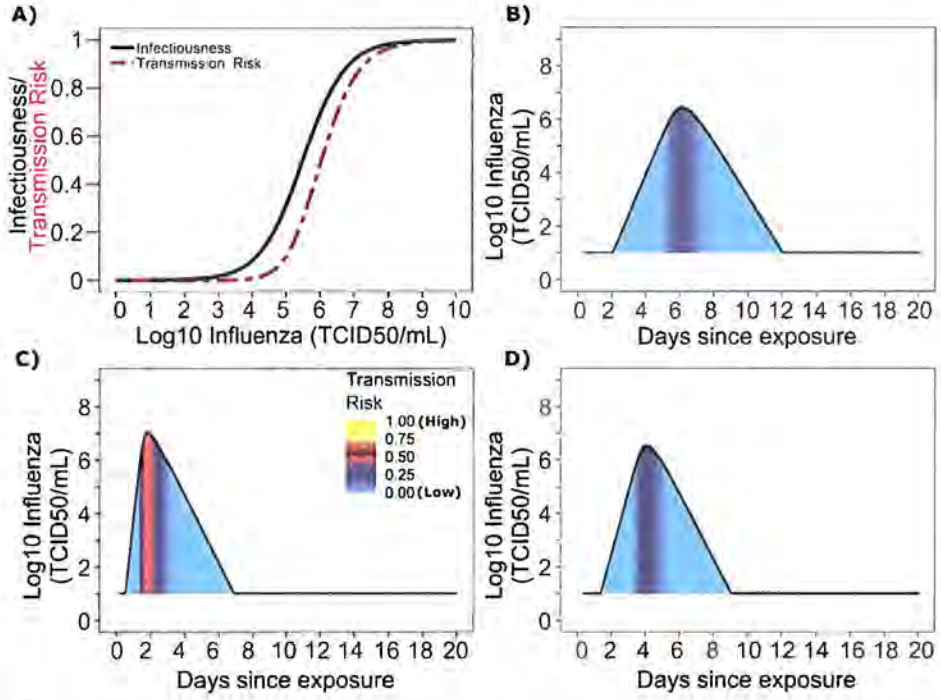
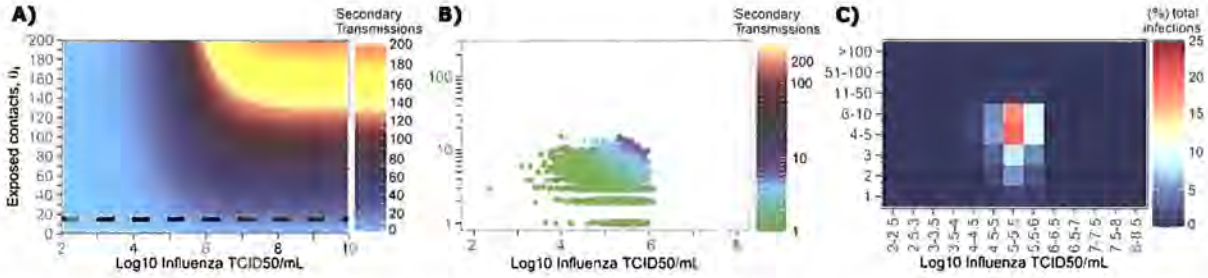


Fig 6. Influenza transmission probability as a function of shedding. A. Optimal infectious dose (ID) response curve (infection risk = P_I) and transmission dose (TD) response curve (transmission risk = $P_I * P_I$) curves for influenza. Transmission probability is a product of two probabilities, contagiousness and infectiousness **(Fig 1). B-D.** Three simulated viral shedding curves. Heat maps represent risk of transmission at each shedding timepoint given an exposed contact with an uninfected person at that time.

337

338 ***Viral load thresholds for influenza transmission.*** Based on the optimized TD curve for
339 influenza **(Fig 6a)**, we next plotted the probability of infection given an exposure to an infected
340 person. The TD50 for influenza was $10^{6.1}$ TCID/mL. Under various shedding scenarios, the
341 window of high probability transmission was limited to time points around peak viral load **(Fig**
342 **6b-d)**. In general, infected persons were likely to be most infectious (i.e., above TD50) for a
343 ~0.5-1.0 days period. The observed low variance in serial interval **(Fig 5c)** resulted primarily
344 from the narrow range of incubation periods within the transmitter and secondarily infected
345 person, as well as the limited variability in shedding patterns across transmitters.

346



347
348

349 **Fig 7. Conditional requirements for influenza super spreading events. A.** Heatmap
350 demonstrating the maximum number of secondary infections per day feasible from a transmitter
351 given an exposure viral load on log10 scale (x-axis) and number of exposed contacts per day (y-
352 axis). The exposed contact network allows a maximum of 15 exposed contacts per day (black
353 dotted line) which is not sufficient for more than 15 transmissions from a single person per day.
354 **B.** 10,000 simulated transmitters followed for 30 days. The white space is a parameter space with
355 no transmissions. Each dot represents the number of secondary transmissions from a transmitter
356 per day. Input variables are log10 influenza TCID on the start of that day and number of contact
357 exposures per day for the transmitter. There are 1,239,984 total exposure contacts and 11,141
358 total infections. **C.** 10,000 simulated infections with percent of infections due to exposure viral
359 load binned in intervals of 0.5 intervals on log10 scale (x-axis) and number of exposed contacts
360 (y-axis).

361

362 ***Determinants of influenza individual R0.*** We generated a heat map from our TD curve to
363 identify conditions governing influenza transmission to multiple people including viral load

exceeding 10^6 influenza TCID and a high number of exposure contacts per day. The contact network never resulted in days with more than 15 exposure contacts per day, which severely limited the possible number of transmissions from a single person relative to SARS-CoV-2 **(Fig 7a, S3b).**

We plotted transmission events simulated on a daily basis over 30 days since infection from 10,000 transmitters according to viral load at exposure and number of exposure contacts on that day **(Fig 7b)**. Secondary transmissions to fewer than 5 people accounted for 90% of infections **(Table 1)** and occurred with fewer than 10 daily exposure contacts and exposure viral loads exceeding 10^4 TCID. Small scale super-spreader events with 5-10 infected people almost always occurred at viral loads exceeding 10^5 TCID with 5-10 concurrent exposure contacts **(Fig 7b).**

We next identified that over 50% of infections were associated with a transmitter who had fewer than 10 exposure contacts per day and a viral load exceeding $10^{4.5}$ TCID **(Fig 7c)**, which is why no infected person ever transmitted to more than 10 other people **(Table 1).**

Differing exposed contact distributions, rather than viral kinetics, explain SARS CoV-2 super-spreader events. We sought to explain why SARS-CoV-2 has a more over-dispersed distribution of individual R0 relative to influenza. To assess viral kinetics as a potential factor, we comparatively plotted transmission risk per exposure contact as a function of time since infection in 10,000 transmitters for each virus. The median per contact transmission risk was slightly higher for influenza; however, 75% and 95% transmission risks were marginally higher for SARS-CoV-2 compared to influenza with slightly higher peak transmission risk, and a longer tail of low transmission risk beyond 7 days **(Fig 8a)**. The transmission risk was considerably higher

for the 25% of simulated SARS-CoV-2 infections with the highest viral loads, suggesting that a substantial subset of infected people may be more pre-disposed to super-spreading. When plotted as time since onset of symptoms, the variability in transmission potential was considerably larger for persons with high SARS-CoV-2 viral load, owing to the variable incubation period of this virus **(Fig 8b).**

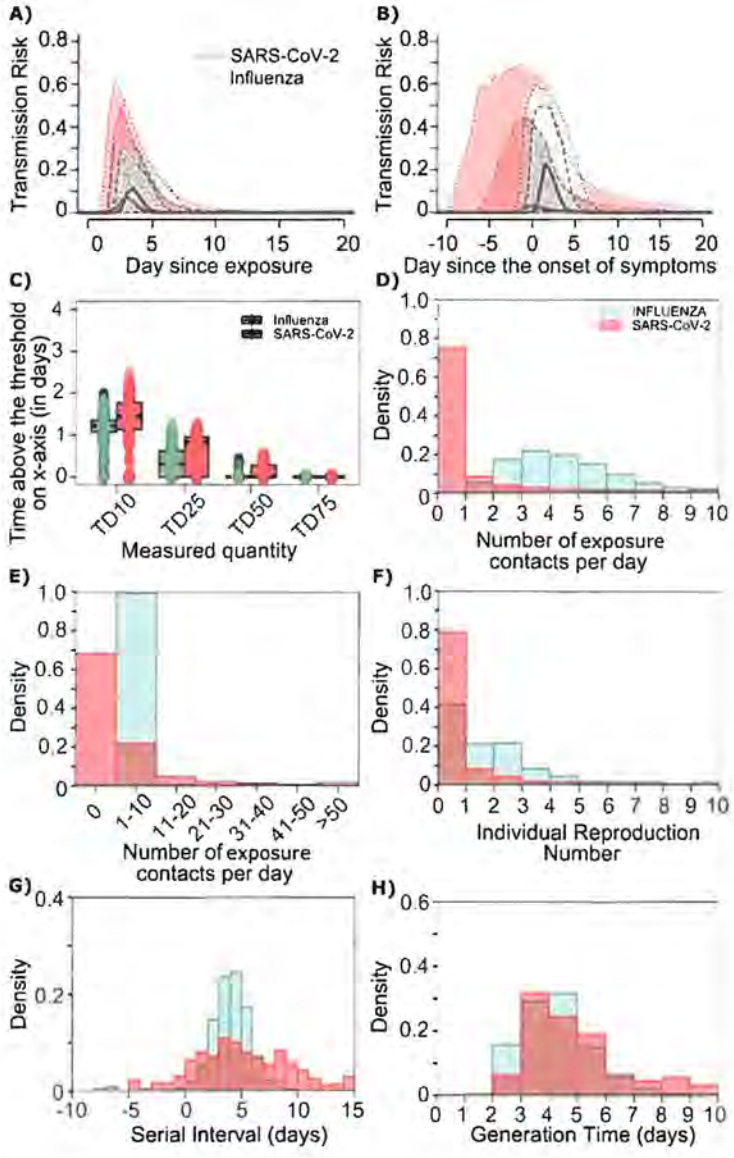


Fig 8. Differing transmission contact distributions, rather than viral kinetics explain SARS CoV-2 super spreader events. A. Simulated transmission risk dynamics for 10,000 infected persons with SARS-CoV-2 and influenza. Solid line is median transmission risk. Dark, dotted line is transmission risk of 75th percentile viral loads, and light dotted line is transmission risk of 95th percentile viral loads. **B.** Same as A but plotted as transmission risk since onset of symptoms. Highest transmission risk for SARS-Co-V-2 is pre-symptoms and for influenza is post symptoms. **C.** Boxplots of duration of time spent above TD10, TD25, TD50, TD75 and TD90 for 10,000 simulated SARS-CoV-2 and influenza shedding episodes. TD10, TD25, TD50, TD75 and TD90 are viral loads at which transmission probability is 10%, 25%, 50%, 75% and 90% respectively. The midlines are median values, boxes are interquartile ranges (IQR), and datapoints are outliers. Superimposed probability distributions of: **D & E.** number of transmission contacts per day, **F.** individual R0, **G.** serial interval and **H.** generation time for influenza and SARS-CoV-2.

The median duration of shedding over infectivity thresholds was short and nearly equivalent for both viruses. For SARS-CoV-2 and influenza, median [range] time above ID10 was 2.7 [0, 7] and 2.4 [1.6, 3.7] days respectively; median time above ID25 was 1.7 [0, 3] and 1.5 [0, 2.2] days respectively; median time above ID50 was 0.8 [0, 1.3] and 0 [0, 1.3] days respectively; median time above ID75 was 0 [0, 0.4] and 0 [0, 0] days respectively; median time above ID90 was 0 [0, 0] and 0 [0, 0] days respectively. ID10, ID25 and ID50 values were more variable across SARS-CoV-2 simulations due to a minority of trajectories with prolonged moderate viral loads.

For SARS-CoV-2 and influenza, median [range] time above TD10 was 1.4 [0, 2.5] and 1.2 [0, 2.0] days respectively; median time above TD25 was 0.8 [0, 1.3] and 0.3 [0, 1.3] days respectively; median time above TD50 was 0 [0, 0.5] and 0 [0, 0.4] days respectively; median time above TD75 was 0 [0, 0] and 0 [0, 0] days respectively. TD10, TD25 and TD50 values were more variable across SARS-CoV-2 simulations due to a minority of trajectories with prolonged moderate viral loads **(Fig 8c)**.

424 We next plotted the frequency of exposure contacts per day for both viruses and noted a
425 higher frequency of days with no exposed contacts **(Fig 8d)**, but also a higher frequency of days
426 with more than 10 exposure contacts **(Fig 8e)** for SARS-CoV-2 relative to influenza, despite an
427 equivalent mean number of daily exposure contacts. To confirm that this distribution drives the
428 different observed distributions of individual R0 values **(Fig 8f)**, we simulated SARS-CoV-2
429 infection with an assumed ρ=1 and generated a distribution of individual R0 similar to that of
430 influenza **(Fig S6a)**. Similarly, we simulated influenza infection with an assumed ρ=40 and
431 generated a distribution of individual R0 similar to that of SARS-CoV-2 **(Fig S6b)**. Under all
432 scenarios, predicted distributions of serial interval **(Fig 8g, Fig S6)** and generation time **(Fig 8h,**
433 **Fig S6)** were unchanged by shifts in the exposed contact network.
434
435 ***Projections of targeted physical distancing.*** Physical distancing is a strategy to decrease R0. We
436 simulated a decrease in the contact rate uniformly across the population and noted a decrease in
437 population R0 **(Fig S7a)** as well the percent of infected people who will transmit **(Fig 7b)** and
438 become super-spreaders **(Fig S7c-d)**. An approximately 40% decrease in the average exposed
439 contact rate decreased R0 below 1 **(Fig S6a).** We further investigated whether lowering contact
440 rate among larger groups only, in particular by banning exposure events with a high number of
441 exposure contacts, could control the epidemic. We identified that limiting exposure contacts to
442 no more than 5 per day is nearly equivalent to limiting exposure contacts altogether and that only
443 a small decrease in mean exposure contact rate can achieve R0<1 if exposure events with less
444 than 20 contacts are eliminated **(Fig S8).**
445

446 ***Pre-symptomatic transmission and super-spreading risk.*** Much of the highest transmission risk
447 for SARS-CoV-2 exists in the pre-symptomatic phase **(Fig8b)** which explains why 62% of
448 simulated transmissions occurred in the pre-symptomatic phase for SARS-CoV-2, compared to
449 10% for influenza. Similarly, 62% and 21% of SARS-CoV-2 and influenza super-spreader
450 events with secondary transmissions ≥5 and 39% of SARS-CoV-2 super-spreader events with
451 secondary transmissions R0≥10 fell in the pre-symptomatic period.

Discussion

Our results demonstrate that SARS-CoV-2 shedding kinetics are directly linked to the virus' most fundamental epidemiologic properties. First, we identify a transmission dose response curve which specifies that a nasal viral load below 10^5 RNA copies is unlikely to commonly result in transmission. For SARS-CoV-2, this threshold is consistent with the overall rarity of positive cultures at these levels.[37] We also predict a relatively steep TD curve such that transmission becomes much more likely when shedding exceeds 10^8 viral RNA copies and there is an exposure contact between an infected person and susceptible person. The amount of viral RNA can be roughly converted to the probability of a positive viral culture which approximates infectiousness. Our results therefore have relevance for dosing of SARS-CoV-2 in human challenge experiments that are being considered for vaccine trials.

While the duration of shedding for SARS-CoV-2 is often three weeks or longer,[11,12] we predict that the duration of shedding above thresholds required for a moderate probability of transmission per contact is much shorter, often less than half a day, and is comparable to that of influenza. While transmission after the first week of infection is quite rare, our model is consistent with the observation that transmissions commonly occur during the pre-symptomatic phase of infection,[2] given the highly variable incubation period associated with SARS-CoV-2.

The observed high heterogeneity in serial interval is attributable almost entirely to the variable nature of the incubation period, rather than transmission occurring extremely late after infection. While our estimate for mean generation time is equivalent to that of mean serial interval, it is notable that the range of SARS-CoV-2 serial intervals is much wider than the range of generation times. This result is evident even though we built substantial heterogeneity into our viral shedding curves beyond that observed in the somewhat limited existing shedding data.

The finding of limited duration of SARS-CoV-2 infectivity has practical implications. First, considerable resources are being used in hospitals and skilled nursing facilities to isolate patients with persistent SARS-CoV-2 shedding. We propose that a low nasal viral load, particularly during late infection, need not justify full patient isolation procedures in the absence of aerosolizing procedures. This observation could save substantial hospital resources and valuable isolation beds during subsequent waves of infection. Similar considerations are relevant for employees wishing to return to work. Our results also suggest that time since first positive test may be predictive of lack of contagion, though more viral load kinetic studies will be needed to confirm the existing observation that viral loads after a week of infection are usually low and associated with negative viral cultures.[37] Finally, our conclusions are supportive of rapid, less sensitive assays which are more likely to detect infection at periods of contagion.[43]

Many of these conclusions, including specific viral load thresholds for transmission, a steep dose response curve and a maximum 2-day duration of contagion within an infected individual are equally relevant for influenza infection. One important difference is that incubation periods for influenza are far less variable which means that at the individual level, the serial interval is much more likely to be predictive of the generation time.

Another finding is that SARS-CoV-2 super-spreading events are dependent on a large number of exposure contacts during the relatively narrow 1-2 days window during which a ~25% subset of infected people is shedding at extremely high levels above the TD50. Because we predict that super-spreader potential may be somewhat of a generalized property of infection, rather than a characteristic of a tiny subset of infected people, this result also has practical implications. A common experience during the pandemic has been early identification of a cluster of infected people within a specific confined environment such as a senior living home,

498 crowded work environment, athletic team, or restaurant. Our results demonstrate that newly
499 diagnosed people within small clusters may be past the peak of their super-spreading potential.
500 At this stage, many more infections have often been established and drastic quarantine
501 procedures should be considered. Other undiagnosed, pre-symptomatic infected people may have
502 super-spreader potential while the known infected person is no longer contagious, highlighting
503 the importance of effective contact tracing.

504 At the prevention level, school opening and work opening strategies should focus on
505 severely limiting the possible number of exposure contacts per day. Where large numbers of
506 exposure contacts are unavoidable, mandatory masking policies, perhaps with N95 masks that
507 may more significantly lower exposure viral loads should be considered.[23]

508 Influenza infection is much less predisposed to super-spreader events than SARS-CoV-2.
509 Yet, influenza shedding at levels above those required for a high probability of transmission
510 occurs with only slightly lower frequency. Therefore, the markedly different probability of
511 super-spreader events between the two viruses is unlikely to relate to different viral host kinetics,
512 despite the fact that the overall duration of SARS-CoV-2 shedding exceeds duration of influenza
513 shedding often by more than two weeks.

514 Rather, our analysis suggests that the exposure contact networks of SARS-CoV-2
515 transmitters are highly variable relative to those of influenza. One possible explanation
516 underlying this finding is that SARS-CoV-2 is more predisposed to airborne transmission than
517 influenza.[44] Here our precise definition of an exposure contact (sufficient contact between a
518 transmitter and an uninfected person to potentially allow transmission) is of high relevance. Our
519 result suggests that a SARS-CoV-2 infected person in a crowded, poorly ventilated room, may
520 generate more exposure contacts than an influenza infected person in the same room, likely

based on wider dispersal and / or longer airborne survival of the virus. Thus, our results suggest a possible downstream quantitative effect of airborne transmission on SARS-CoV-2 epidemiology. Another possibly important variable is that pre-symptomatic transmission, which is a common feature of SARS-CoV-2 may predispose to multiple transmissions. This prediction reinforces current public health recommendation to avoid crowded indoor spaces with poor air recirculation.

On the other hand, a much higher proportion of SARS-CoV-2 infected people than influenza infected people do not transmit at all. This result lacks a clear mechanistic explanation but may imply that aerosolization occurs only in a subset of infected people. One theoretical explanation is that high viral load shedding in the pre-symptomatic phase is defined by lack of cough or sneeze leading to limited spatial diffusion of virus. Alternatively, it is also possible that a proportion of infected people never shed virus at high enough viral loads to allow efficient transmission. This possibility speaks to the need for more quantitative viral load data gathered during the initial stages of infection.

Age cohort structure differs between the two infections, with a lower proportion of observed pediatric infections for SARS-CoV-2. If adults have more high exposure events than children, then this could also explain super-spreader events. We are less enthusiastic about this hypothesis. First, SARS-CoV-2 super-spreader events have occurred in schools and camps and would likely be more common in the absence of widespread global school closures in high prevalence regions. Second, a sufficient proportion of influenza cases occur in adults to rule out the presence of frequent large super-spreading events in this population.

Our analysis has important limitations. First, exposure contacts were assumed to be homogeneous and we do not capture the volume of the exposing aerosol or droplet. For instance,

544 if a large-volume droplet contains ten times more viral particles than an aerosol droplet, then the
545 exposure could be dictated by this volume as well as the viral load of the potential transmitter. It
546 is possible that under rare circumstances with extremely high-volume exposures, even persons
547 with extremely low viral loads may transmit. Second, based on the quality of available data, we
548 fit our models for SARS-CoV-2 and influenza to viral RNA and viral culture respectively.
549 Existing data suggest that kinetics of viral RNA and culture are similar during both infections,
550 with culture having lower sensitivity to detect virus.[37] Third, our intra-host model of SARS-
551 CoV-2 was fit to heterogeneous data with different sampling techniques and PCR assays.[24]
552 Moreover, R0 estimates have varied across the globe. Our estimates of TD50 are necessarily
553 imprecise based on available data and should serve only as a conservative benchmark. Most
554 importantly, we cannot rule out the possibility that a small minority of infected people shed at
555 sufficient levels for transmission for much longer than has been observed to date. Fourth,
556 contagiousness could have different dose response dynamics than viral load dependent
557 infectiousness and may require investigation in the future upon the availability of
558 epidemiologically relevant additional data. Finally, the model is intended to capture a general
559 property of SARS-CoV-2 infection but is not specific for local epidemics. The degree of R0
560 overdispersion in various countries and regions is likely to vary dramatically according to
561 numerous factors related to social contact networks that are not explicitly captured in our model.
562 In conclusion, fundamental epidemiologic features of SARS-CoV-2 and influenza
563 infections can be directly related to viral shedding patterns in the upper airway as well as the
564 nature of exposure contact networks. We contend that this information should be leveraged for
565 more nuanced public health practice in the next phase of the pandemic.

Methods

SARS-CoV-2 within-host model. To simulate SARS-CoV-2 shedding dynamics, we employed our previously-described viral infection model.[24] In this model, susceptible cells (S) after coming into contact with SARS-CoV-2 (V) become infected at rate βVS. The infected cells (I) produce new virus at a per-capita rate π. The model also includes the clearance of infected cells in two ways: (1) by an innate response with density dependent rate δI^k; and (2) an acquired response with rate $\frac{mE^r}{E^r+\phi^r}$ mediated by SARS-CoV-2-specific effector cells (E). The clearance mediated by innate immunity depends on the infected cell density and is controlled by the exponent k. The Hill coefficient r parameterizes the nonlinearity of the second response and allows for rapid saturation of the killing. Parameter ϕ defines the effector cell level by which killing of infected cells by E is half maximal.

In the model, SARS-CoV-2-specific effector cells rise after 2 stages from precursors cells (M_1 and M_2). The first precursor cell compartment (M_1) proliferates in the presence of infection with rate $\omega I M_1$ and differentiates into the effector cell at a per capita rate q during the next intermediate stage. Finally, effector cells die at rate δ_E. The model is expressed as a system of ordinary differential equations:

$$\frac{dS}{dt} = -\beta VS$$
$$\frac{dI}{dt} = \beta VS - \delta I^k I - m\frac{E^r}{E^r + \phi^r} I$$
$$\frac{dV}{dt} = \pi I - \gamma V$$
$$\frac{dM_1}{dt} = \omega I M_1 - qM_1$$
$$\frac{dM_2}{dt} = q(M_1 - M_2)$$
$$\frac{dE}{dt} = qM_2 - \delta_E E$$

We assumed $S(0) = 10^7$ cells/mL, $I(0) = 1$ cells/mL, $V(0) = \frac{\pi I(0)}{c}$ copies/mL, $M_1(0) = 1$, $M_2(0) = 0$ and $E_0 = 0$.

When we introduce simulated heterogeneity in cases of SARS-CoV-2 (by increasing the standard deviation of the random effects of parameters β by 20, δ by 2, k by 2 and π by 5 in the original distribution from[24]), some of the viral shedding curves suggest that viral shedding could continue for long period (over 6 weeks). Indeed, while median viral shedding duration has been estimated at 12-20 days, shedding for many months is also observed commonly.[45] We assumed that viral loads after day 20 drop to a exposure-level viral load level (i.e., $V(0)$) as most viral shedding observed after this point is transient and at an extremely low viral load.[46] The population distribution of parameters to simulate artificial SARS-CoV-2 viral shedding dynamics is provided in **Table S1**.

Influenza within-host model. To simulate viral shedding dynamics of influenza viral, we employ a model[38] that is a simplified version of the viral dynamics model presented for SARS-CoV-2. This model assumes $k = 0$ and $m = 0$ and can be expressed as a system of ordinary differential equations:

$$\frac{dS}{dt} = -\beta VS$$

$$\frac{dI}{dt} = \beta VS - \delta I$$

$$\frac{dV}{dt} = \pi I - \gamma V$$

Following this model,[38] we assumed $S(0) = 4 \times 10^8$ cells/mL, $I(0) = 1$ cells/mL, $V(0) = \frac{\pi I(0)}{c}$ copies/mL. To simulate artificial influenza viral shedding dynamics, we assumed the population distribution of parameters $Log10(\beta)$, $Log10(\pi)$, $Log10(\gamma)$ and $Log10(\delta)$ are -4.56 (0.17), -1.98 (0.14), 0.47 (0.03) and 0.60 (0.06), respectively.

Dose-response model. For both viruses, to estimate the infectiousness $P_t[V(t)]$ based on viral loads $V(t)$, we employed the function, $P_t[V(t)] = \frac{V(t)^\alpha}{\lambda^\alpha + V(t)^\alpha}$. Here, λ is the infectivity parameter that represents the viral load that corresponds to 50% infectiousness and 50% contagiousness, and α is the Hill coefficient that controls the slope of the dose-response curve.

Transmission Model and Reproduction number. Our transmission model assumes that only some contacts of an infected individual with viral load dependent infectiousness are physically exposed to the virus (defined as exposure contacts), that only some exposure contacts have virus passaged to their airways (contagiousness) and that only some exposed contacts with virus in their airways become secondarily infected (successful secondary infection). Contagiousness and infectiousness are then treated as viral load dependent multiplicative probabilities with transmission risk for a single exposure contact being the product. Contagiousness is considered to be viral load dependent based on the concept that a transmitter's dispersal cloud of virus is more likely to prove contagious

at higher viral load, which is entirely separate from viral infectivity within the airway once a virus contacts the surface of susceptible cells.

We next assume that the total exposed contacts within a time step (η_{Δ_t}) is gamma distributed, i.e. $\eta_{\Delta_t} \sim \Gamma\left(\frac{\theta}{\rho}, \rho\right)\Delta_t$, using the average daily contact rates (θ) and the dispersion parameter (ρ). To obtain the true number of exposure contacts with airway exposure to virus, we simply multiply the contagiousness of the transmitter with the total exposed contacts within a time step (i.e., $\zeta_t = \eta_{\Delta_t} P_t$).

Transmissions within a time step are simulated stochastically using time-dependent viral load to determine infectiousness (P_t). Successful transmission is modelled stochastically by drawing a random uniform variable ($U(0,1)$) and comparing it with infectiousness of the transmitter. In the case of successful transmission, the number of secondary infections within that time step (T_{Δ_t}) is obtained by the product of the infectiousness (P_t) and the number of exposure contacts drawn from the gamma distribution (ζ_t). In other words, the number of secondary infections for a time step is $T_{\Delta_t} = Ber(P_t) P_t \eta_{\Delta_t}$. If we disregard contagiousness by assuming $P_t = 1$ in ζ_t, we identify that there are little to no differences on overall results other than the emergent TD curve and optimal parameter set describing dose-response curve and exposed contact network, which no longer agrees as closely with in vitro probability of positive virus culture **(Fig S5)**.[37]

We obtain the number of secondary infections from a transmitter on a daily basis noting that viral load, and subsequent risk, does not change substantially within a day. We then summed up the number of secondary infections over 30 days since the time of exposure to obtain the individual reproduction number, i.e. $R_0 = \sum_{\Delta_t} T_{\Delta_t}$.

644 ***Serial interval and generation time.*** We further assume that upon successful infection, it takes τ
645 days for the virus to move within-host, reach infection site and produce the first infected cell.
646 To calculate serial interval (time between the onset of symptoms of transmitter and secondarily
647 infected person), we sample the incubation period in the transmitter and in the secondarily infected
648 person from a gamma distribution with a shape described in the **Fig S4**.[3,30] In cases in which
649 symptom onset in the newly infected person precedes symptom onset in the transmitter, the serial
650 interval is negative; otherwise, serial interval is non-negative. We calculate generation time as the
651 difference between the time of infection of transmitter and the time of infection of secondarily
652 infected person.
653
654 ***Individual R0 and serial interval data for model fitting.*** There is abundance of data confirming
655 over-dispersed R0 for SARS-CoV-2. From contact tracing of 391 SARS-CoV-2 cases in
656 Shenzhen, China, 1286 close contacts were identified: the distribution of individual R0 values in
657 this cohort was highly over-dispersed, with 80% of secondary infections being caused by 8-9% of
658 infected people.[6] In another study, authors analyzed the contact/travel history of 135 infected cases
659 in Tianjin, China and determined heterogeneity in the individual R0.[34] Another contract tracing
660 study also identified and characterized SARS-CoV-2 clusters in Hong Kong and estimated that
661 20% of cases were responsible for 80% of local transmission.[35]
662 A modeling study that simulated observed outbreak sizes in ~40 affected countries during
663 the early phase of epidemics also confirmed that ~80% of secondary transmissions may have been
664 caused by a small fraction of infectious individuals (~10%).[4] The latter study provided the
665 distribution of individual R0 (**Fig 2A**) that we employed for fitting purposes. Using the data on
666 468 COVID-19 transmission events reported in mainland China, Du et al. estimated the mean

serial interval as well as the distribution of serial interval (**Fig 2C**).[31] We employed this data for fitting purposes.

The cumulative distribution function of individual R0 for influenza was obtained from a modeling study that simulated the transmission dynamics of seasonal influenza in Switzerland from 2003 to 2015.[10] We picked the parameters mean R0=1.26 and dispersion parameter=2.36 in the negative binomial distribution that corresponded to the 2008-2009 influenza A H1N1 pandemic.[10] Another modeling study that simulated the age-specific cumulative incidence of 2009 H1N1 influenza in 8 Southern Hemisphere Countries yielded similar results.[40] By following the household members of index cases, a study estimated the cumulative distribution of serial interval based on symptom-onset times from 14 transmission pairs.[9] We employed these cumulative distribution functions of individual R0 and serial interval of influenza for fitting purposes.

Fitting procedure. To estimate the values of unknown parameters in cases of SARS-CoV-2, we performed a grid search comprehensively exploring a total of ~500,000 combinations of 5 parameters taking the following values,

(i) $\tau \in [0.5, 1, 2, 3]$ days,

(ii) $\alpha \in [0.01, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 2.0, 3.0, 4.0, 5.0, 10.0]$

(iii) $\lambda \in [10^0, 10^{0.5}, 10^{1.0} \ldots, 10^8]$

(iv) $\theta \in [0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 2.0, 3.0, 4.0, 5.0, 10.0, 20.0, 50.0]$.

(v) $\rho \in [0.0001, 0.001, 0.01, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 2.0, 5.0, 10.0,$ $20.0, 30.0, 40.0, 50.0, 75.0, 100, 200, 500]$.

The parameter sets of $(\lambda, \tau, \alpha, \theta)$ were simulated for 1000 infected individuals to determine how well each set generates the summary statistics of mean R0, mean SI and the R0 histograms by following a procedure explained in **Fig S1** and below:

Step A:

1. Simulate viral load $V(t)$ of 1,000 simulated infected individuals using **Eq. 1**
2. For each combination of $(\lambda, \tau, \alpha, \theta, \rho)$
    a. For each time step Δ_t
        i. Compute $P_t[V(t); \lambda, \alpha]$
        ii. Draw $\eta_{\Delta_t} \sim \Gamma\left(\frac{\theta}{\rho}, \rho\right)\Delta_t$
        iii. Calculate $T_{\Delta_t} = Ber(P_t)P_t\eta_{\Delta_t}$
    b. Calculate $R_0 = \sum_{\Delta_t} T_{\Delta_t}$
        i. Check if calculated mean R_0 is in the range:[3,31]
    c. Calculate Serial Interval based on τ and incubation period
        i. Check if calculated SI is in the range in:[3,31,33]

Step B:

1. If the parameter combination in Step A satisfy the criteria, then
        i. Compute RSS for the obtained R_0 and histogram from:[4,6,34,36] [Ref]

We visually checked whether our dose-response curve matched the observed probability of positive virus culture.[37] We assumed that viral loads derived from positive culture[37] can be considered equivalent to viral loads in the within-host model if divided by a positive integer. We identified an integer of 25 to provide closest fit to the empirical data (**Fig S5**).

We performed a global sensitivity analysis to identify which parameter variability accounted for fit to different components of the data. Only narrow ranges of λ permitted close fit to the mean of R0 and distribution functions of individual R0 **(Fig S9),** while a specific value for α was necessary to fit to mean serial interval and distribution functions of individual R0 **(Fig S9)**. Only narrow ranges of θ permitted close fit to the mean of R0 and distribution functions of individual R0 **(Fig S10),** while a specific value for ρ was necessary to fit to distribution functions of individual R0 **(Fig S10)**.

To obtain TD50 (λ_T) based on ID50 (λ), we use the relation

$$\frac{1}{(\left(\frac{10^{\lambda}}{V}\right)^{\alpha}+1)^2} = \frac{1}{\left(\frac{10^{\lambda_T}}{V}\right)^{\alpha_T}+1} = 0.5$$

From solving the second half ($\frac{1}{\left(\frac{10^{\lambda_T}}{V}\right)^{\alpha_T}+1} = 0.5$), we get

$$V = 10^{\lambda_T}$$

Substituting $V = 10^{\lambda_T}$ in the first-half, we have

$$\frac{1}{(\left(\frac{10^{\lambda}}{10^{\lambda_T}}\right)^{\alpha}+1)^2} = 0.5$$

Or, $(\left(\frac{10^{\lambda}}{10^{\lambda_T}}\right)^{\alpha}+1)^2 = 2$

Or, $\left(\frac{10^{\lambda}}{10^{\lambda_T}}\right)^{\alpha} = \sqrt{2}-1$

Or, $10^{\lambda_T \alpha} = \frac{10^{\lambda\alpha}}{\sqrt{2}-1}$

Or, $\lambda_T = \lambda + \frac{0.38}{\alpha}$

727 **Acknowledgements**

728

729 We are grateful to study participants from around the globe who donated critical virologic data
730 early during the pandemic. We thank Jeroen van Kampen and Marion Koopmans for helpful
731 discussions.

732

733 **Funding:** This study was supported by Fred Hutchinson Cancer Research Center faculty
734 discretionary funds and by National Institute of Allergy and Infectious Diseases (grant #
735 5R01AI121129-05).

736

737 **Author contributions**: J.T.S. and B.M. conceived the study. A.G., E.F.C., B.M. and D.B.R.
738 assembled data, wrote all code, performed all calculations and derivations, ran the models, and
739 analyzed output data. J.T.S. wrote the manuscript with contributions from all other authors.

740

741 **Competing interests:** The authors declare no competing interests. J.T.S. is on the trial planning
742 committee for a Gilead funded trial of remdesivir but is not reimbursed for this activity.

743

744 **Data and materials availability**: The original data and code is shared at:
745 https://github.com/ashish2goyal/SARS_CoV_2_Super_Spreader_Event

Supplementary Materials

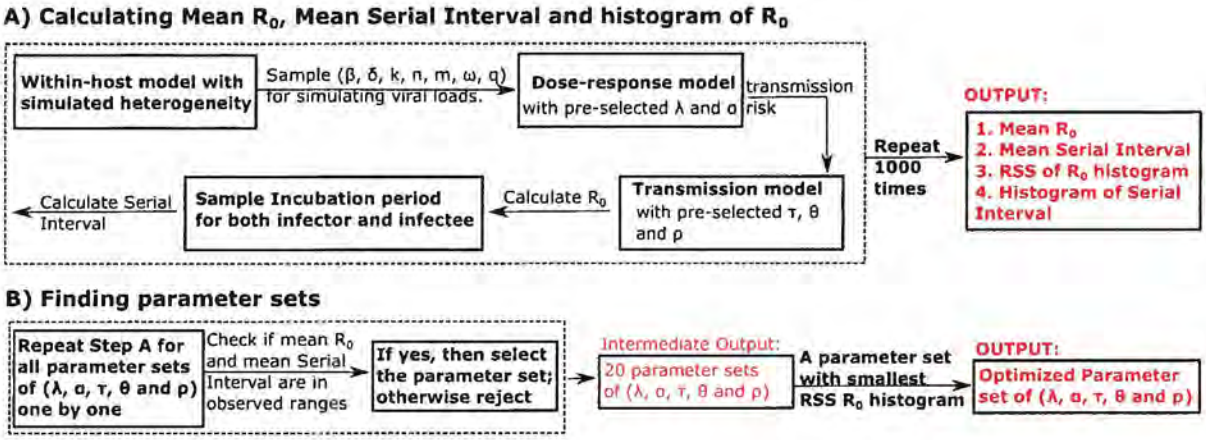


Fig S1. Mathematical model workflow.

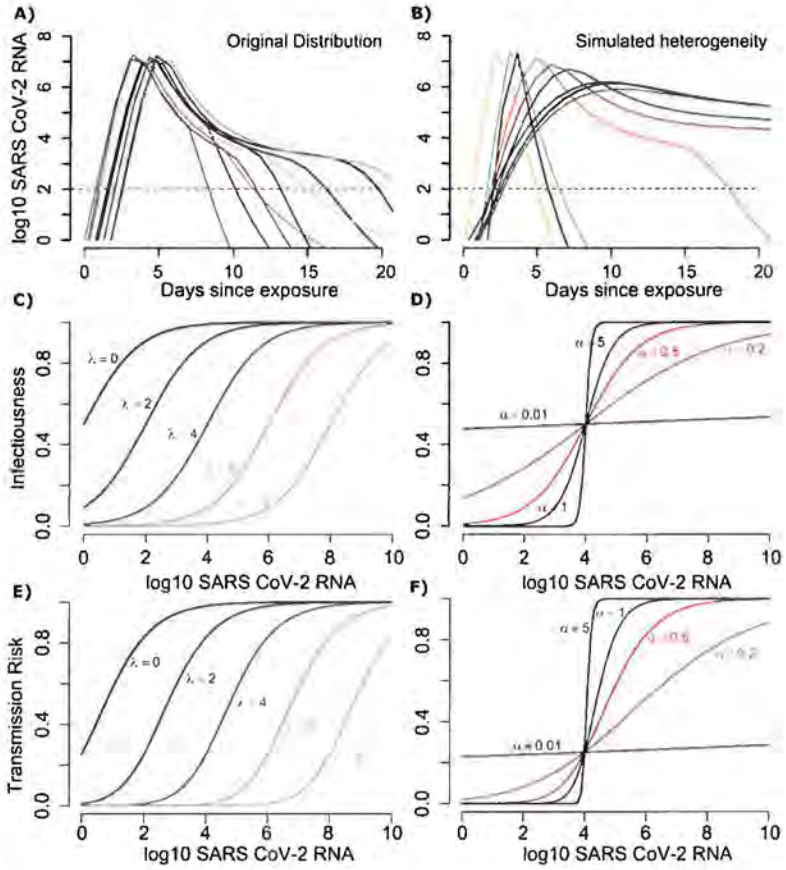


Fig S2. Mathematical model of SARS-CoV-2 transmission dynamics. A. Simulated viral load shedding tracings of possible transmitters. **B.** Simulated viral load shedding with imputed heterogeneity. **C.** Simulated infection dose (ID) response curves with variance in infectivity (ID50) and **D.** dose response slopes. **E.** Simulated transmission dose (TD) response curves with variance in infectivity (TD50) and **F.** dose response slopes. The TD response curve is a product of the infection and contagion dose response curves.

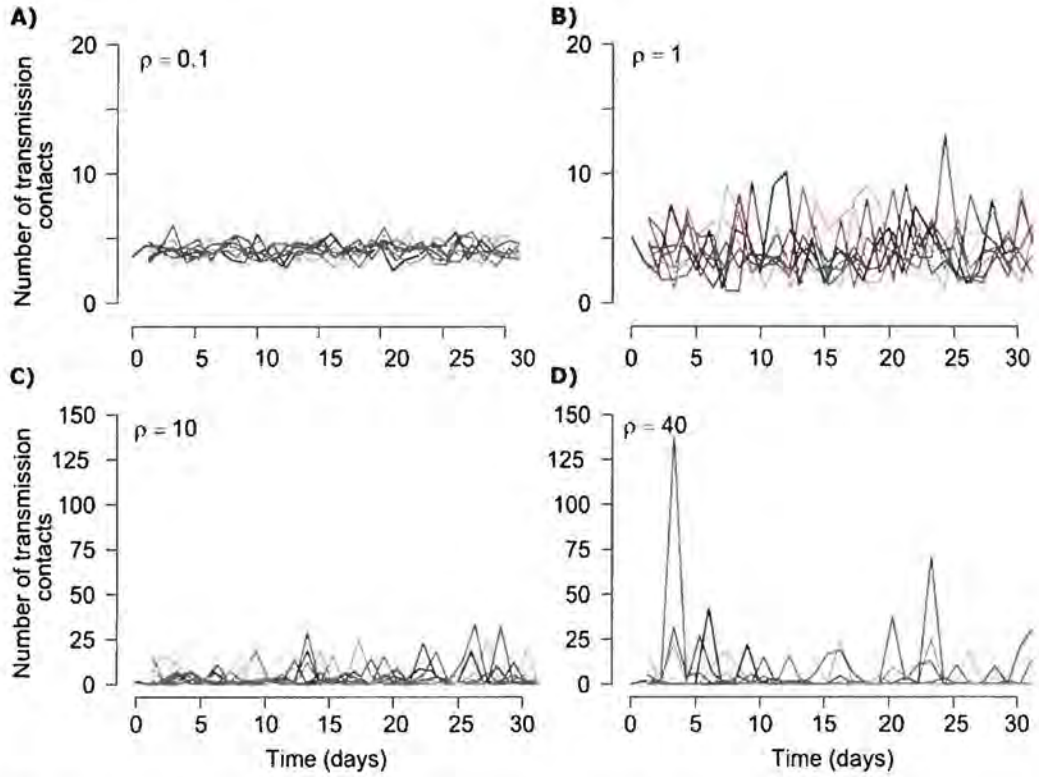
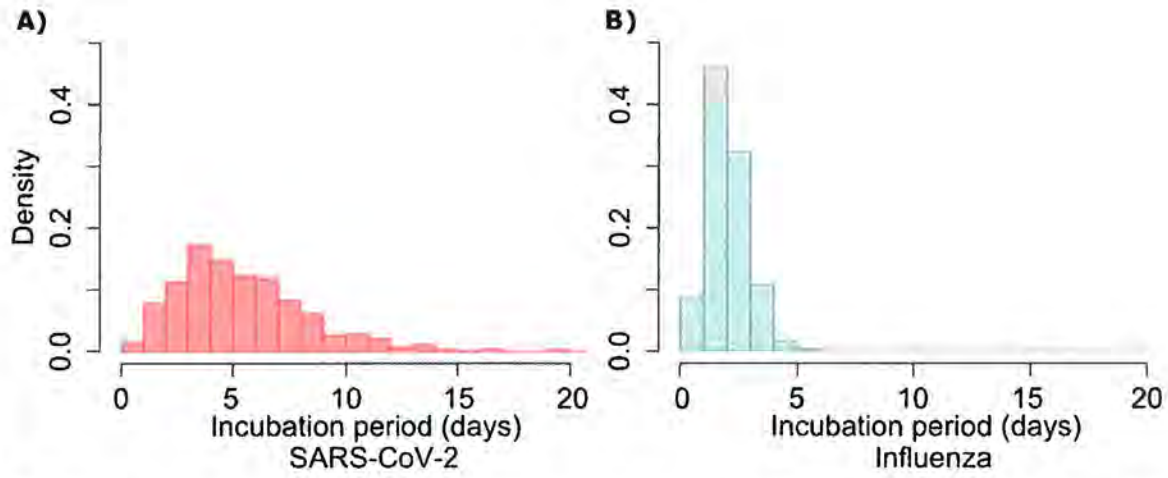


Fig S3. Stochastic simulations of exposed contact frequency for varying dispersion (ρ). The average number of exposed contacts is 4 per day in each example with imputed daily heterogeneity based on an elevated value of ρ from a gamma distribution~$\Gamma(4/\rho, \rho)$.



762

763 **Fig S4. Gamma distribution functions of incubation periods. A.** SARS-CoV-2 (mean 5.2
764 days, shape parameter =3.45 and rate =0.66) and **B.** influenza (mean 2 days, shape
765 parameter=6.25 and scale parameter=0.32).

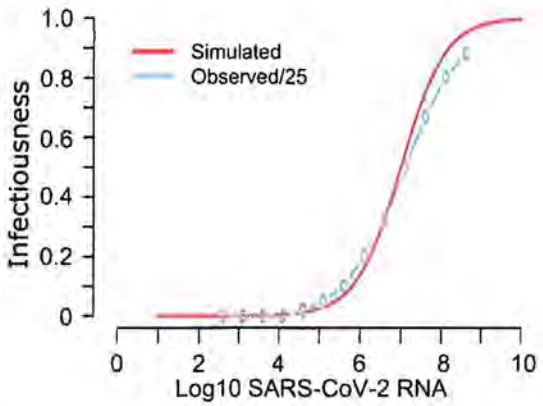


Fig S5. Mathematical model recapitulation of relationship between SARS-CoV-2 viral load and viral culture. In a clinical study, probability of positive viral culture was projected against SARS-CoV-2 RNA (https://www.medrxiv.org/content/10.1101/2020.06.08.20125310v1). When we divided these PCR values by 25 (light blue line), we identified high similarity between the clinical data and our projected infectiousness dose response curve (red line).

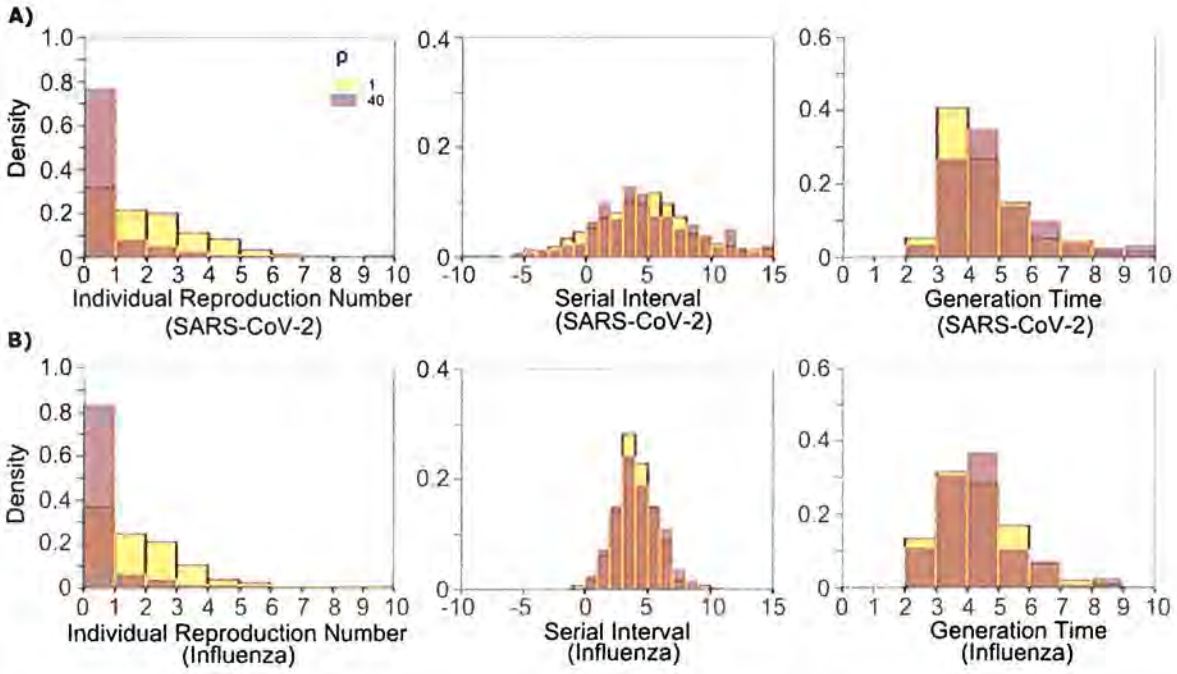


Fig S6. Impact of changes in contact network heterogeneity on individual R0, serial interval, and generation time. A. SARS-CoV-2, and **B.** influenza. Lowering exposed contact network heterogeneity to levels observed with influenza decreases SARS-CoV-2 individual R0 over-dispersion. Increasing exposed contact network heterogeneity to levels observed with SARS-CoV-2 increases influenza R0 over-dispersion. Neither change impacts observed serial interval or estimate generation time.

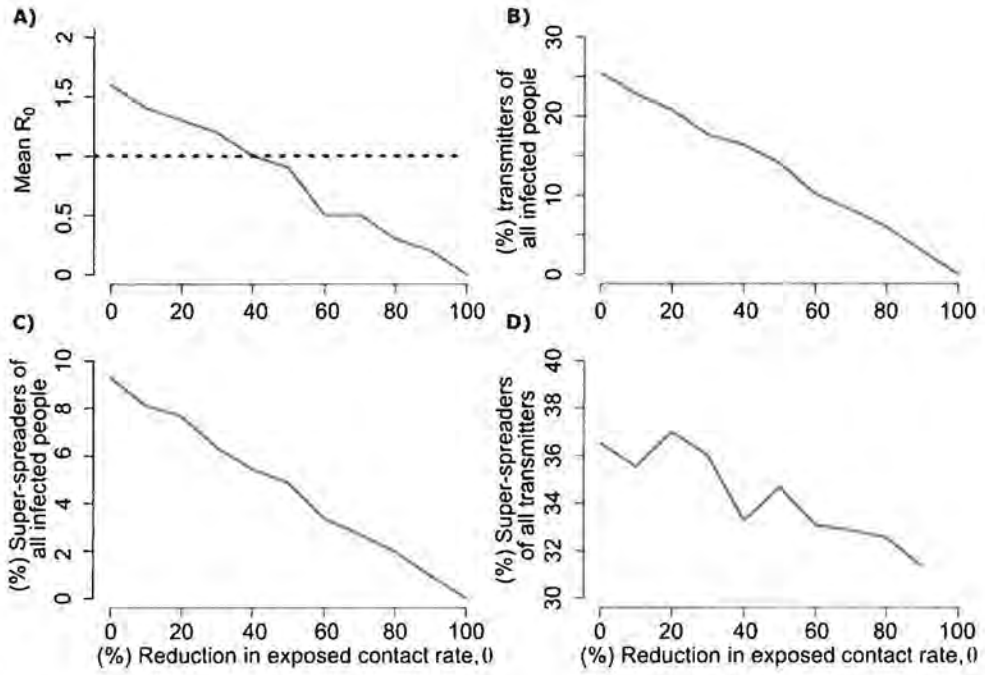


Fig S7. Potential impact of population physical distancing on SARS-Co-V2 epidemiology. **A.** Mean reproductive number **B.** Percent transmitters of all infected people **C.** Percent super-spreaders (individual R0>5) of all infected people **D.** Percent super spreaders of all transmitters. Transmitters are defined as infected people who generate at least one secondary infection.

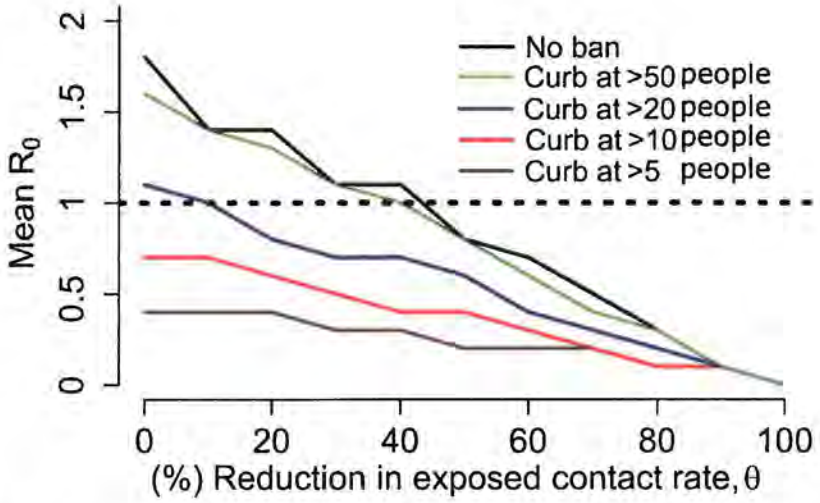


Fig S8. Potential impact of enhanced physical distancing only within high exposure contact networks on SARS-CoV-2 epidemiology. Simulations assume limitation of exposed contacts only among daily exposures of more than 5, 10, 20 or 50 people. Mean reproductive number decreases below one with only marginal decreases in overall rate of exposure contacts when contacts are limited to fewer than 20 people.

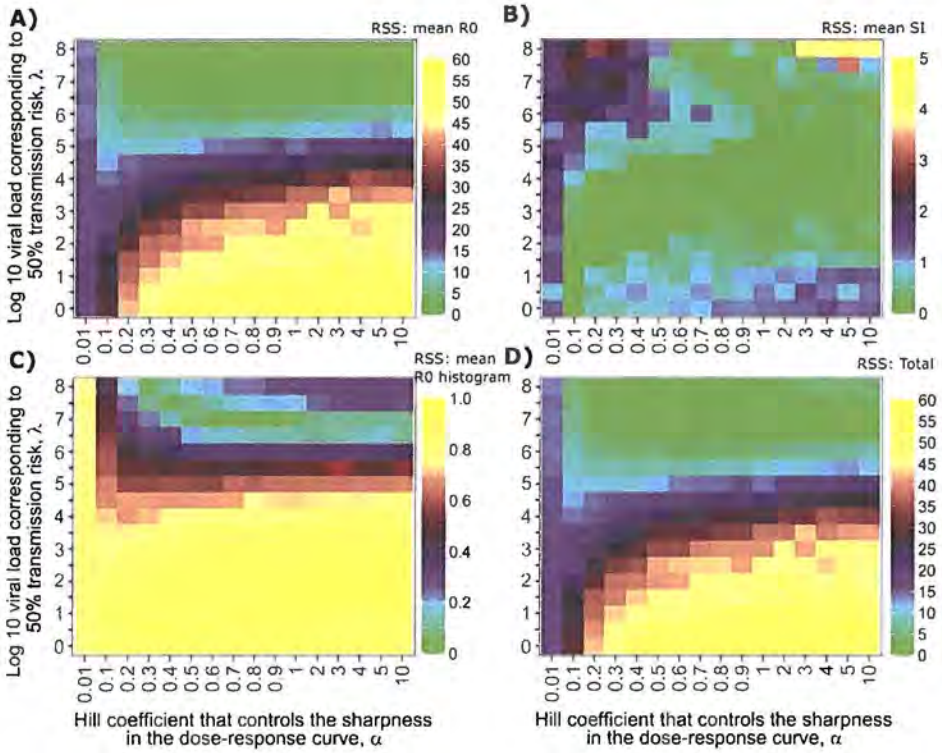
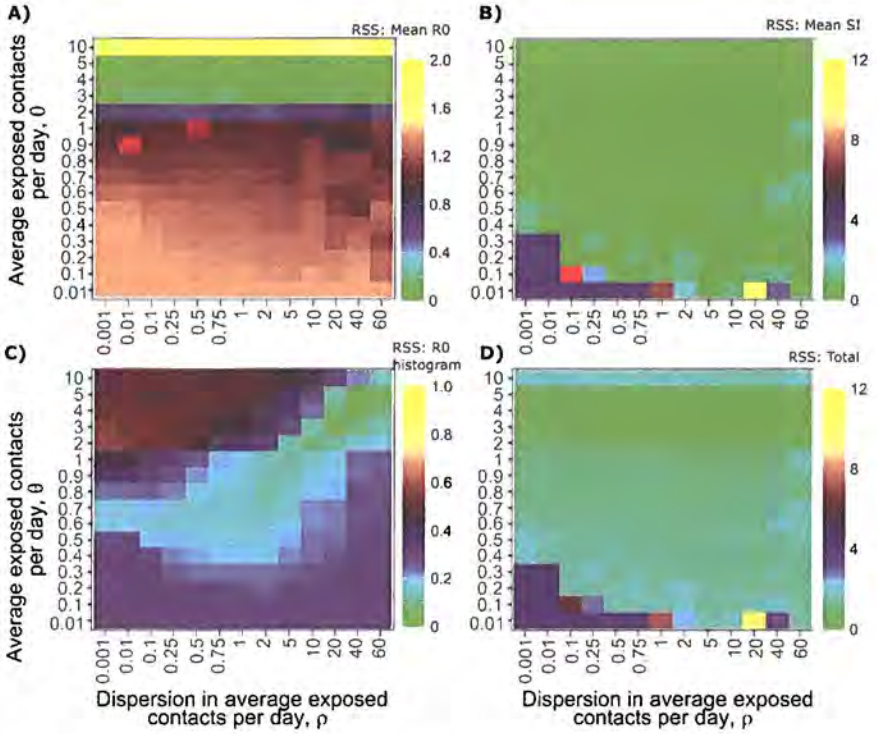


Fig S9. Sensitivity analysis of transmission curve parameter for model fit to SARS-CoV-2 data. Effects of varying transmission curve slope (x-axis) and TD50 for infectiousness (y-axis) on fit to **A.** Mean R0, **B.** Mean serial interval, **C.** Cumulative distribution function of individual R0, and **D.** Sum of Errors in A, B and C.

801



802
803

804 **Fig S10. Sensitivity analysis of contact network structure for model fit to SARS-CoV-2**
805 **data.** Effects of dispersion parameter (x-axis) and average exposed contacts per day (y-axis) on
806 fit to **A.** Mean R0, **B.** Mean serial interval, **C.** Cumulative distribution function of individual R0,
807 and **D.** Sum of Errors in A, B and C.

$Log_{10}\beta$ (virions^{-1} day^{-1})	δ (day^{-1} cells^{-k})	k (-)	$Log_{10}\pi$ (log_{10} day^{-1})	m (day^{-1} cells^{-1})	$Log_{10}\omega$ (day^{-1} cells^{-1})
-7.23	3.13	0.08	2.59	3.21	-4.55
0.2	0.02	0.02	0.05	0.33	0.01

Table S1: Population parameter estimates for simulated SARS-CoV-2 viral shedding dynamics. Parameters are from (doi: https://doi.org/10.1101/2020.04.10.20061325). The top row is the fixed effects (mean) and the bottom row is the standard deviation of the random effects. We also fixed r=10, δE=1/day, q=2.4×10-5/day and c=15/day.

References

1 *https://coronavirus.jhu.edu/map.html*.

2 He, X. *et al.* Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nat Med* **26**, 672-675, doi:10.1038/s41591-020-0869-5 (2020).

3 Ganyani, T. *et al.* Estimating the generation interval for coronavirus disease (COVID-19) based on symptom onset data, March 2020. *Euro Surveill* **25**, doi:10.2807/1560-7917.ES.2020.25.17.2000257 (2020).

4 Endo, A., Centre for the Mathematical Modelling of Infectious Diseases COVID-19 Working Group, Abbott, S., Kucharski, A. & Funk, S. Estimating the overdispersion in COVID-19 transmission using outbreak sizes outside China. *Wellcome Open Res* **5**, doi:10.12688/wellcomeopenres.15842.3 (2020).

5 Lloyd-Smith, J. O., Schreiber, S. J., Kopp, P. E. & Getz, W. M. Superspreading and the effect of individual variation on disease emergence. *Nature* **438**, 355-359, doi:10.1038/nature04153 (2005).

6 Bi, Q. *et al.* Epidemiology and transmission of COVID-19 in 391 cases and 1286 of their close contacts in Shenzhen, China: a retrospective cohort study. *Lancet Infect Dis*, doi:10.1016/S1473-3099(20)30287-5 (2020).

7 L., H., P., D., I., C. & al., e. High SARS-CoV-2 Attack Rate Following Exposure at a Choir Practice — Skagit County, Washington, March 2020. . *MMWR Morb Mortal Wkly Rep* **69:606–610.** (2020).

8 Park, S. Y. *et al.* Coronavirus Disease Outbreak in Call Center, South Korea. *Emerg Infect Dis* **26**, 1666-1670, doi:10.3201/eid2608.201274 (2020).

9 Cowling, B. J., Fang, V. J., Riley, S., Malik Peiris, J. S. & Leung, G. M. Estimation of the serial interval of influenza. *Epidemiology* **20**, 344-347, doi:10.1097/EDE.0b013e31819d1092 (2009).

10 Brugger, J. & Althaus, C. L. Transmission of and susceptibility to seasonal influenza in Switzerland from 2003 to 2015. *Epidemics* **30**, 100373, doi:10.1016/j.epidem.2019.100373 (2020).

11 Qi, L. *et al.* Factors associated with the duration of viral shedding in adults with COVID-19 outside of Wuhan, China: a retrospective cohort study. *Int J Infect Dis* **96**, 531-537, doi:10.1016/j.ijid.2020.05.045 (2020).

12 Cao, B. *et al.* A Trial of Lopinavir-Ritonavir in Adults Hospitalized with Severe Covid-19. *N Engl J Med*, doi:10.1056/NEJMoa2001282 (2020).

13 Pawelek, K. A. *et al.* Modeling within-host dynamics of influenza virus infection including immune responses. *PLoS Comput Biol* **8**, e1002588, doi:10.1371/journal.pcbi.1002588 (2012).

14 Memoli, M. J. *et al.* Validation of the wild-type influenza A human challenge model H1N1pdMIST: an A(H1N1)pdm09 dose-finding investigational new drug study. *Clin Infect Dis* **60**, 693-702, doi:10.1093/cid/ciu924 (2015).

15 Pebody, R. G. *et al.* Use of antiviral drugs to reduce household transmission of pandemic (H1N1) 2009, United Kingdom. *Emerg Infect Dis* **17**, 990-999, doi:10.3201/eid/1706.101161 (2011).

16 Goldstein, E. *et al.* Oseltamivir for treatment and prevention of pandemic influenza A/H1N1 virus infection in households, Milwaukee, 2009. *BMC Infect Dis* **10**, 211, doi:10.1186/1471-2334-10-211 (2010).

17 Mayer, B. T. *et al.* Estimating the Risk of Human Herpesvirus 6 and Cytomegalovirus Transmission to Ugandan Infants from Viral Shedding in Saliva by Household Contacts. *Viruses* **12**, doi:10.3390/v12020171 (2020).

18 Boucoiran, I. *et al.* Nonprimary Maternal Cytomegalovirus Infection After Viral Shedding in Infants. *Pediatr Infect Dis J* **37**, 627-631, doi:10.1097/INF.0000000000001877 (2018).

19 Corey, L. *et al.* Once-daily valacyclovir to reduce the risk of transmission of genital herpes. *N Engl J Med* **350**, 11-20, doi:10.1056/NEJMoa035144 (2004).

20 Rodger, A. J. *et al.* Risk of HIV transmission through condomless sex in serodifferent gay couples with the HIV-positive partner taking suppressive antiretroviral therapy (PARTNER): final results of a multicentre, prospective, observational study. *Lancet* **393**, 2428-2438, doi:10.1016/S0140-6736(19)30418-0 (2019).

21 Cohen, M. S. *et al.* Antiretroviral Therapy for the Prevention of HIV-1 Transmission. *N Engl J Med* **375**, 830-839, doi:10.1056/NEJMoa1600693 (2016).

22 Schiffer, J. T., Johnston, C., Wald, A. & Corey, L. An Early Test-and-Treat Strategy for Severe Acute Respiratory Syndrome Coronavirus 2. *Open Forum Infect Dis* **7**, ofaa232, doi:10.1093/ofid/ofaa232 (2020).

23 Leung, N. H. L. *et al.* Respiratory virus shedding in exhaled breath and efficacy of face masks. *Nat Med* **26**, 676-680, doi:10.1038/s41591-020-0843-2 (2020).

24 Goyal, A., Cardozo-Ojeda, E. & Schiffer, J. Potency and timing of antiviral therapy as determinants of duration of SARS CoV-2 shedding and intensity of inflammatory response. *medRxiv* **2020.04.10.20061325**, doi:10.1101/2020.04.10.20061325 (2020).

25 Wölfel, R. *et al.* Virological assessment of hospitalized patients with COVID-2019. *Nature* **581**, 465-469, doi:10.1038/s41586-020-2196-x (2020).

26 Lescure, F. X. *et al.* Clinical and virological data of the first cases of COVID-19 in Europe: a case series. *Lancet Infect Dis* **20**, 697-706, doi:10.1016/S1473-3099(20)30200-0 (2020).

27 Young, B. E. *et al.* Epidemiologic Features and Clinical Course of Patients Infected With SARS-CoV-2 in Singapore. *JAMA*, doi:10.1001/jama.2020.3204 (2020).

28 Kim, J. Y. *et al.* Viral Load Kinetics of SARS-CoV-2 Infection in First Two Patients in Korea. *J Korean Med Sci* **35**, e86, doi:10.3346/jkms.2020.35.e86 (2020).

29 Brouwer, A. F., Weir, M. H., Eisenberg, M. C., Meza, R. & Eisenberg, J. N. S. Dose-response relationships for environmentally mediated infectious disease transmission models. *PLoS Comput Biol* **13**, e1005481, doi:10.1371/journal.pcbi.1005481 (2017).

30 Lauer, S. A. *et al.* The Incubation Period of Coronavirus Disease 2019 (COVID-19) From Publicly Reported Confirmed Cases: Estimation and Application. *Ann Intern Med* **172**, 577-582, doi:10.7326/M20-0504 (2020).

31 Du, Z. *et al.* Serial Interval of COVID-19 among Publicly Reported Confirmed Cases. *Emerg Infect Dis* **26**, 1341-1343, doi:10.3201/eid2606.200357 (2020).

32 World Health Organization. Statement on the meeting of the International Health Regulations (2005) Emergency Committee regarding the outbreak of novel coronavirus (2019-nCoV). (2020).

33 Nishiura, H., Linton, N. M. & Akhmetzhanov, A. R. Serial interval of novel coronavirus (COVID-19) infections. *Int J Infect Dis* **93**, 284-286, doi:10.1016/j.ijid.2020.02.060 (2020).

34 Zhang, Y., Li, Y., Wang, L., Li, M. & Zhou, X. Evaluating Transmission Heterogeneity and Super-Spreading Event of COVID-19 in a Metropolis of China. *Int J Environ Res Public Health* **17**, doi:10.3390/ijerph17103705 (2020).

35 Dillon, A. *et al.* Clustering and superspreading potential of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infections in Hong Kong. *PREPRINT (Version 1) available at Research Square*, doi:10.21203/rs.3.rs-29548/v1 (2020).

36 Miller, D. *et al.* Full genome viral sequences inform patterns of SARS-CoV-2 spread into and within Israel. *medRxiv*, 2020.2005.2021.20104521, doi:10.1101/2020.05.21.20104521 (2020).

37 van Kampen, J. J. A. *et al.* Shedding of infectious virus in hospitalized patients with coronavirus disease-2019 (COVID-19): duration and key determinants. *medRxiv*, 2020.2006.2008.20125310, doi:10.1101/2020.06.08.20125310 (2020).

38 Baccam, P., Beauchemin, C., Macken, C. A., Hayden, F. G. & Perelson, A. S. Kinetics of influenza A virus infection in humans. *J Virol* **80**, 7590-7599, doi:10.1128/JVI.01623-05 (2006).

39 Lessler, J. *et al.* Outbreak of 2009 pandemic influenza A (H1N1) at a New York City school. *N Engl J Med* **361**, 2628-2636, doi:10.1056/NEJMoa0906089 (2009).

40 Opatowski, L. *et al.* Transmission characteristics of the 2009 H1N1 influenza pandemic: comparison of 8 Southern hemisphere countries. *PLoS Pathog* **7**, e1002225, doi:10.1371/journal.ppat.1002225 (2011).

41 Cowling, B. J. *et al.* The effective reproduction number of pandemic influenza: prospective estimation. *Epidemiology* **21**, 842-846, doi:10.1097/EDE.0b013e3181f20977 (2010).

927 42 Roberts, M. G. & Nishiura, H. Early estimation of the reproduction number in the
928 presence of imported cases: pandemic influenza H1N1-2009 in New Zealand. *PLoS One*
929 **6**, e17835, doi:10.1371/journal.pone.0017835 (2011).
930 43 Larremore, D. B. *et al.* Test sensitivity is secondary to frequency and turnaround time for
931 COVID-19 surveillance. *medRxiv*, 2020.2006.2022.20136309,
932 doi:10.1101/2020.06.22.20136309 (2020).
933 44 van Doremalen, N. *et al.* Aerosol and Surface Stability of SARS-CoV-2 as Compared
934 with SARS-CoV-1. *N Engl J Med*, doi:10.1056/NEJMc2004973 (2020).
935 45 Widders, A., Broom, A. & Broom, J. SARS-CoV-2: The viral shedding vs infectivity
936 dilemma. *Infect Dis Health*, doi:10.1016/j.idh.2020.05.002 (2020).
937 46 Huang, C.-G. *et al.* Relative COVID-19 viral persistence and antibody kinetics. *medRxiv*,
938 2020.2007.2001.20143917, doi:10.1101/2020.07.01.20143917 (2020).
939

Provisional death counts and excess mortality, January 2020 to February 2021

Released at 8:30 a.m. Eastern time in The Daily, Friday, May 14, 2021

COVID-19 continues to affect communities and families in Canada. Beyond deaths attributed to the disease itself, the pandemic could also have indirect consequences that increase or decrease the number of deaths as a result of various factors, including delayed medical procedures or increased substance use.

To understand both the direct and indirect consequences of the pandemic, it is important to measure excess mortality, which occurs when there are more deaths during a period of time than what would be expected for that period. It should be noted that, even without a pandemic, there is always some year-to-year variation in the number of people who die in a given week. This means that the number of expected deaths should fall within a certain range of values. There is evidence of excess mortality when weekly deaths are consistently higher than the expected number, but especially when they exceed the range of what would be expected over consecutive weeks.

As part of Statistics Canada's commitment to providing timely and relevant information on COVID-19 and its impact on Canadians, a new updated provisional dataset from the Canadian Vital Statistics Death Database, covering the period from January 2020 to February 2021 has been released today. Updates were also made to the provisional death estimates, which have been adjusted, where possible, to account for the incomplete nature of the counts. The provisional estimates will continue to be revised in future releases as more information is reported by provincial and territorial vital statistics agencies and as methods continue to be enhanced.

From January 2021 to early February 2021, there were 31,509 deaths in Canada. This amounts to 2.1%, or 658, more deaths than expected if there were no pandemic, after accounting for changes in the population, such as aging. While some of these excess deaths may be related to indirect effects of the pandemic or other unrelated factors, they are still largely explained by the deaths attributed directly to COVID-19.

The risk of severe outcomes due to COVID-19 varies depending on individual vulnerabilities. One of these susceptibilities is pre-existing health conditions. The Public Health Agency of Canada has advised that certain pre-existing conditions such as diabetes, chronic obstructive pulmonary disease, cancer and heart disease put individuals at higher risk of severe illness or death from COVID-19. In addition, the suggested Canadian vaccination rollout prioritizes vulnerable populations, including those with underlying conditions. The provisional data released today confirm that about 9 out of 10 Canadians who have died of COVID-19 had at least one other condition or complication, or comorbidity, reported on their medical certificate of death.

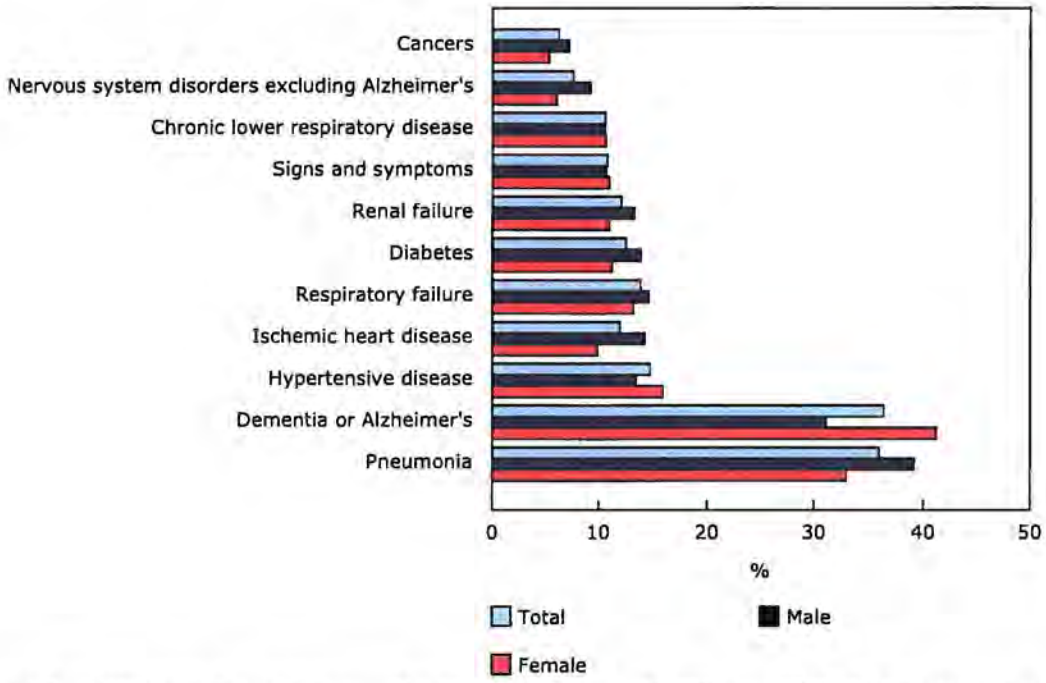
Almost 90% of people who died of COVID-19 in 2020 had a least one other comorbidity

Of the nearly 15,300 people who died of COVID-19 between March and December 2020, 89% had one or more other conditions or complications reported on their death certificate. In fact, almost two-thirds (65%) had two or more comorbidities and almost half (46%) had three or more comorbidities reported. These results, along with the specific conditions listed on the death certificate, highlight some of the populations in Canada most vulnerable to severe outcomes of COVID-19. Although individuals had pre-existing conditions, it does not imply that they were at risk of dying if there had been no COVID-19 infection.

Dementia or Alzheimer's is the most common comorbidity associated with deaths due to COVID-19

Of all COVID-19 deaths in 2020, dementia or Alzheimer's was reported on 36% of COVID-19 death certificates. However, the frequency with which it was reported varied between women and men. It was the most common comorbidity among women, reported on 41% of records, whereas for men, it was the second most common comorbidity, reported on 31% of records. These results can be partly explained by the age and sex profile of Canadians who died of COVID-19 in 2020: 63% of women who died of COVID-19 were older than 85, whereas 47% of men who died of COVID-19 were older than 85. According to the Public Health Agency of Canada, about 1 in 4 Canadians aged 85 or older live with dementia or Alzheimer's.

Chart 1
Common COVID-19 comorbidities by sex



Note(s): Comorbidities for deaths occurring between March 1, 2020, and December 31, 2020, where COVID-19 is the underlying cause of death.
Source(s): Canadian Vital Statistics – Death Database (2020) (3233).

Other common COVID-19 comorbidities reported on death certificates included pre-existing cardiovascular and respiratory conditions such as hypertensive diseases (15%), ischemic heart disease (14%) and chronic lower respiratory diseases (11%).

In addition to pre-existing conditions, comorbidities such as pneumonia and respiratory failure were also commonly reported. These, however, can also be the result of COVID-19 rather than underlying reasons why the individual had a severe COVID-19 outcome.

The prevalence of specific comorbidities varies with age

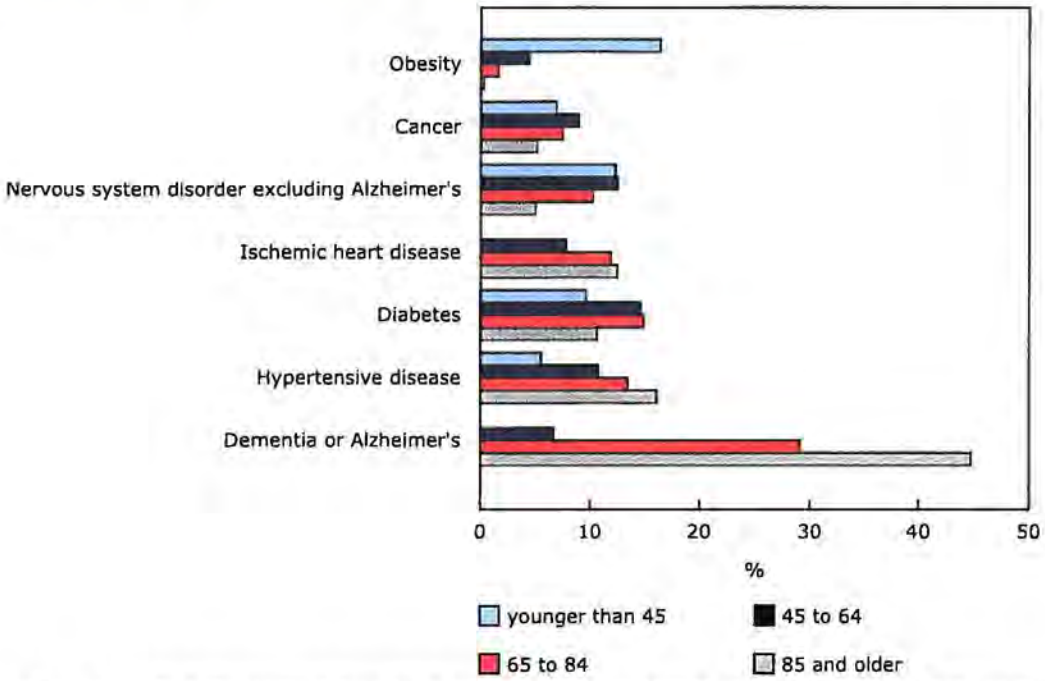
Since 94% of Canadians who died of COVID-19 in 2020 were older than 65, the overall trends for common COVID-19 comorbidities are largely driven by age. However, comorbidities were clearly present in the majority of COVID-19 deaths regardless of age.

For younger populations who died of COVID-19, diabetes was a common pre-existing condition reported on the death certificate. In fact, 15% of COVID-19 deaths among the 45-to-84 age group also had diabetes reported on the death certificate. This was lower for those younger than 45, with 9% of those who died of COVID-19 also having diabetes reported. However, given that, according to the 2019 Canadian Community Health Survey, 6% of Canadians younger than 49 have diabetes, this highlights the elevated risk facing younger populations with underlying conditions.

Another pre-existing comorbidity that was frequently reported on COVID-19 death certificates for individuals younger than 65 was nervous system disorders, such as Parkinson's or amyotrophic lateral sclerosis diseases (excluding Alzheimer's), with 13% among those in the 45-to-64 age group and 12% among those younger than 45.

Obesity was also frequently reported among COVID-19 deaths in the younger-than-45 age category. It should be noted that, in 2020, there were fewer than 100 deaths due to COVID-19 in this age group.

Chart 2
Frequency of chronic conditions reported on death certificates where death is due to COVID-19



Note(s): Comorbidities for deaths occurring between March 1, 2020, and December 31, 2020, where COVID-19 is the underlying cause of death.
Source(s): Canadian Vital Statistics – Death Database (2020) (3233).

The emergence of COVID-19 variants of concern and the rollout of COVID-19 vaccination strategies in Canada will likely result in further changes to the dynamics of the COVID-19 pandemic. According to a recent media report that analyzed surveillance data from the Public Health Agency of Canada, there is evidence that, as vaccination rates among those aged 80 and older are increasing, the number of COVID-19 deaths among this age group is decreasing. To better understand the evolving impacts of the pandemic on mortality in Canada, Statistics Canada will continue to provide timely information on a regular basis on excess deaths, causes of death and comorbidities as it becomes available.

Note to readers

In Canada, the Canadian Vital Statistics Death Database (CVSD) is the authoritative source for cause of death data, including COVID-19 deaths. In addition to identifying the underlying cause of death, the CVSD also includes information on the contributing causes and conditions (or comorbidities). In the context of a death caused by COVID-19, these comorbidities include diseases or conditions such as diabetes or hypertension that likely put those individuals at higher risk of death from COVID-19. While there may be challenges associated with the distinction between chronic conditions and other causes, and the nature of these with respect to COVID-19, the CVSD data provide additional insight on COVID-19-related deaths.

This analysis does not consider the relationship between the comorbidities listed on death certificates for deaths due to COVID-19. It is difficult to determine from the death certificate whether the condition was pre-existing or whether it resulted from a complication due to COVID-19.

Some deaths may have involved COVID-19 but were ultimately attributable to another disease such as ischemic heart disease, or an accidental injury such as a fall. COVID-19 is not considered as the underlying cause of these deaths, but the virus was reported as being present on the medical certificate of death, either as a contributing cause or condition.

Nevertheless, COVID-19 was identified as the underlying cause of death in the vast majority (91%) of cases where COVID-19 was reported on the medical certificate (15,360 of the 16,945 the COVID-19-involved deaths).

More information on the certification and classification of COVID-19 deaths can be found in the study, "COVID-19 death comorbidities in Canada."

About 12% of provisional information on causes of death for the reference period from January 2020 to February 2021 is unknown or pending investigation. For this reason, among others, the number of COVID-19 deaths published today may differ from the surveillance figures compiled by the Public Health Agency of Canada. More information on the two sources is provided in the article, "Provisional death count and excess mortality, January to August 2020."

The provisional figures on the number of deaths, the causes of death and excess mortality will continue to be updated as more information is reported to Statistics Canada by the provinces and territories and as further enhancements are made to the estimation models. More information on excess mortality during the COVID-19 pandemic in Canada is available in the article, "Excess mortality in Canada during the COVID-19 pandemic."

A number of different reference period have been used in this article:

- *References to the period of 2020, are to the period from January 1 to December 31, 2020. Excess deaths and COVID-19 deaths in Canada did not become prevalent until March 2020—which is when both excess deaths and COVID-19 deaths began to be tallied.*
- *References to the period from January 2021 to February 2021 are to the period from the week ending January 9, 2021, to the week ending February 6, 2021.*

Available tables: 13-10-0768-01, 13-10-0783-01, 13-10-0784-01, 13-10-0792-01 and 13-10-0810-01.

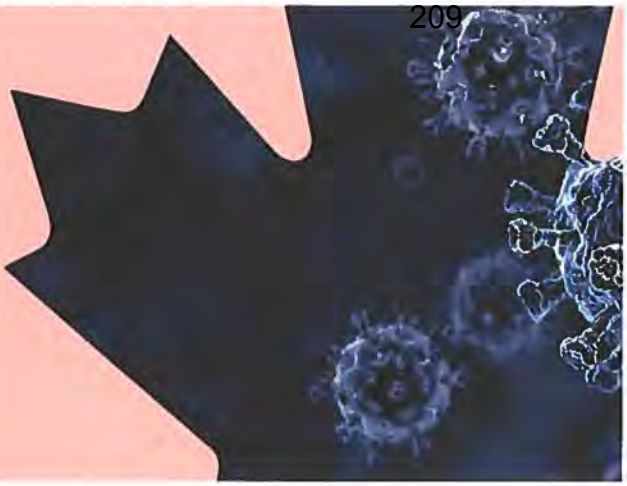
Definitions, data sources and methods: survey number 3233.

To facilitate the identification of trends in excess deaths by province and territory, the interactive visualization tool "Provisional weekly estimates of the number of deaths, expected number of deaths and excess mortality: Interactive Tool" has been updated.

To facilitate the identification of trends in the number of weekly deaths by age group and sex and by province and territory, the interactive visualization tool "Provisional weekly death counts: Interactive tool" has also been updated.

For more information, or to enquire about the concepts, methods or data quality of this release, contact us (toll-free 1-800-263-1136; 514-283-8300; **STATCAN.infostats-infostats.STATCAN@canada.ca**) or Media Relations (613-951-4636; **STATCAN.mediahotline-ligneinfomedias.STATCAN@canada.ca**).

People who are at risk of more severe disease or outcomes from COVID-19



While COVID-19 can make anyone sick, some Canadians are at risk of more severe disease or outcomes because of their age or if they have other medical conditions. If you are at risk of more severe disease or outcomes, you can take action to reduce your risk of getting sick from COVID-19.

Who is at risk of more severe disease or outcomes?

- Older adults (increasing risk with each decade, especially over 60 years)
- People of any age with chronic medical conditions including:
  - Lung disease
  - Heart disease
  - Hypertension (high blood pressure)
  - Diabetes
  - Kidney disease
  - Liver disease
  - Dementia
  - Stroke
- People of any age who are immunocompromised , including those:
  - With an underlying medical condition (e.g., cancer)
  - Taking medications that lower the immune system (e.g., chemotherapy)
- People living with obesity (BMI of 40 or higher)

THIS IS EXHIBIT "K" referred to in the Affidavit / Declaration of
Dr. Deena Hinshaw
affirmed
~~Sworn / Declared~~ before me this 12th day
of July A.D. 2021
H Veale
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public
Heather L. Veale
Barrister & Solicitor

Be prepared

- Learn about COVID-19 and stay informed by visiting **canada.ca/coronavirus.**
- Visit your **provincial/territorial** and municipal health websites to keep up to date about COVID-19 in your community.
- Stock up on the supplies you would need if you were to have to stay home for a few weeks, such as groceries, pet food and cleaning/disinfecting products.
- Talk with your health care provider about how to protect yourself and ensure you have enough of your prescribed medications and medical supplies.
- Prepare to stay connected with others by phone or email.
- Ask family, a neighbour or friend to help with essential errands (e.g., picking up prescriptions, buying groceries).
- Identify which services are available to deliver food or medications to your home.
- Monitor yourself for **symptoms.**

How to reduce your risk of COVID-19

- If possible, only leave your home for medically necessary appointments.
- Stay away from people who are sick.
- Avoid contact with others, especially those who have travelled or been exposed to the virus.
- If contact cannot be avoided, take the following precautions:
  - keep at least 2 metres between yourself and the other people
  - give a friendly wave instead of a handshake, kiss or hug
  - keep interactions brief

- Clean hands frequently with soap and water for at least 20 seconds or, if not available, use an **alcohol-based hand sanitizer** containing at least 60% alcohol.
- Avoid touching your mouth, nose, and eyes and/or food with your hands.
- Carry an **alcohol-based hand sanitizer** containing at least 60% alcohol when you are outside of your home.
- Avoid touching high-touch surfaces such as doorknobs, handrails and elevator buttons in public places.
- If you need to touch surfaces in public places, use a tissue or your sleeve to cover your hand.
- At least once daily, clean and disinfect surfaces that you touch often, like toilets, bedside tables, doorknobs, phones and television remotes.
- To disinfect, use only **approved hard-surface disinfectants** that have a Drug Identification Number (DIN). A DIN is an 8-digit number given by Health Canada that confirms the disinfectant product is approved and safe for use in Canada.
- When approved hard surface disinfectants are not available for household disinfection, a diluted bleach solution can be prepared in accordance with the instructions on the label, or in a ratio of 5 millilitres (mL) of bleach per 250 mL of water OR 20 mL of bleach per litre of water. This ratio is based on bleach containing 5% sodium hypochlorite, to give a 0.1% sodium hypochlorite solution. Follow instructions for **proper handling of household (chlorine) bleach**.
- If they can withstand the use of liquids for disinfection, high-touch electronic devices (e.g., keyboards, touch screens) may be disinfected with 70% alcohol at least daily.
- Remind others who are sick, or may have been exposed to the virus, to stay away.
- Avoid crowds and large gatherings.
- Avoid cruises and non-essential travel outside of Canada.

What to do if you get a symptom of COVID-19

- **Symptoms** of COVID-19 can:
  - take up to 14 days to appear after exposure to the virus
  - be very mild or more serious
  - vary from person to person
- If you develop a **symptom**, stay home and call your health care provider or local public health unit and tell them about your symptoms.
- Always call ahead before going to see a health provider or health care facility so that they can keep others from being exposed.
- The following symptoms should be considered urgent:
  - significant difficulty breathing (e.g., can't catch breath, gasping)
  - chest pain or pressure
  - new confusion or difficulty waking up
- If you develop these urgent symptoms, call 911 or your local emergency help line and inform them that you may have COVID-19 and are at high risk for complications.

We can all do our part in preventing the spread of COVID-19. For more information:

Canada.ca/coronavirus
or contact 1-833-784-4397

Website Labeled Figures – COVID-19

Note: Data included in the interactive data application are up-to-date as of end of day July 06, 2021, unless stated otherwise.

Figure 1

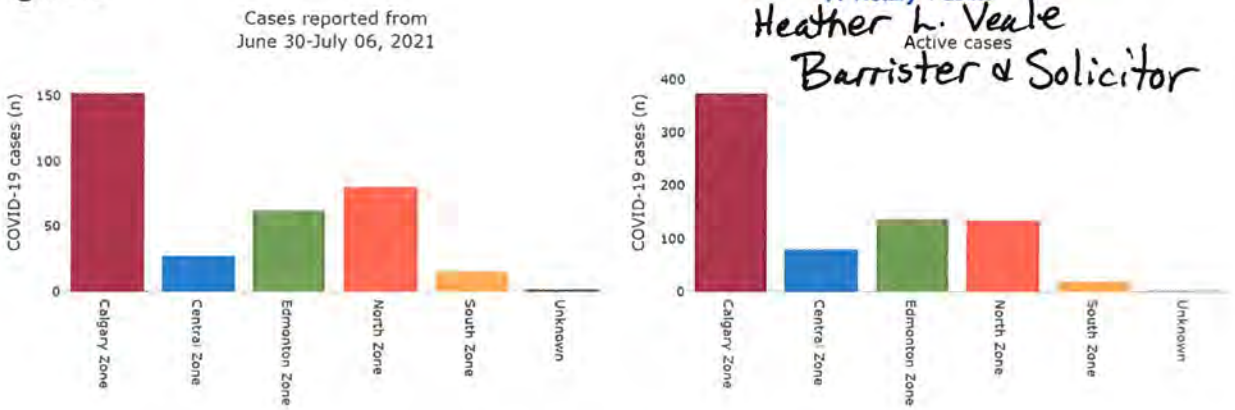


Figure 1: COVID-19 cases in Alberta by zone. First and second panels display new (from June 30-July 06, 2021) and active cases, respectively. Cases without a postal code or incorrect postal codes are labelled as unknown. Cases are under investigation and numbers may fluctuate as cases are resolved.

Figure 2

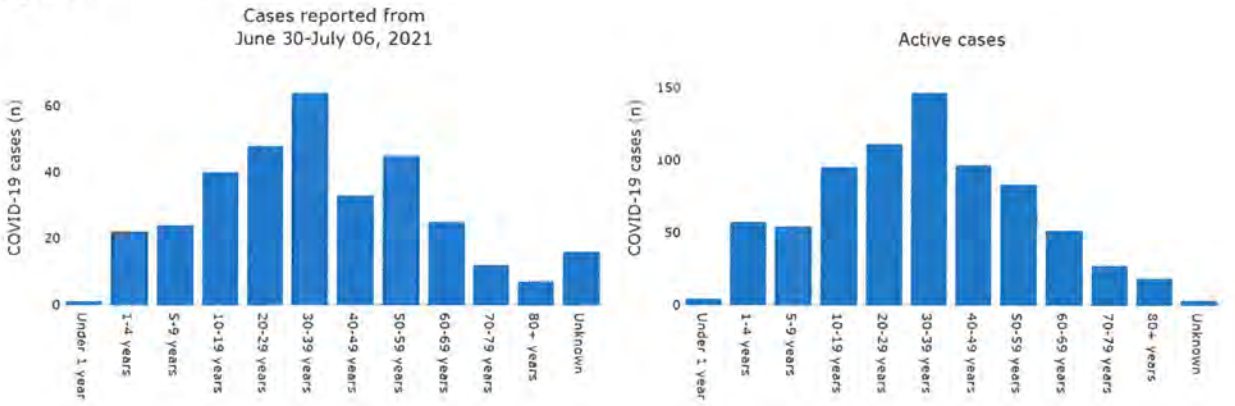


Figure 2: COVID-19 cases in Alberta by age group. First and second panels display new (from June 30-July 06, 2021) and active cases, respectively. Cases are under investigation and numbers may fluctuate as cases are resolved.

Figure 3

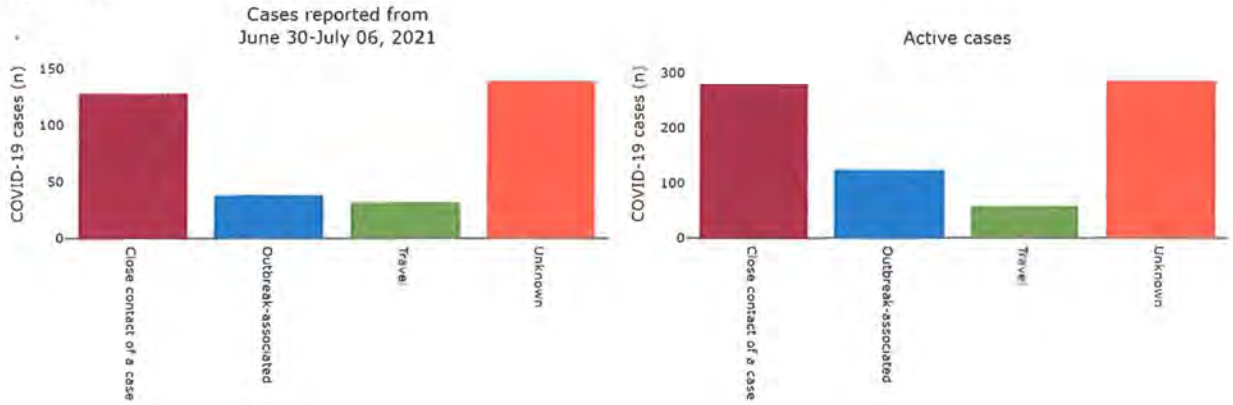


Figure 3: COVID-19 cases in Alberta by route of suspected acquisition. First and second panels display new (from June 30-July 06, 2021) and active cases, respectively. Cases are under investigation and numbers may fluctuate as cases are resolved.

Figure 4

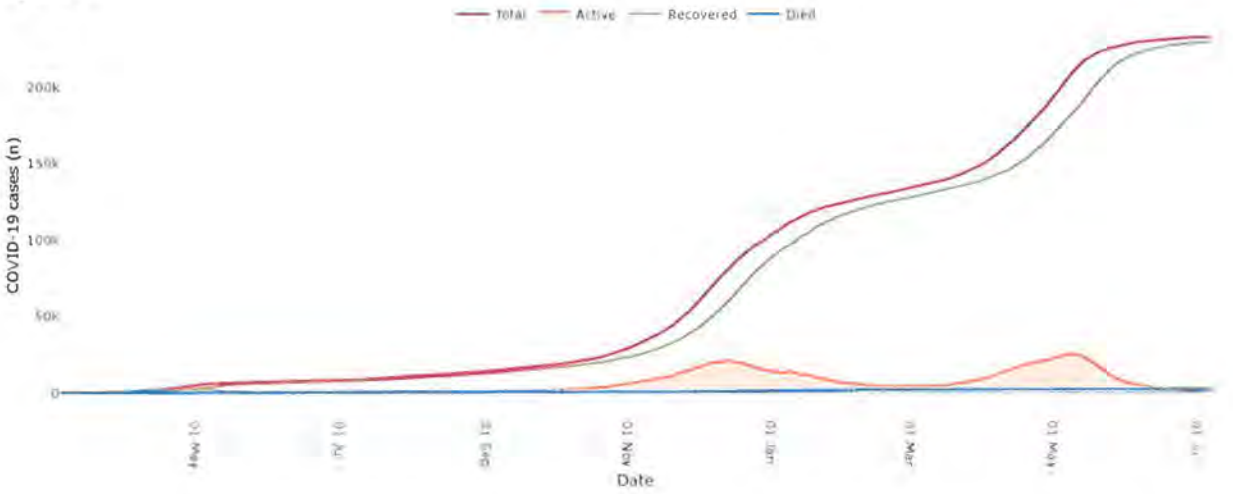


Figure 4: COVID-19 cases in Alberta by day and case status. Recovered is based on the assumption that a person is recovered 14 days after a particular date (see data notes tab), if they did not experience severe outcomes (hospitalized or deceased). Cases are under investigation and numbers may fluctuate as cases are resolved. Data included up to end of day July 06, 2021.

Figure 5

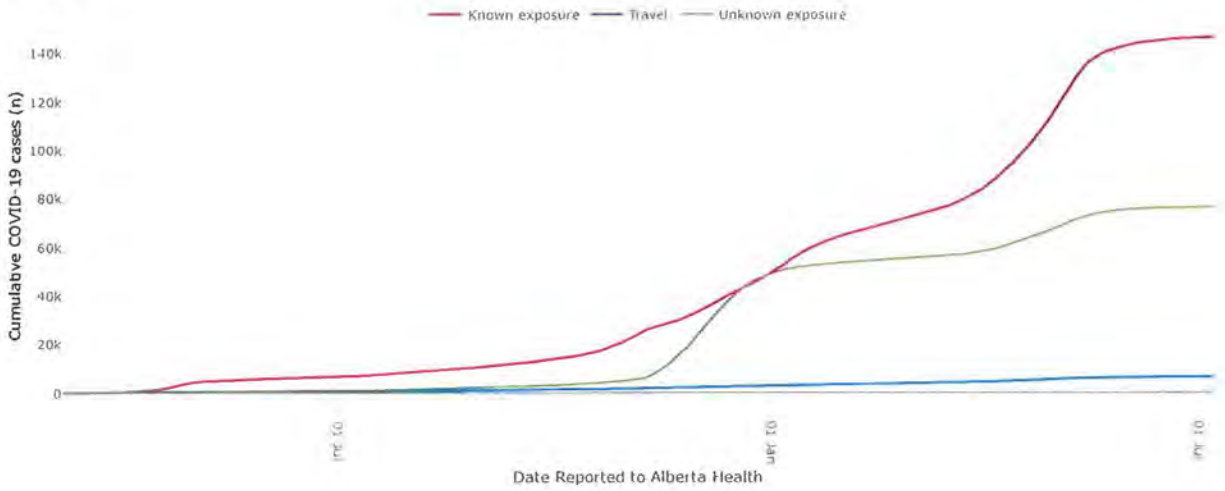


Figure 5: Cumulative COVID-19 cases in Alberta by route of suspected acquisition. Only includes COVID-19 cases where case report forms have been received. Data included up to end of day July 06, 2021.

Figure 6

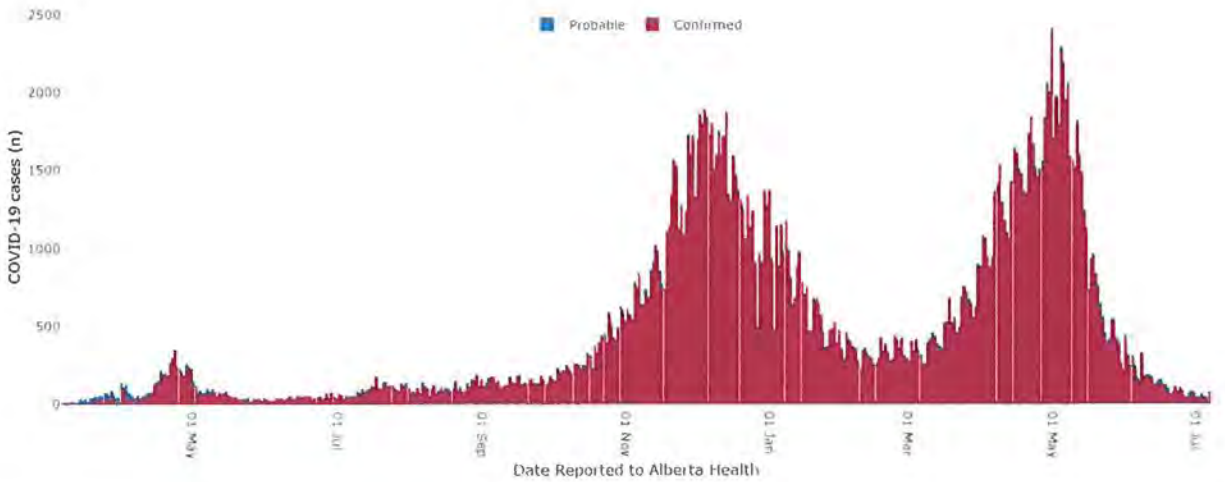


Figure 6: COVID-19 cases in Alberta by day and case status. Probable cases include cases where the lab confirmation is pending. Data included up to end of day July 06, 2021.

Figure 7

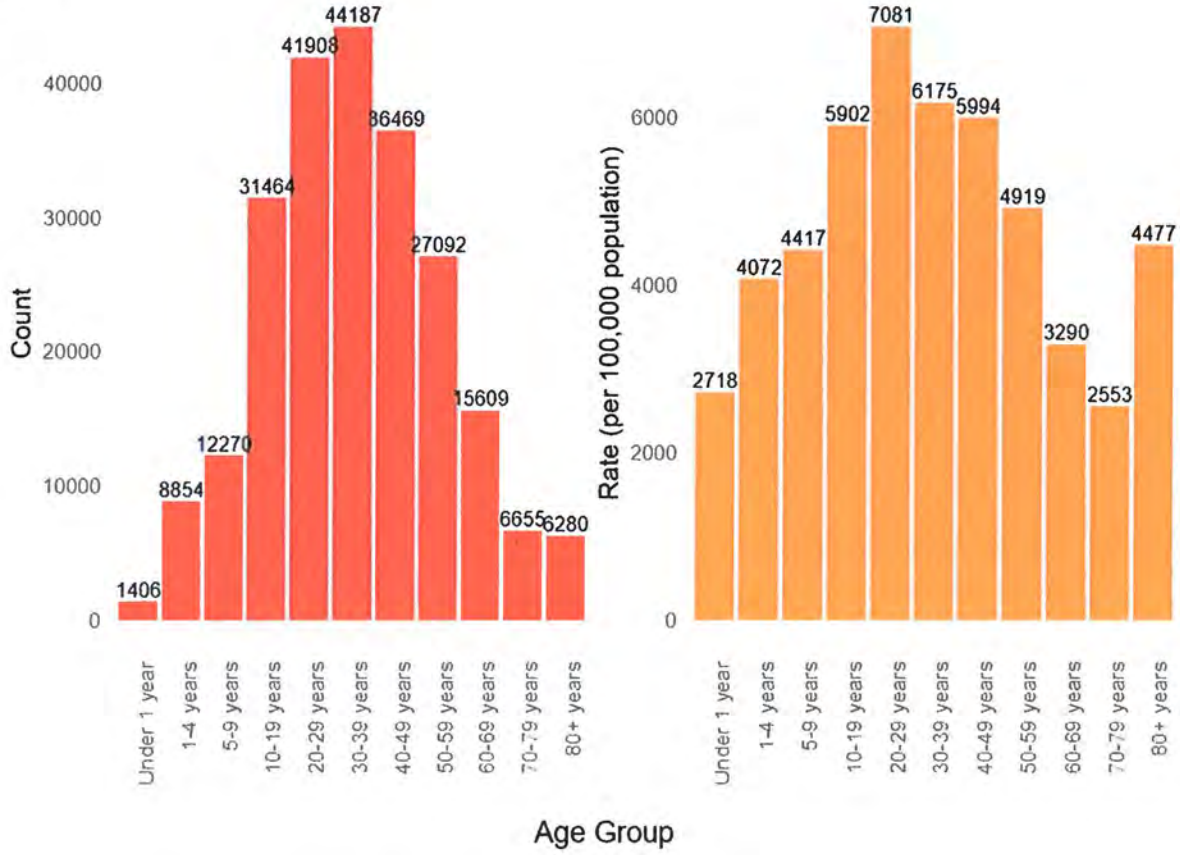


Figure 7: Number and rate of COVID-19 cases in Alberta by age group

Figure 8

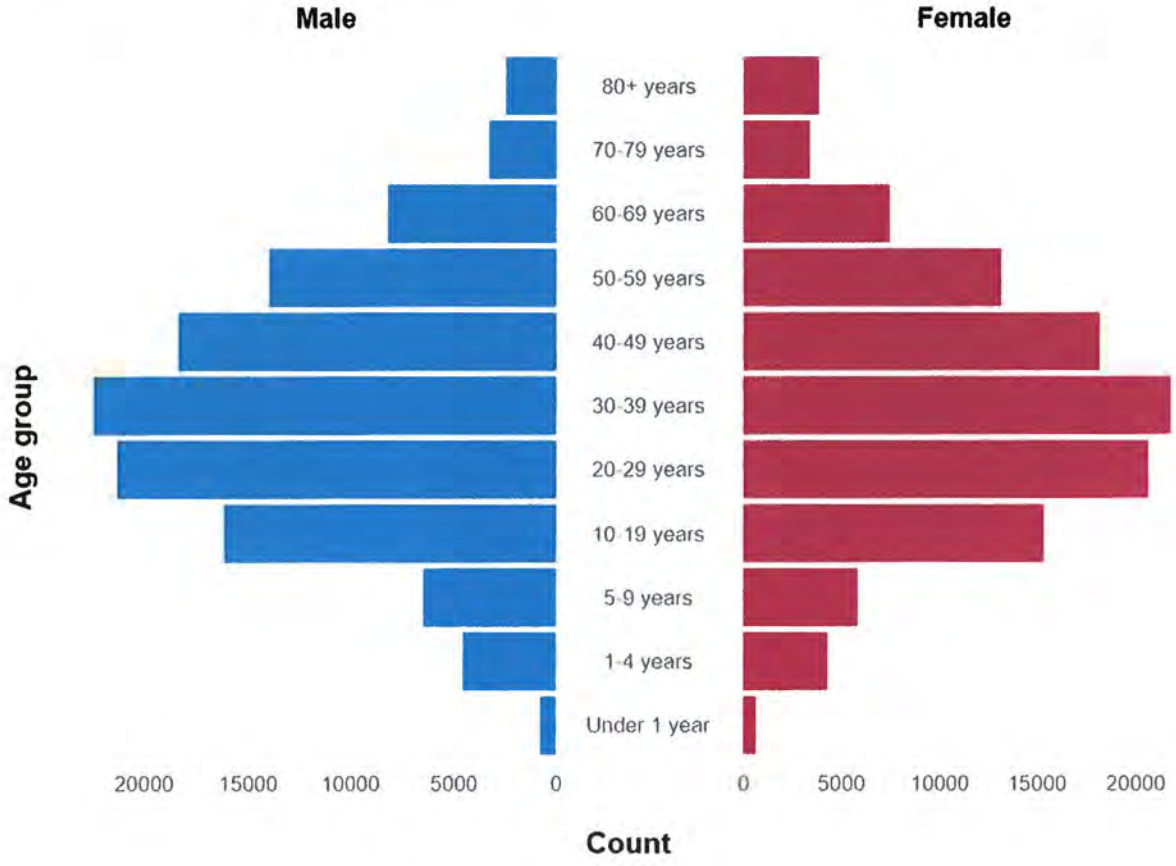


Figure 8: COVID-19 cases in Alberta by age group and gender

Table 1

Table 1. COVID-19 cases in Alberta by age group and gender

	Gender							
	Female		Male		Unknown		All	
Age	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Under 1 year	651	0	752	0	3	0	1,406	1
1-4 years	4,289	2	4,559	2	6	0	8,854	4
5-9 years	5,818	3	6,449	3	3	0	12,270	5
10-19 years	15,316	7	16,129	7	19	0	31,464	14
20-29 years	20,606	9	21,273	9	29	0	41,908	18
30-39 years	21,748	9	22,429	10	10	0	44,187	19
40-49 years	18,128	8	18,336	8	5	0	36,469	16
50-59 years	13,123	6	13,962	6	7	0	27,092	12
60-69 years	7,420	3	8,186	4	3	0	15,609	7
70-79 years	3,376	1	3,278	1	1	0	6,655	3
80+ years	3,834	2	2,445	1	1	0	6,280	3
Unknown	65	0	63	0	14	0	142	0
All	114,374	49	117,861	51	101	0	232,336	100

Figure 9

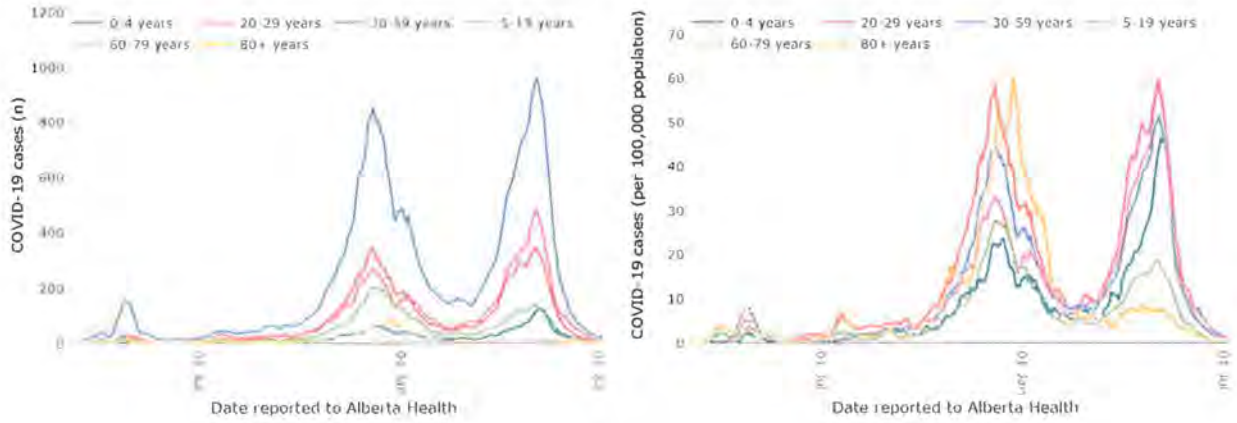


Figure 9: COVID-19 cases in Alberta by age group. First and second panels display counts (7-day rolling average) and rate per 100,000 (7-day rolling average), respectively.

Table 2

Healthcare Workers

Table 2. Healthcare workers among COVID-19 cases

	Total	Active	Recovered	Died
Calgary Zone	4546	9	4533	4
Central Zone	1000	0	1000	0
Edmonton Zone	5249	3	5243	3
North Zone	936	2	934	0
South Zone	656	0	655	1
Alberta	12387	14	12365	8

Note:
Status of Healthcare workers is self-reported and might be different from other sources. Please note these are not necessarily healthcare workers who were infected at work.

Table 6

Table 6. Number and percent of health conditions among COVID-19 deaths. Data updated on 2021-07-06.

Condition	Count	Percent
Hypertension	1944	84.3%
Cardio-Vascular Diseases	1205	52.2%
Renal Diseases	1158	50.2%
Dementia	1055	45.7%
Diabetes	1040	45.1%
Respiratory Diseases	941	40.8%
Cancer	552	23.9%
Stroke	457	19.8%
Liver Diseases	102	4.4%
Immuno-Deficiency Diseases	66	2.9%

Note:
One individual can have multiple conditions.

Tab: Severe Outcomes – Figure 12

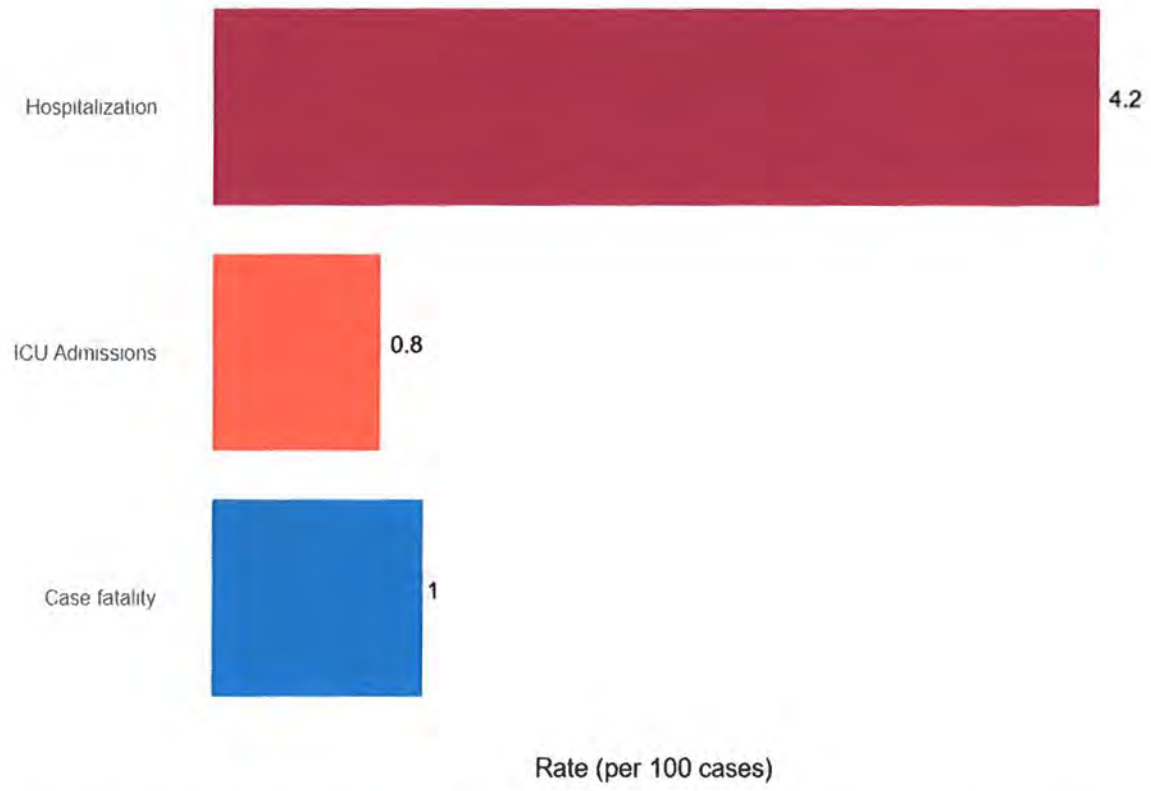


Figure 12: Rate of total hospitalizations, ICU admissions, and deaths among COVID-19 cases in Alberta

Tab: Severe Outcomes – Figure 13

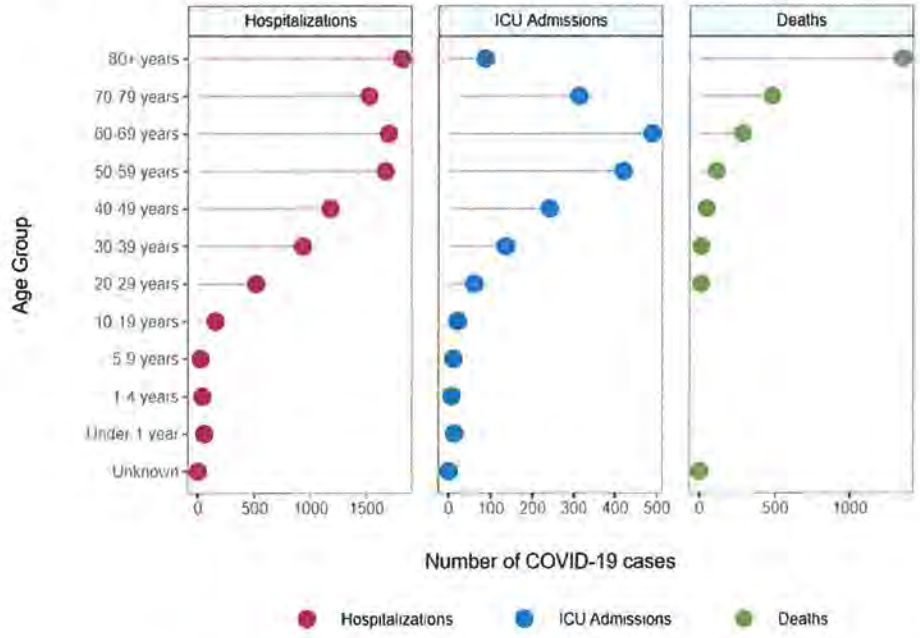


Figure 13: Total hospitalizations, ICU admissions and deaths (ever) among COVID-19 cases in Alberta by age group. Each ICU admission is also included in the total number of hospitalizations.This is based on totals rather than current hospitalizations and ICU admissions.

Tab: Severe Outcomes – Table 5

Table 5. Total Hospitalizations, ICU admissions and deaths (ever) among COVID-19 cases in Alberta by age group

Age Group	Cases	Hospitalized			ICU			Deaths		
	Count	Count	Case rate	Pop. rate	Count	Case rate	Pop. rate	Count	Case rate	Pop. rate
Total	232336	9642	4.2	218.1	1811	0.8	41	2307	1	52.2
Under 1 year	1406	58	4.1	112.1	14	1	27.1	0	0	0
1-4 years	8854	42	0.5	19.3	8	0.1	3.7	0	0	0
5-9 years	12270	25	0.2	9	12	0.1	4.3	0	0	0
10-19 years	31464	159	0.5	29.8	22	0.1	4.1	0	0	0
20-29 years	41908	517	1.2	87.4	62	0.1	10.5	11	0	1.9
30-39 years	44187	930	2.1	130	137	0.3	19.1	14	0	2
40-49 years	36469	1178	3.2	193.6	242	0.7	39.8	48	0.1	7.9
50-59 years	27092	1676	6.2	304.3	421	1.6	76.4	114	0.4	20.7
60-69 years	15609	1703	10.9	359	490	3.1	103.3	285	1.8	60.1
70-79 years	6655	1529	23	586.6	314	4.7	120.5	481	7.2	184.5

80+ years	6280	1822	29	1298.9	88	1.4	62.7	1353	21.5	964.6
Unknown	142	3	2.1	NA	1	0.7	NA	1	0.7	NA

Tab: Severe Outcomes – Figure 14

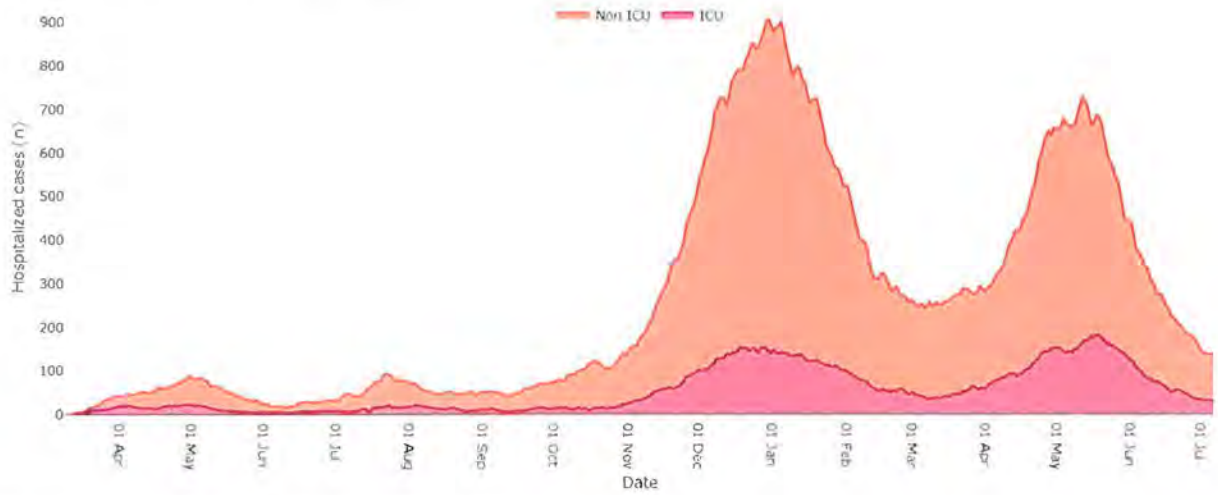


Figure 14: Number of current COVID-19 patients in hospital, ICU and non-ICU

Tab: Severe Outcomes – Figure 15

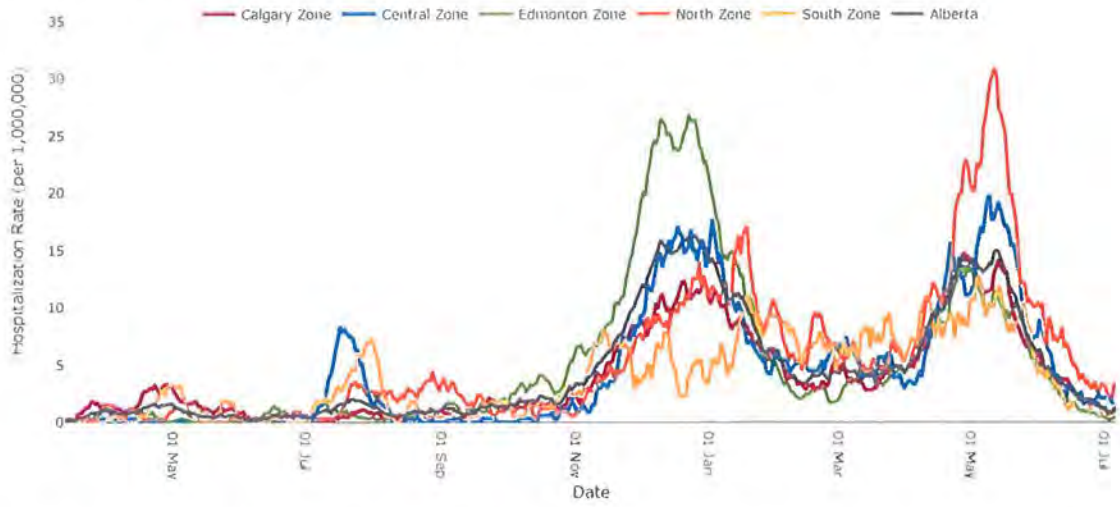


Figure 15: Rate of new hospitalizations (7-day rolling average, average of current day and previous 6 days) by admission date in Alberta and by zone

Tab: Severe Outcomes – Figure 16

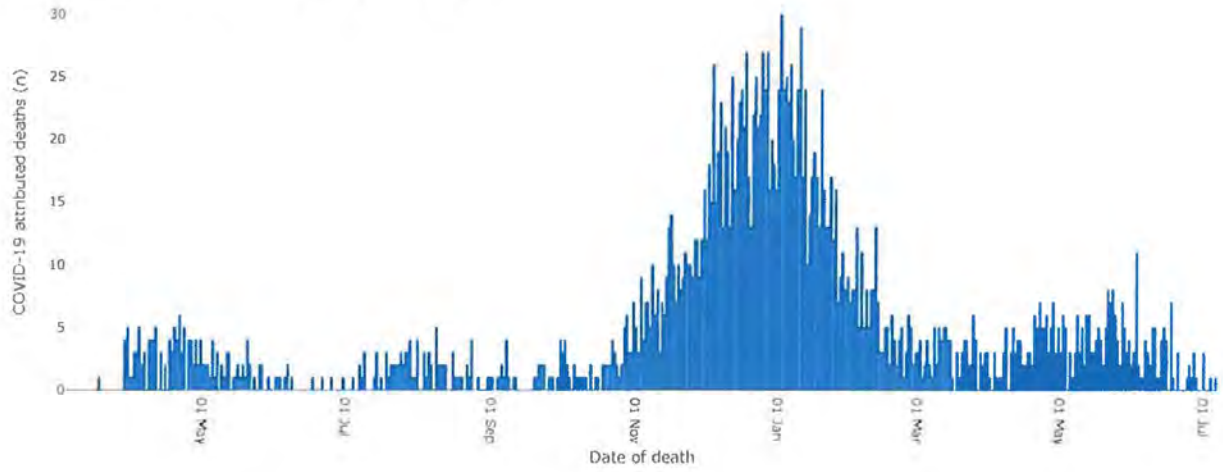


Figure 16: Daily COVID-19 attributed deaths. Data are subject to change; when death date is unavailable the date reported to Alberta Health is used until a death date is known.

Figure 17

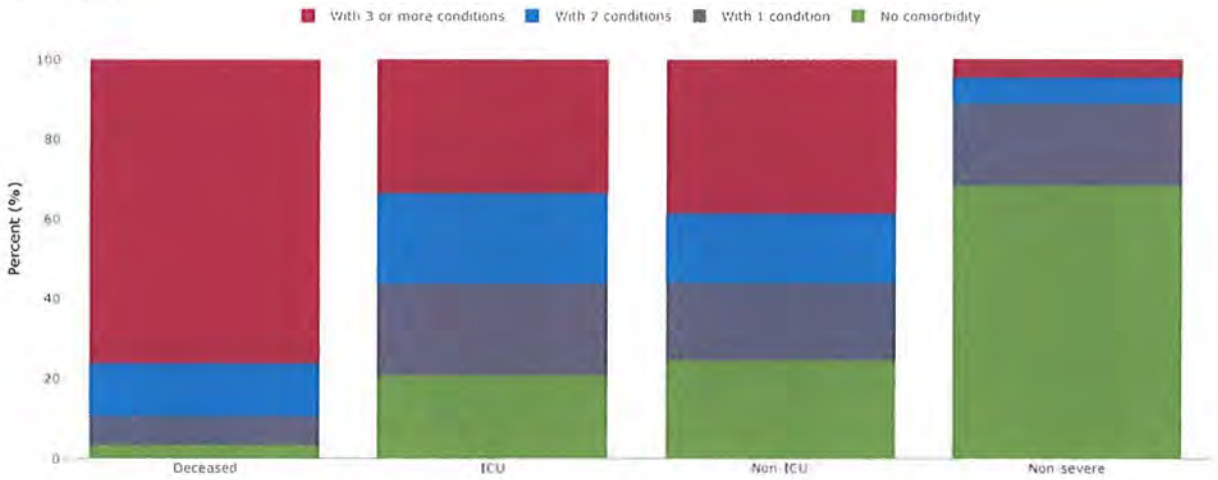


Figure 17: Percent of COVID-19 cases with no comorbidities, one comorbidity, two comorbidities, or three or more comorbidities by case severity (non-severe, hospitalized but non-ICU, ICU but not deceased, and deceased), all age groups and both sexes combined, all Alberta. Comorbitities included are: Diabetes, Hypertension, COPD, Cancer, Dementia, Stroke, Liver cirrhosis, Cardiovascular diseases (including IHD and Congestive heart failure), Chronic kidney disease, and Immuno-deficiency. Data updated on 2021-07-06.

Table 7

Table 7. Number and percent of COVID-19 cases with no comorbidities, one comorbidity, two comorbidities, or three or more comorbidities by case severity (non-severe, hospitalized but non-ICU, ICU but not deceased, and deceased), all age groups and both sexes combined, Alberta. Comorbitities included are: Diabetes, Hypertension, COPD, Cancer, Dementia, Stroke, Liver cirrhosis, Cardiovascular diseases (including IHD and Congestive heart failure), Chronic kidney disease, and Immuno-deficiency. Data updated on 2021-07-08.

	Non-Severe		Non-ICU		ICU		Deaths	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
No comorbidity	151645	68.4%	1677	24.5%	284	20.9%	75	3.3%
With 1 condition	45806	20.7%	1332	19.4%	310	22.8%	166	7.2%
With 2 conditions	14264	6.4%	1203	17.6%	312	22.9%	305	13.2%
With 3 or more conditions	10102	4.6%	2639	38.5%	455	33.4%	1761	76.3%

Table 8

Table 8. COVID-19 cases in Alberta by zone

Zone	Count	Percent
Calgary Zone	94,628	41
Central Zone	20,824	9
Edmonton Zone	77,779	33
North Zone	26,587	11
South Zone	12,507	5
Unknown	11	0
All	232,336	100

Table 9

Table 9. COVID-19 testing in Alberta

	Number (n)
Test volume	4,725,987
People tested	2,197,069

Table 10

Table 10. Number of people tested for COVID-19 in Alberta by zone

Zone	Count	Percent
Calgary Zone	887,981	40
Central Zone	199,890	9
Edmonton Zone	701,380	32
North Zone	213,879	10
South Zone	137,288	6
Unknown	56,651	3
All	2,197,069	100

Table 11

	Female		Male		Unknown		All	
Age	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
Under 1 year	7,680	0	8,755	0	20	0	16,455	1
1-4 years	44,781	2	49,725	2	51	0	94,557	4
5-9 years	72,699	3	78,882	4	97	0	151,678	7
10-19 years	145,940	7	148,008	7	309	0	294,257	13
20-29 years	177,402	8	157,071	7	556	0	335,029	15
30-39 years	207,993	9	185,691	8	533	0	394,217	18
40-49 years	165,456	8	144,780	7	431	0	310,667	14
50-59 years	137,642	6	115,922	5	324	0	253,888	12
60-69 years	99,233	5	88,104	4	193	0	187,530	9
70-79 years	47,580	2	43,101	2	61	0	90,742	4
80+ years	40,870	2	25,927	1	89	0	66,886	3
Unknown	413	0	415	0	334	0	1,163	0
All	1,147,689	52	1,046,381	48	2,998	0	2,197,069	100

Note:
Count represents the number of people tested

Figure 18

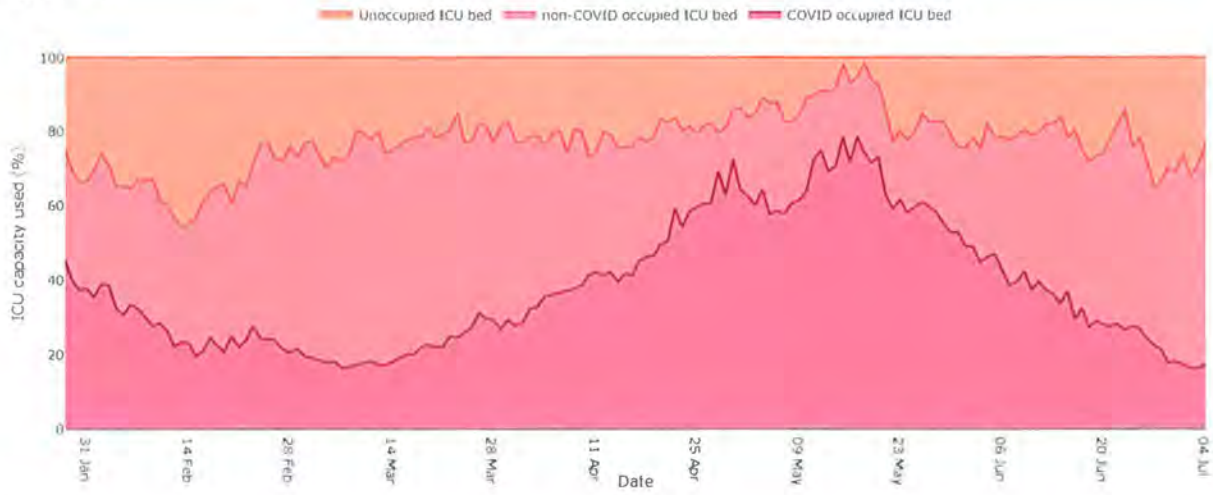


Figure 18: Intensive Care Unit (ICU) bed capacity. Data included may only be available at a lagged interval. As a result, the number of COVID occupied ICU beds on a particular day may not match the number reported elsewhere on the dashboard.

Figure 19

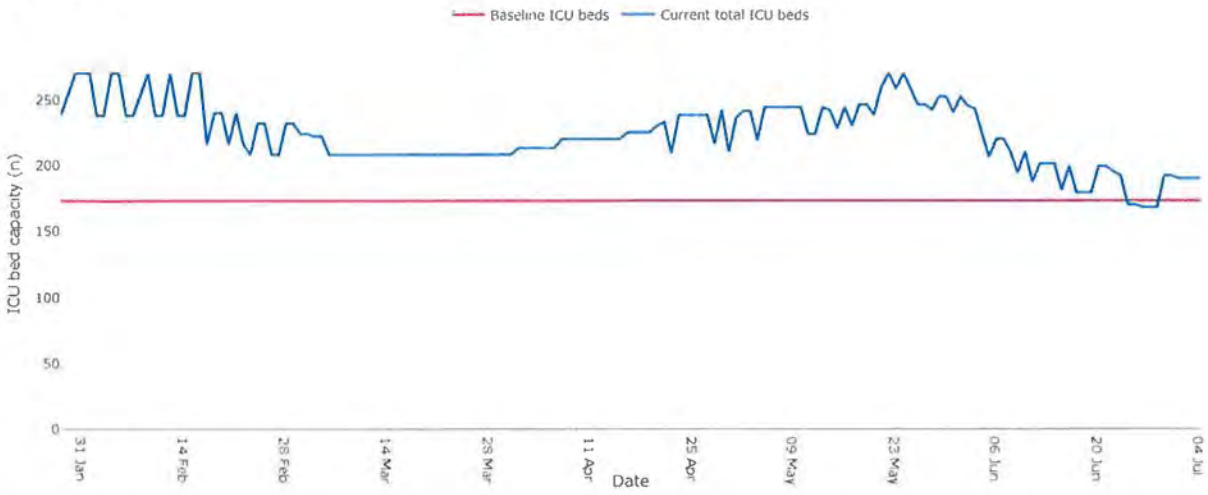


Figure 19: Total ICU bed capacity over time. Data included may only be available at a lagged interval. As a result, the number of COVID occupied ICU beds on a particular day may not match the number reported elsewhere on the dashboard.

Figure 20

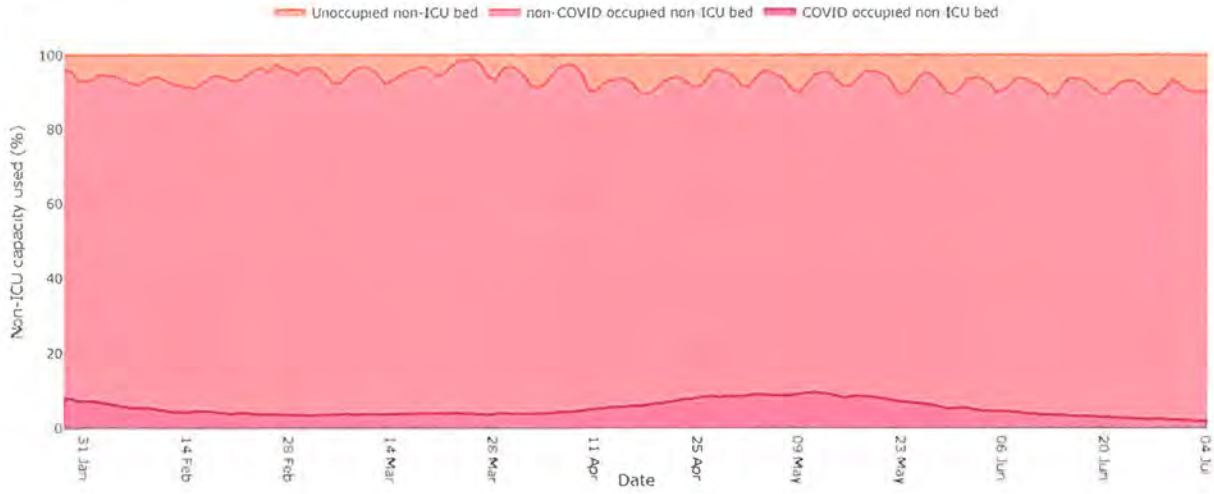


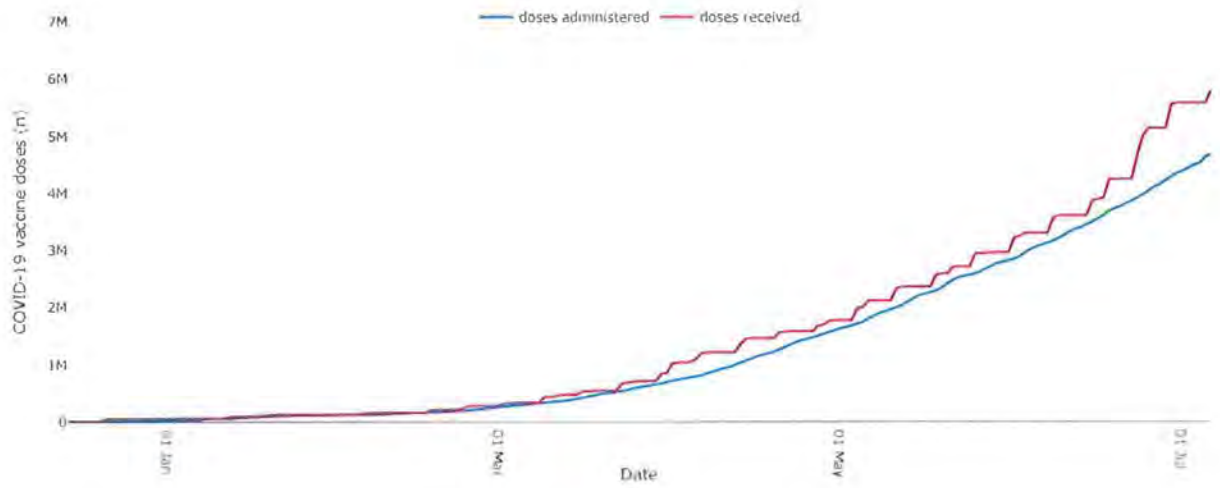
Figure 20: Non-ICU bed capacity. Data included may only be available at a lagged interval. As a result, the number of COVID occupied inpatient beds on a particular day may not match the number reported elsewhere on the dashboard. Data reflects the non-ICU hospital occupancy at the 14 largest hospitals, excluding pediatrics.

Website Labeled Figures – Vaccination

Note there is inconsistency with the sequential labeling of figures and tables on the alberta.ca COVID-19 Alberta statistics webpage. Vaccination specific figures and tables are below.

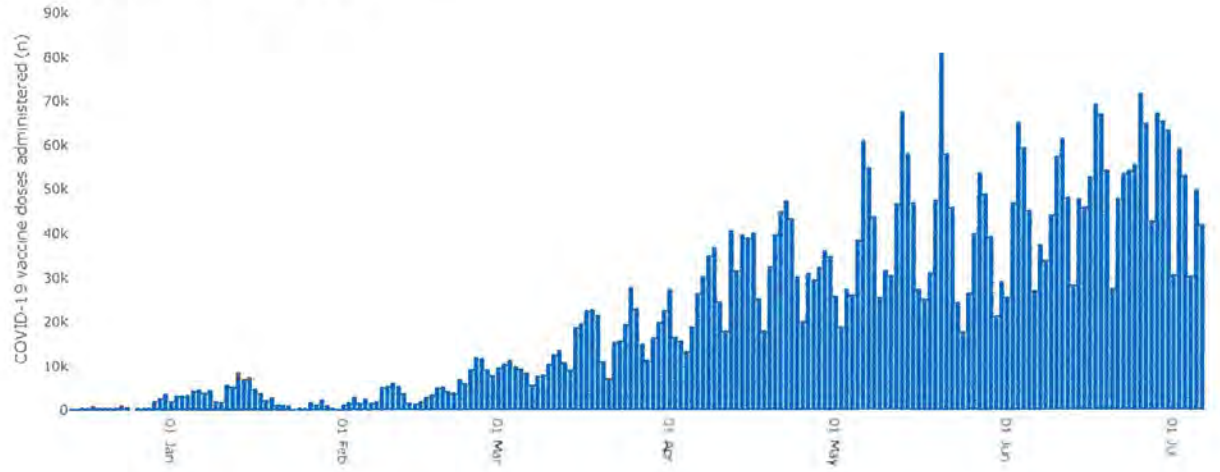
Tab: Vaccinations – Figure 1

- **4,673,582** doses of COVID-19 vaccine have been administered in Alberta
- **73.6** percent of 12+ population has received at least one dose (**62.6%** total population)
- **50.7** percent of 12+ population fully vaccinated (**43.1%** total population)



Cumulative COVID-19 vaccine doses received and administered by day in Alberta

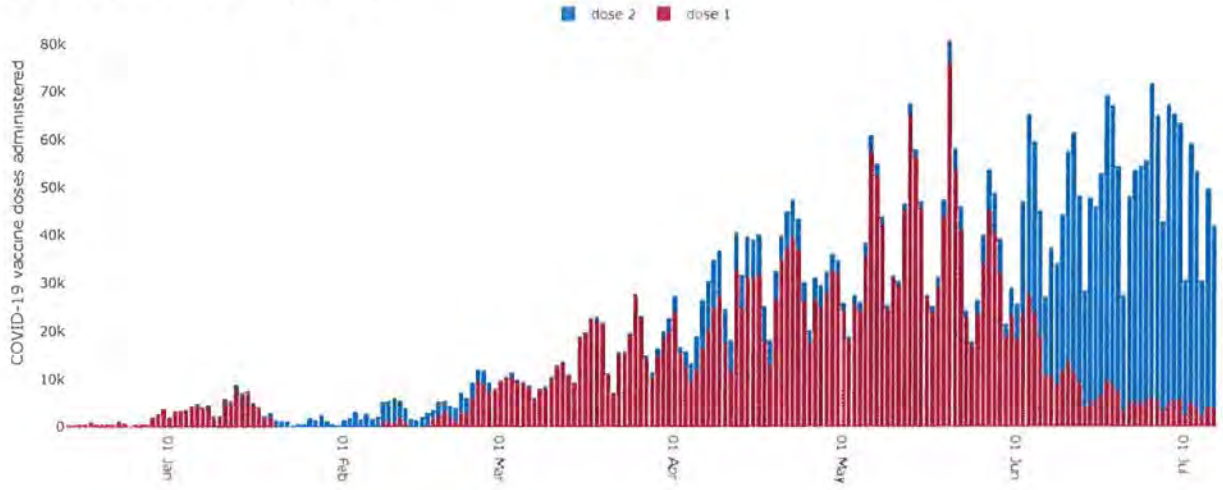
Tab: Vaccinations – Figure 2



Number of COVID-19 vaccine doses administered by day in Alberta

Note: Excludes aggregate doses reported by First Nations Inuit and Health Branch, Indigenous Services Canada

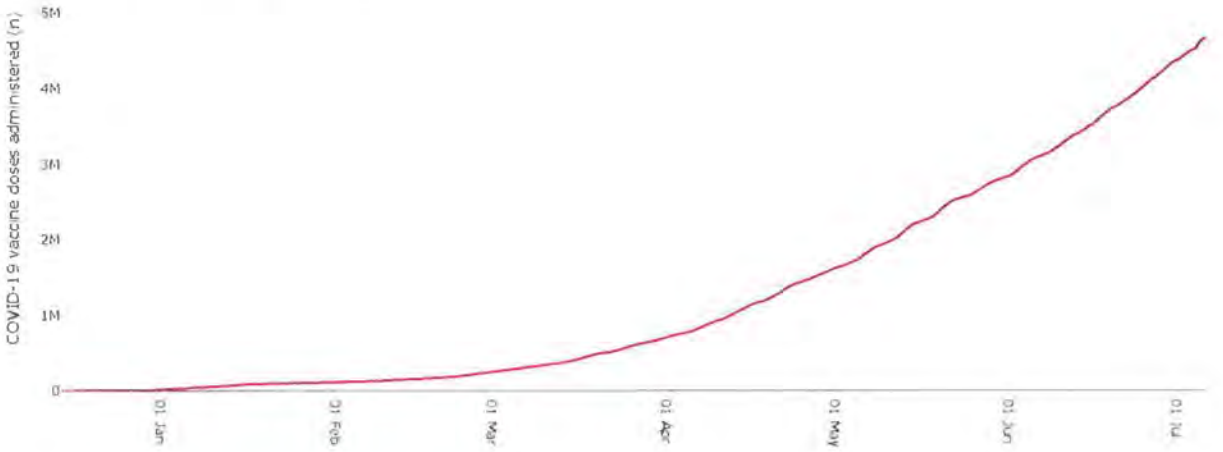
Tab: Vaccinations – Figure 3



Number of COVID-19 vaccine doses administered by dose 1 and dose 2 and day

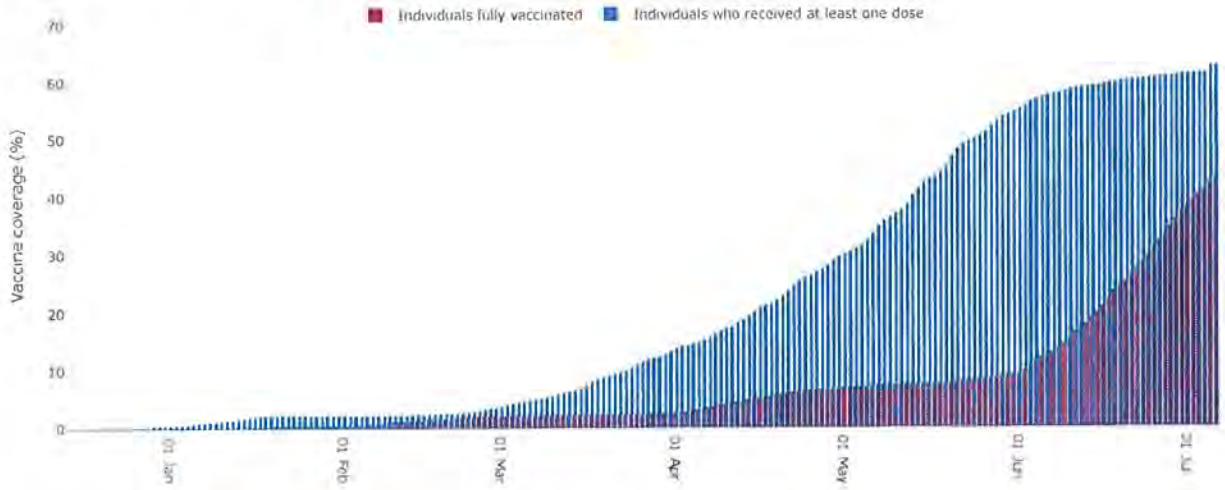
Note: Excludes aggregate doses reported by First Nations Inuit and Health Branch, Indigenous Services Canada

Tab: Vaccinations – Figure 4



Cumulative COVID-19 vaccine doses administered in Alberta

Tab: Vaccinations – Figure 5



Cumulative percent of individuals who received at least one dose or are fully vaccinated by day in Alberta

Tab: Vaccinations – Table 1

Table 1. Breakdown of COVID-19 vaccine doses administered by provider.

	Dose 1	Dose 2	Total administered
Alberta Health Services	1,557,660	997,278	2,554,938
Pharmacies	1,115,760	848,514	1,964,274
Other	94,762	59,608	154,370
Total	2,768,182	1,905,400	4,673,582

Note: Other includes submissions from First Nations communities and online submissions from other providers (e.g. physician clinics)

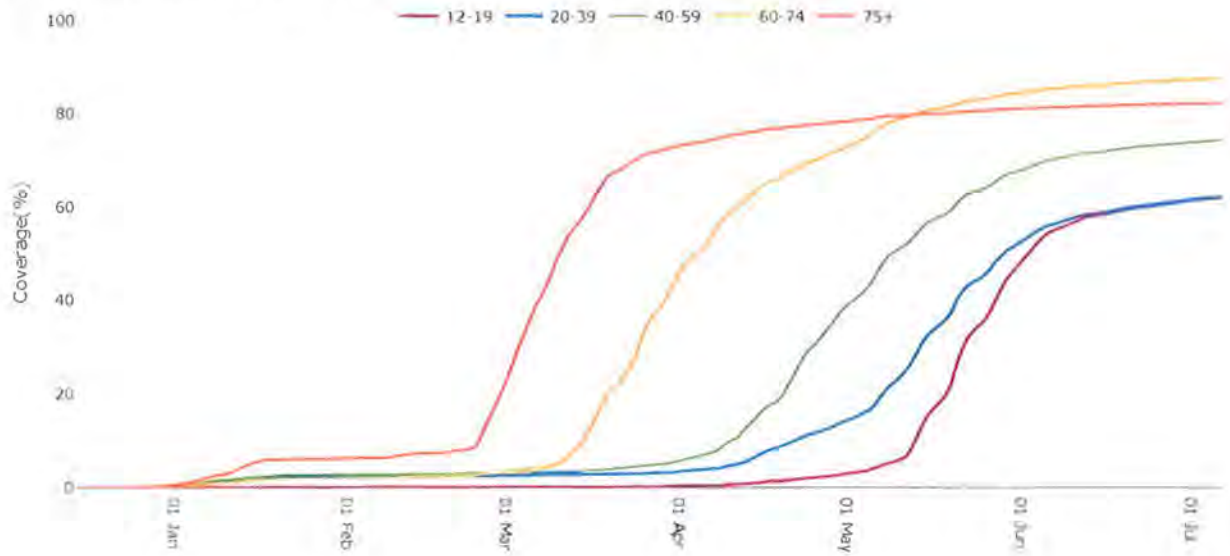
Tab: Vaccinations – Table 2

Table 2. Summary of COVID-19 vaccine doses administered and vaccine coverage by age group

Age group	Population	At least 1 dose	% of population with at least 1 dose	2 doses	% of population fully vaccinated	Total administered
00-11	660,747	0	0	0	0	0
12-14	162,530	97,390	59.9	40,421	24.9	137,811
15-19	256,743	162,319	63.2	76,842	29.9	239,161
20-24	277,328	168,092	60.6	87,644	31.6	255,736
25-29	314,508	185,297	58.9	103,388	32.9	288,685
30-34	356,228	220,173	61.8	131,591	36.9	351,764
35-39	359,302	238,562	66.4	146,252	40.7	384,814
40-44	319,889	225,108	70.4	148,470	46.4	373,578
45-49	288,547	211,062	73.2	144,832	50.2	355,894
50-54	266,491	204,327	76.7	147,361	55.3	351,688

55-59	284,260	221,353	77.9	167,824	59	389,177
60-64	264,339	221,840	83.9	181,001	68.5	402,841
65-69	210,073	186,913	89	166,627	79.3	353,540
70-74	157,657	143,896	91.3	134,055	85	277,951
75-79	102,977	92,999	90.3	88,712	86.2	181,711
80-84	68,566	61,740	90	59,082	86.2	120,822
85-89	44,034	39,462	89.6	37,878	86	77,340
90+	27,669	25,111	90.8	24,230	87.6	49,341
Unknown	NA	62,538	NA	19,190	NA	81,728
12+	3,761,140	2,768,182	73.6	1,905,400	50.7	4,673,582
ALL	4,421,887	2,768,182	62.6	1,905,400	43.1	4,673,582

Tab: Vaccinations – Figure 6



Cumulative coverage for at least one dose by age group

Tab: Vaccine Outcomes – Table 3 and Table 4

Table 3. COVID-19 vaccine effectiveness in Alberta by vaccine manufacturer

Vaccine	Vaccine Effectiveness: Partial (95% CI)	Vaccine Effectiveness: Complete (95% CI)
Moderna	82% (80 to 84%)	93% (90 to 96%)
Pfizer	73% (72 to 74%)	90% (88 to 91%)

Table 4. COVID-19 vaccine effectiveness against variants of concern in Alberta

Variant of Concern	Vaccine Effectiveness: Partial (95% CI)	Vaccine Effectiveness: Complete (95% CI)
B.1.1.7 UK Variant	73% (72 to 75%)	91% (89 to 92%)
P1 Brazilian Variant	75% (68 to 81%)	89% (77 to 95%)

Note:
(a) Vaccine effectiveness estimates include 95% confidence intervals (CI) and describes the protection against symptomatic infection. Vaccine effectiveness for hospitalization and death could have different estimates.
(b) Vaccine effectiveness estimates for AstraZeneca/other products and emerging variants are not provided due to limited sample sizes, which make estimates unstable and difficult to interpret. Information on other vaccine products and variants will be provided when estimates become stable
(c) Partial vaccination: people are considered partially vaccinated 14 days after their first dose of a two dose series (for vaccines that require two doses)
(d) Effectiveness: how well a vaccine prevents the outcome of interest in the real world

Tab: Vaccine Outcomes – Figure 10

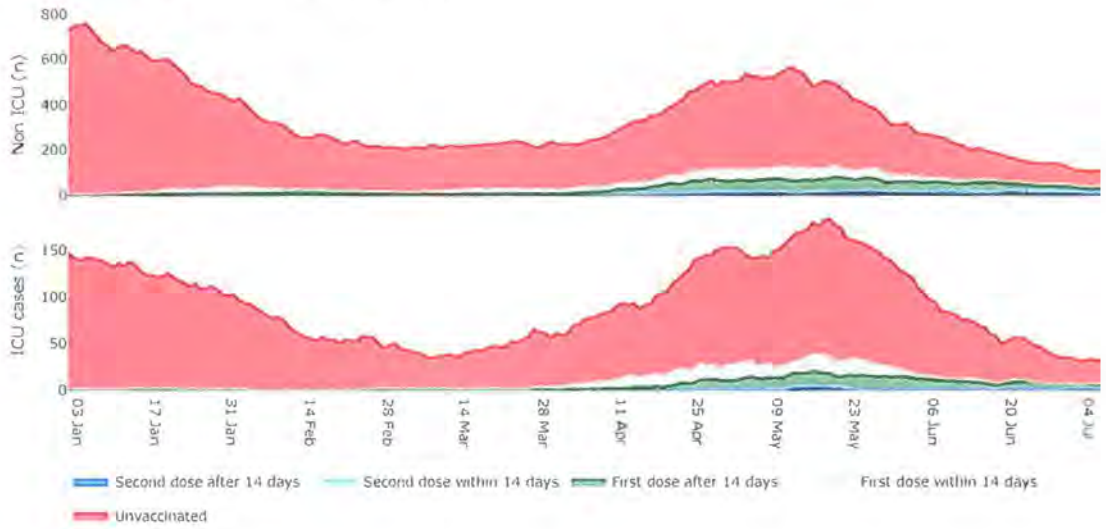


Figure 10: Current non-ICU (top) and ICU(bottom) by vaccine status.
Note:
Time from immunization date to COVID diagnosis date (or Date reported to Alberta Health). COVID-19 hospitalizations reported are not due to immunization events.

Tab: Vaccine Outcomes – Figure 11 (6 charts)

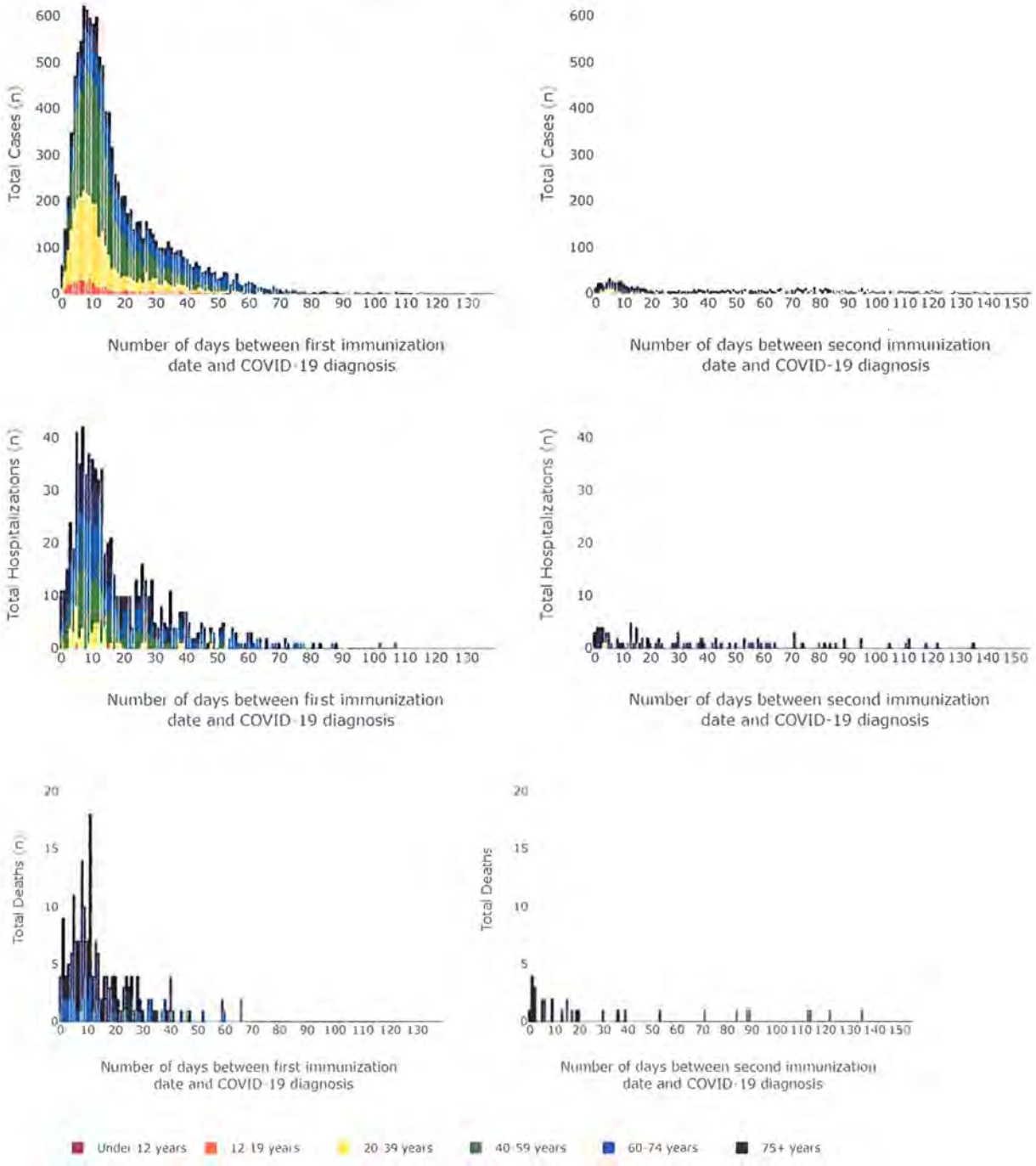


Figure 11: Time from first dose (left) and second dose immunization (right) to COVID-19 diagnosis by age group:
TOP: cases
MIDDLE: of those who became hospitalized
BOTTOM: of those who died from COVID-19
Note: First dose immunization also includes people who became a case prior to their second dose immunization date. COVID-19 hospitalizations reported are not due to immunization events.

Letters

RESEARCH LETTER

All-Cause Excess Mortality and COVID-19–Related Mortality Among US Adults Aged 25-44 Years, March-July 2020

Coronavirus disease 2019 (COVID-19) has caused a marked increase in all-cause deaths in the US, mostly among older adults.[1] Although the burden of COVID-19 among hospitalized younger adults has been described, fewer data focus on mortality in this demographic, owing to lower case-fatality rates.[2]

Excess mortality reflects the full burden of the pandemic that may go uncaptured due to uncoded COVID-19 and other pandemic-related deaths. Accordingly, we examined all-cause excess mortality and COVID-19–related mortality during the early pandemic period among adults aged 25 to 44 years. Because unintentional drug overdoses are the usual leading cause of death in this demographic, COVID-19 deaths were compared with unintentional opioid deaths.

Multimedia

Supplemental content

Methods | To determine excess mortality (the gap between observed and expected deaths), projected monthly expected deaths for 2020 were calculated by applying autoregressive integrated moving averages to US population and mortality counts (2015-2019).[3] We examined 2020 population and seasonal autoregressive integrated moving averages for each of the 10 US Department of Health and Human Services (HHS) regions, which comprise the entire US and are the smallest subdivisions for which 2020 age-stratified COVID-19 mortality data are currently available from the National Center for Health Statistics. Population covariates were used to calculate 95% CIs for expected deaths.

Observed all-cause mortality and COVID-19 mortality (coded as either "underlying cause" or "multiple cause" of death) for March 1, 2020, to July 31, 2020, were obtained from provisional National Center for Health Statistics data (released October 28, 2020).[4] Unintentional opioid overdose death counts (*International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* codes X41-X44, Y11-Y15, and T40.0-6) for the corresponding period of 2018 (the most recently available data) were assembled for each HHS region.[3] Incident rates per 100 000 person-months with 95% CIs were calculated for COVID-19 and unintentional opioid deaths using SAS, version 9.4. Statistical significance was defined as a 95% CI that excluded the null value.

This study used publicly available data and was not subject to institutional review approval.

Results | From March 1, 2020, to July 31, 2020, a total of 76 088 all-cause deaths occurred among US adults aged 25 to 44 years, which was 11 899 more than the expected 64 189 deaths (incident rate ratio, 1.19 [95% CI, 1.14-1.23]; Table). Nationally, excess mortality occurred in every month of the study period and overall in every HHS region (Table and eTable in the Supplement). Among adults aged 25 to 44 years, 4535 COVID-19 deaths were recorded, accounting for 38% (95% CI, 32%-48%) of the measured excess mortality.

During surges in HHS Region 2 (New York, New Jersey), the incident rate for all-cause mortality was 2.30 (95% CI, 2.03-2.66) and 80% of deaths were related to COVID-19; during surges in HHS Region 6 (Arkansas, Louisiana, New Mexico, Oklahoma, Texas), the incident rate was 1.46 (95% CI, 1.33-1.63) and 48% were related to COVID-19; and during surges in HHS Region 9 (Arizona, California, Hawaii, Nevada), the incident rate was 1.47 (95% CI, 1.36-1.59) and 40% were attributed to COVID-19.

In contrast, from March through July 2018, a total of 10 347 unintentional opioid deaths occurred among US adults aged 25 to 44 years. Deaths due to COVID-19 exceeded 2018 unintentional opioid deaths during 1 month in 2020 in HHS Region 2 (April), HHS Region 6 (July), and HHS Region 9 (July) and either exceeded (HHS Region 6) or were similar to (HHS Regions 2 and 9) unintentional opioid deaths during the entire study period (Table).

Discussion | The COVID-19 pandemic was associated with increases in all-cause mortality among US adults aged 25 to 44 years from March through July 2020. In 3 HHS regions, COVID-19 deaths were similar to or exceeded unintentional opioid overdoses that occurred during several corresponding months of 2018.

Only 38% of all-cause excess deaths in adults aged 25 to 44 years recorded during the pandemic were attributed directly to COVID-19. Although the remaining excess deaths are unexplained, inadequate testing in this otherwise healthy demographic likely contributed. These results suggest that COVID-19–related mortality may have been underdetected in this population.

This study has limitations. The provisional data used represent lower-bound estimates due to reporting lags, necessitating future updates. Additionally, although COVID-19 deaths exceeded unintentional opioid deaths in 2018 in some areas, it is possible that simultaneous increases in opioid deaths may have occurred during the pandemic period, making it less clear which of these 2 diseases represents the current leading cause of death among younger adults in areas experiencing COVID-19 surges.

Jeremy Samuel Faust, MD, MS
Harlan M. Krumholz, MD, SM
Chengan Du, PhD
Katherine Dickerson Mayes, MD, PhD
Zhenqiu Lin, PhD
Cleavon Gilman, MD
Rochelle P. Walensky, MD, MPH

Table. Excess, Coronavirus Disease 2019 (COVID-19)–Related, and Unintentional Opioid Overdose Deaths

	March-July 2020							March-July 2018	
HHS region	Expected deaths, No. (95% CI)	Observed deaths, No.	Ratio of observed/ expected deaths (95% CI)	Excess deaths, No. (95% CI)	COVID-19 deaths, No.	COVID-19 death rates per 100 000 person-months (95% CI)	Excess deaths attributed to COVID-19, %	Unintentional opioid overdose deaths, No.	Unintentional opioid overdose death rates per 100 000 person-months (95% CI)
US total	64 189 (61 822-66 556)	76 088	1.19 (1.14-1.23)	11 899 (9373 to 14 266)	4535	1.02 (0.99-1.06)	38	10 347	2.38 (2.33-2.43)
March	12 881 (11 952-13 855)	13 531	1.05 (0.98-1.13)	650 (−333 to 1579)	332	0.38 (0.34-0.42)	51	2119	2.44 (2.33-2.54)
April	12 602 (11 611-13 620)	15 106	1.20 (1.11-1.30)	2504 (1476 to 3495)	1539	1.74 (1.65-1.83)	61	1994	2.29 (2.19-2.40)
May	12 848 (11 786-13 895)	15 792	1.23 (1.14-1.34)	2944 (1883 to 4006)	848	0.96 (0.89-1.03)	29	2068	2.38 (2.28-2.48)
June	12 761 (11 671-13 851)	15 078	1.18 (1.09-1.29)	2317 (1190 to 3407)	604	0.68 (0.63-0.74)	26	2062	2.37 (2.27-2.48)
July	13 098 (11 897-14 234)	16 581	1.27 (1.16-1.39)	3483 (2258 to 4684)	1212	1.37 (1.29-1.45)	35	2104	2.42 (2.32-2.52)
Region 2	4128 (3879-4377)	6305	1.53 (1.44-1.63)	2177 (1928 to 2426)	1310	3.56 (3.37-3.76)	60	1229	3.23 (3.05-3.42)
March	825 (721-929)	1120	1.36 (1.21-1.55)	295 (191 to 399)	172	2.34 (2.00-2.71)	58	238	3.13 (2.74-3.55)
April	810 (702-918)	1867	2.30 (2.03-2.66)	1057 (949 to 1165)	842	11.44 (10.68-12.24)	80	218	2.87 (2.50-3.27)
May	826 (715-937)	1286	1.56 (1.37-1.80)	460 (349 to 571)	221	3.00 (2.62-3.42)	48	260	3.42 (3.02-3.86)
June	824 (709-938)	1033	1.25 (1.10-1.46)	209 (95 to 324)	56	0.76 (0.57-0.99)	27	250	3.29 (2.89-3.72)
July	843 (725-961)	999	1.18 (1.04-1.38)	156 (38 to 274)	19	0.26 (0.16-0.40)	12	263	3.46 (3.05-3.90)
Region 6	8504 (8127-8882)	10 408	1.22 (1.17-1.28)	1904 (1526 to 2281)	725	1.21 (1.12-1.30)	38	539	0.92 (0.85-1.00)
March	1711 (1546-1875)	1774	1.04 (0.95-1.15)	63 (−101 to 228)	31	0.26 (0.18-0.37)	49	101	0.86 (0.70-1.05)
April	1688 (1521-1854)	1932	1.14 (1.04-1.27)	244 (78 to 411)	118	0.98 (0.81-1.18)	48	105	0.90 (0.73-1.09)
May	1712 (1543-1880)	2072	1.21 (1.10-1.34)	360 (192 to 529)	74	0.62 (0.48-0.77)	21	124	1.06 (0.88-1.26)
June	1689 (1517-1860)	2132	1.26 (1.15-1.41)	443 (272 to 615)	122	1.01 (0.84-1.21)	28	107	0.91 (0.75-1.10)
July	1706 (1533-1880)	2498	1.46 (1.33-1.63)	792 (618 to 965)	380	3.16 (2.85-3.50)	48	102	0.87 (0.71-1.06)
Region 9	8351 (8054-8648)	10 094	1.21 (1.17-1.25)	1743 (1446 to 2040)	668	0.91 (0.84-0.99)	38	677	0.94 (0.87-1.01)
March	1643 (1515-1772)	1698	1.03 (0.96-1.12)	55 (−74 to 183)	28	0.19 (0.13-0.28)	51	141	0.98 (0.82-1.15)
April	1656 (1525-1787)	1764	1.07 (0.99-1.16)	108 (−23 to 239)	90	0.62 (0.49-0.76)	83	117	0.81 (0.67-0.97)
May	1660 (1528-1793)	2015	1.21 (1.12-1.32)	355 (222 to 487)	99	0.68 (0.55-0.82)	28	122	0.85 (0.70-1.01)
June	1667 (1532-1802)	2086	1.25 (1.16-1.36)	419 (284 to 554)	129	0.88 (0.74-1.05)	31	155	1.08 (0.91-1.26)
July	1725 (1588-1861)	2531	1.47 (1.36-1.59)	806 (670 to 943)	322	2.20 (1.97-2.46)	40	142	0.99 (0.83-1.16)

Author Affiliations: Department of Emergency Medicine, Brigham and Women's Hospital, Boston, Massachusetts (Faust); Section of Cardiovascular Medicine, Yale School of Medicine, New Haven, Connecticut (Krumholz); Center for Outcomes Research and Evaluation, Yale School of Medicine, New Haven, Connecticut (Du, Lin); Harvard Affiliated Emergency Medicine Residency, Boston, Massachusetts (Mayes); Emergency Medicine Department, Yuma Regional Medical Center, Yuma, Arizona (Gilman); Division of Infectious Diseases, Massachusetts General Hospital, Boston (Walensky).

Corresponding Author: Jeremy Samuel Faust, MD, MS, Brigham and Women's Hospital Department of Emergency Medicine, 10 Vining St, Boston, MA 02115 (jsfaust@gmail.com).

Accepted for Publication: November 18, 2020.

Published Online: December 16, 2020. doi:10.1001/jama.2020.24243

Author Contributions: Dr Faust had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Faust, Lin, Mayes, Gilman, Walensky.
Acquisition, analysis, or interpretation of data: Faust, Krumholz, Du, Lin, Mayes, Walensky.
Drafting of the manuscript: Faust, Mayes, Gilman, Walensky.
Critical revision of the manuscript for important intellectual content: Faust, Krumholz, Du, Lin, Walensky.
Statistical analysis: Faust, Du, Lin, Mayes.
Obtained funding: Walensky.
Administrative, technical, or material support: Mayes, Walensky.
Supervision: Faust, Lin, Gilman.

Conflict of Interest Disclosures: Dr Krumholz reported receiving personal fees from UnitedHealth, IBM Watson Health, Element Science, Aetna, Facebook, Siegfried & Jensen Law Firm, Arnold & Porter Law Firm, Martin/Baughman Law Firm, F-Prime, and the National Center for Cardiovascular Diseases, Beijing; being a cofounder of HugoHealth, a personal health information platform, and Refactor Health, an enterprise health care artificial intelligence-augmented data management company; receiving contracts from the Centers for Medicare & Medicaid Services, through Yale New Haven Hospital, to develop and maintain measures of hospital performance; and receiving grants from Medtronic, the US Food and Drug Administration, Johnson & Johnson, and Shenzhen Center for Health Information outside the submitted work. Dr Lin reported working under contract with the Centers for Medicare & Medicaid Services to develop quality measures. Dr Walensky reported receiving grants from the Mass General Research Institute as the Steven and Deborah Gorlin MGH Research Scholar during the conduct of the study. No other disclosures were reported.

Additional Contributions: We thank Lauren M. Rossen, PhD, MS (National Center for Health Statistics), for facilitating the public release of National Center for Health Statistics data used for this study and for providing expertise on excess death determination and Michael Colin Tasi, MD, MBA (Harvard Affiliated Emergency Medicine Residency), for assistance in supporting data preparation. Neither individual received compensation for their contributions.

1. Woolf SH, Chapman DA, Sabo RT, Weinberger DM, Hill L, Taylor DDH. Excess deaths from COVID-19 and other causes, March-July 2020. *JAMA*. 2020;324(15):1562-1564. doi:10.1001/jama.2020.19545

2. Cunningham JW, Vaduganathan M, Claggett BL, et al. Clinical outcomes in young US adults hospitalized with COVID-19. *JAMA Intern Med*. Published online September 9, 2020. doi:10.1001/jamainternmed.2020.5313

3. Centers for Disease Control and Prevention. Underlying cause of death, 1999-2018. Accessed October 28, 2020. https://wonder.cdc.gov/ucd-icd10.html

4. Centers for Disease Control and Prevention. Monthly provisional counts of deaths by age group and HHS region for select causes of death. Accessed October 28, 2020. https://data.cdc.gov/NCHS/Monthly-provisional-counts-of-deaths-by-age-group-/ezfr-g6hf

COMMENT & RESPONSE

Risk of Spinal Hematoma After Lumbar Puncture

To the Editor The recently published article by Dr Bodilsen and colleagues reported the association between lumbar puncture and spinal hematoma in patients with coagulopathy.[1] When interpreting their results, some issues should be considered. First, this study defined spinal hematoma based on diagnosis codes regarding spinal hematoma-related symptoms or treatments. The diagnosis of spinal hematoma should be based on neuroimaging data, including magnetic resonance imaging and computed tomographic scan results[2] since diagnosis codes without regard to neuroimaging data may cause a misdiagnosis of spinal hematoma. Second, the location of lumbar puncture-related spinal hematoma was not mentioned in this article. The location of spinal hematoma (eg, lumbar, cervical, thoracic, epidural, intradural, subarachnoid) may affect the outcome of spinal hematoma[2] so should have be included in this study. Third, because differentiating traumatic spinal tap from subarachnoid hemorrhage can be difficult in clinical practice,[3] the authors should have more clearly stated how these conditions were distinguished. Fourth, this article did not include cases with failed attempts of lumbar puncture. Among patients with successful lumbar puncture, some may have to undergo multiple attempts, which can be associated with higher risk of lumbar puncture-related injury. Fifth, although not mentioned in this study, in clinical practice, some patients may have more than 1 coagulation disorder, such as thrombocytopenia and an increased international normalized ratio, which may increase their risk of spinal hematoma.

In summary, while this study can aid in decision-making, the safety of lumbar puncture in patients with coagulopathy deserves further investigation via prospective studies and clinical trials.

Tao Xu, PhD
You Wang, MD
Yangmei Chen, PhD

Author Affiliations: Department of Neurology, Second Affiliated Hospital of Chongqing Medical University, Chongqing, China.

Corresponding Author: Yangmei Chen, PhD, Department of Neurology, Second Affiliated Hospital of Chongqing Medical University, Yuzhong District, Chongqing 400010, China (chenym1997@sina.com).

Conflict of Interest Disclosures: None reported.

1. Bodilsen J, Mariager T, Vestergaard HH, et al. Association of lumbar puncture with spinal hematoma in patients with and without coagulopathy. *JAMA*. 2020;324(14):1419-1428. doi:10.1001/jama.2020.14895

2. Kreppel D, Antoniadis G, Seeling W. Spinal hematoma: a literature survey with meta-analysis of 613 patients. *Neurosurg Rev*. 2003;26(1):1-49. doi:10.1007/s10143-002-0224-y

3. Perry JJ, Alyahya B, Sivilotti ML, et al. Differentiation between traumatic tap and aneurysmal subarachnoid hemorrhage: prospective cohort study. *BMJ*. 2015;350:h568. doi:10.1136/bmj.h568

To the Editor Dr Bodilsen and colleagues showed very low rates of spinal hematoma in patients both with and without coagulopathy in their large patient cohort.[1] In a subgroup analysis of 1694 lumbar punctures among 1237 patients, the authors reported that the median needle size was 22 gauge (interquartile range, 22-22), and listed the number of procedures performed with traumatic vs atraumatic needles. Needle size and the use of atraumatic pencil-point needles have been previously shown to modulate the risk of other post-lumbar puncture complications; the use of smaller, atraumatic needles reduces the risk of complications such as postdural puncture

Letters

RESEARCH LETTER

Clinical Outcomes in Young US Adults Hospitalized With COVID-19

Coronavirus disease 2019 (COVID-19) is increasing rapidly among young adults in the US.[1] Often described as a disease affecting older adults, to our knowledge, few studies have included younger patients to better understand their anticipated clinical trajectory. We investigated the clinical profile and outcomes of 3222 young adults (defined by the US Census as age 18-34 years) who required hospitalization for COVID-19 in the US.

Editor's Note page 381

Methods | Young adults age 18 to 34 years with the *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10)* code U07.1 (COVID-19, virus identified) discharged between April 1 and June 30, 2020, were identified in the Premier Healthcare Database, a hospital-based, all-payer database including 1030 US hospitals and health care systems and more than 8 million annual inpatient admissions.[2,3] Pregnant young adults (n = 1644) were excluded because many were admitted for childbirth and not for COVID-19 infection. Only a patient's first hospitalization for COVID-19 was considered.

Comorbidities and outcomes during COVID-19 hospitalization were defined using diagnosis, procedure, or billing *ICD-10* codes. Intensive care utilization was defined by a billing code for intensive care unit room or daily ventilator management. Independent factors associated with the composite outcome of mechanical ventilation or death were identified by multivariable logistic regression. Race and ethnicity were reported by participating hospitals.

Data were collected and deidentified by Premier and transferred to and analyzed at Brigham and Women's Hospital using Stata, version 14 (StataCorp). The Mass General Brigham institutional review board approved the study protocol; the requirement for informed consent was waived because of the deidentified nature of the data. A 2-sided *P* value of <.05 was considered significant.

Results | Among 780 969 adults discharged between April 1, 2020, and June 30, 2020, 63 103 (8.1%) had the *ICD-10* code for COVID-19, of whom 3222 (5%) were nonpregnant young adults (age 18-34 years) admitted to 419 US hospitals. The mean (SD) age of this population was 28.3 (4.4) years; 1849 (57.6%)

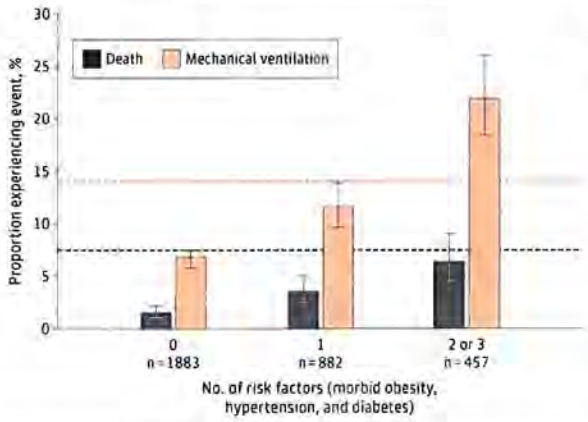
Table. Baseline Characteristics of Young Adults Age 18 to 34 Years With COVID-19[a]

Characteristic	No. (%) Full case series (N = 3222)	No death or ventilation (n = 2879)	Death or ventilation (n = 343)	*P* value
Age, mean (SD), y	28.3 (4.4)	28.3 (4.4)	28.3 (4.5)	.90
Men	1849 (57.6)	1626 (56.7)	223 (65.0)	.003
Race/ethnicity				
White non-Hispanic	536 (16.6)	479 (16.6)	57 (16.6)	
White Hispanic	350 (10.9)	324 (11.3)	26 (7.6)	
Black non-Hispanic	748 (23.2)	675 (23.4)	73 (21.3)	.14
Black Hispanic	14 (0.4)	13 (0.5)	1 (0.3)	
Other/unknown	1574 (48.9)	1388 (48.2)	186 (54.2)	
Black and/or Hispanic	1838 (57.0)	1669 (58.0)	169 (49.3)	.002
Discharge month				
April 2020	1680 (52.1)	1495 (51.9)	185 (53.9)	
May 2020	1063 (33.0)	936 (32.5)	127 (37.0)	.004
June 2020	479 (14.9)	448 (15.6)	31 (9.0)	
Region				
Northeast	1298 (40.3)	1161 (40.4)	137 (39.9)	
South	1130 (35.1)	1032 (35.9)	98 (28.6)	.002
Midwest	558 (17.3)	488 (17.0)	70 (20.4)	
West	233 (7.2)	195 (6.8)	38 (11.1)	
Any obesity, BMI ≥ 30	1187 (36.8)	1007 (35.0)	180 (52.5)	<.001
Morbid obesity, BMI ≥ 40	789 (24.5)	649 (22.5)	140 (40.8)	<.001
Asthma	545 (16.9)	495 (17.2)	50 (14.6)	.22
Hypertension	519 (16.1)	412 (14.3)	107 (31.2)	<.001
Smoking	513 (15.9)	472 (16.4)	41 (12.0)	.03
Diabetes	588 (18.2)	494 (17.2)	94 (27.4)	<.001

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); COVID-19, coronavirus disease 2019.

[a] Race/ethnicity groups include only patients whose race and ethnicity were reported. Patients with missing data for 1 or both were considered other/unknown.

Figure. Death and Mechanical Ventilation in Young Adults With and Without Morbid Obesity, Hypertension, and Diabetes



Morbid obesity, diabetes, and hypertension were determined by *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10)* codes during coronavirus disease 2019 (COVID-19) admission. Proportions of patients experiencing death and mechanical ventilation were compared with a reference group of 8862 middle-aged (age 35-64 years) nonpregnant patients with COVID-19 with none of these conditions in the Premier database (dotted lines). Error bars refer to 95% CIs.

were men and 1838 (57.0%) were Black or Hispanic. Overall, 1187 (36.8%) had obesity, 789 (24.5%) morbid obesity, 588 (18.2%) diabetes, and 519 (16.1%) hypertension (**Table**).

During hospitalization, 684 patients (21%) required intensive care, 331 (10%) required mechanical ventilation, and 88 (2.7%) died. Vasopressors or inotropes were used for 217 patients (7%), central venous catheters for 283 (9%), and arterial catheters for 192 (6%). The median length of stay was 4 days (interquartile range, 2-7 days). Among those who survived hospitalization, 99 (3%) were discharged to a postacute care facility.

Morbid obesity (adjusted odds ratio [OR], 2.30; 95% CI, 1.77-2.98; vs no obesity; $P < .001$) and hypertension (adjusted OR, 2.36; 95% CI, 1.79-3.12; $P < .001$) were common and in addition to male sex (adjusted OR, 1.53; 95% CI, 1.20-1.95; $P = .001$) were associated with greater risk of death or mechanical ventilation. Odds of death or mechanical ventilation did not vary significantly with race and ethnicity. Morbid obesity was present in 140 patients (41%) who died or required ventilation. Diabetes was associated with increased risk of this outcome in univariable analysis (OR, 1.82; 95% CI, 1.41-2.36; $P < .001$) but did not reach statistical significance after adjustment (adjusted OR, 1.31; 95% CI, 0.99-1.73; $P = .06$). Patients with multiple risk factors (morbid obesity, hypertension, and diabetes) faced risks similar to 8862 middle-aged (age 35-64 years) nonpregnant adults with COVID-19 infection without these conditions (**Figure**).

Discussion | Young adults age 18 to 34 years hospitalized with COVID-19 experienced substantial rates of adverse outcomes: 21% required intensive care, 10% required mechanical ventilation, and 2.7% died. This in-hospital mortality rate is lower than that reported for older adults with COVID-19, but approximately double that of young adults with acute myocardial infarction.[4] Morbid obesity, hypertension, and diabetes were common and associated with greater risks of adverse events. Young adults with more than 1 of these conditions faced risks comparable with those observed in middle-aged adults without them. More than half of these patients requiring hospitalization were Black or Hispanic, consistent with prior findings of disproportionate illness severity in these demographic groups.[5,6]

Limitations of this study included defining COVID-19 infection and comorbidities by *ICD-10* codes, which may be subject to misclassification, and variable reporting of race and ethnicity across hospitals. The definition of COVID-19 infection did not require microbiological confirmation. Given the sharply rising rates of COVID-19 infection in young adults, these findings underscore the importance of infection prevention measures in this age group.

Jonathan W. Cunningham, MD
Muthiah Vaduganathan, MD, MPH
Brian L. Claggett, PhD
Karola S. Jering, MD
Ankeet S. Bhatt, MD, MBA
Ning Rosenthal, MD, MPH, PhD
Scott D. Solomon, MD

Author Affiliations: Brigham and Women's Hospital, Boston, Massachusetts (Cunningham, Vaduganathan, Claggett, Jering, Bhatt, Solomon); Premier Applied Sciences, Premier Inc, Charlotte, North Carolina (Rosenthal).

Accepted for Publication: August 14, 2020.

Corresponding Author: Scott D. Solomon, MD, Cardiovascular Division, Brigham and Women's Hospital, 75 Francis St, Boston, MA 02115 (ssolomon@bwh.harvard.edu).

Published Online: September 9, 2020. doi:10.1001/jamainternmed.2020.5313

Author Contributions: Dr Solomon had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Drs Cunningham and Vaduganathan contributed equally as co-first authors.
Concept and design: Cunningham, Jering, Bhatt, Solomon.
Acquisition, analysis, or interpretation of data: Cunningham, Vaduganathan, Claggett, Jering, Rosenthal, Solomon.
Drafting of the manuscript: Cunningham, Vaduganathan.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Cunningham, Claggett, Jering, Rosenthal, Solomon.
Obtained funding: Solomon.
Administrative, technical, or material support: Jering.
Supervision: Solomon.

Conflict of Interest Disclosures: Dr Cunningham reported grants from the National Heart, Lung, and Blood Institute (T32HL094301) during the conduct of the study. Dr Vaduganathan reported grants from Harvard Catalyst, grants and personal fees from Amgen, and personal fees from AstraZeneca, Baxter HealthCare, Bayer AG, Boehringer Ingelheim, Cytokinetics, and Relypsa outside the submitted work. Dr Claggett reported personal fees from Amgen, Boehringer Ingelheim, Corvia, MyoKardia, and Novartis outside the submitted work. Dr Rosenthal is an employee of Premier Inc, which curates the Premier Healthcare Database. Dr Bhatt reported speaking fees from Sanofi Pasteur and is supported by the Heart, Lung, and Blood Institute T32 postdoctoral training grant T32HL007604. Dr Solomon reported grants from Alnylam, Amgen, AstraZeneca, Bellerophon, Bayer, BMS, Celladon, Cytokinetics, Eidos, Gilead, GSK, Ionis, Lone Star Heart, Mesoblast, MyoKardia, Neurotronik, National Institutes of Health/National Heart, Lung, and Blood Institute, Novartis, Respicardia, Sanofi Pasteur, Theracos and personal fees from Akros, Alnylam, Amgen, Arena, AstraZeneca, Bayer, BMS, Cardior, Cardurion, Corvia, Cytokinetics, Daiichi-Sankyo, Gilead, GSK, Ironwood, Merck, Myokardia, Novartis, Roche, Takeda, Theracos, Quantum Genetics, Cardurion, AoBiome,

Janssen, Cardiac Dimensions, Sanofi-Pasteur, Tenaya, Dinaqor, Tremeau, CellProThera, and Moderna outside the submitted work. No other disclosures were reported.

1. COVID-NET. COVID-19-associated hospitalization surveillance network. Centers for Disease Control and Prevention. Accessed July 21, 2020. https://gis.cdc.gov/grasp/covidnet/COVID19_3.html

2. Premier Applied Sciences. Premier Healthcare Database: data that informs and performs. Accessed August 7, 2020. https://learn.premierinc.com/white-papers/premier-healthcare-database-whitepaper

3. Vail E, Gershengorn HB, Hua M, Walkey AJ, Rubenfeld G, Wunsch H. Association between US norepinephrine shortage and mortality among patients with septic shock. *JAMA*. 2017;317(14):1433-1442. doi:10.1001/jama.2017.2841

4. Yang J, Biery DW, Singh A, et al. Risk factors and outcomes of very young adults who experience myocardial infarction: the Partners YOUNG-MI Registry. *Am J Med*. 2020;133(5):605-612.e1. doi:10.1016/j.amjmed.2019.10.020

5. Martinez DA, Hinson JS, Klein EY, et al. SARS-CoV-2 positivity rate for Latinos in the Baltimore-Washington, DC region. *JAMA*. 2020. doi:10.1001/jama.2020.11374

6. Price-Haywood EG, Burton J, Fort D, Seoane L. Hospitalization and mortality among Black patients and White patients with Covid-19. *N Engl J Med*. 2020;382(26):2534-2543. doi:10.1056/NEJMsa2011686

Editor's Note

Regardless of Age, Obesity and Hypertension Increase Risks With COVID-19

Older age has consistently been associated with higher mortality in patients with coronavirus disease 2019 (COVID-19).[1,2] Unfortunately, as shown by Cunningham et al[3] in this issue of *JAMA Internal Medicine*, COVID-19 does not spare young people. Using a national all-payer hospital database, the investigators identified 3222 nonpregnant adults aged 18 to 34 years who were admitted to US hospitals for COVID-19. Morbidity was substantial: 21% required intensive care, and 2.7% died. Mortality was higher among those who had obesity, hypertension, and male sex, as has been noted in general adult populations.

Combined with what we know about the greater risk of older persons, what does this study tell us about COVID-19 and young adults? First, while young adults are much less likely than older persons to become seriously ill, if they reach the point of hospitalization, their risks are substantial. Second, obesity, hypertension, and male sex put patients of all ages at greater risk. As obesity and hypertension are preventable and treatable conditions, reducing the risk of serious COVID 19 illness should be added to the already long list of reasons to increase medical and public health efforts in young adults to promote healthful diets and increased exercise. Finally, the article by Cunningham et al[3] establishes that COVID-19 is a life-threatening disease in people of all ages and that social distancing, facial coverings, and other approaches to prevent transmission are as important in young adults as in older persons.

Mitchell H. Katz, MD

Author Affiliations: NYC Health and Hospitals, New York (Katz); Deputy Editor, *JAMA Internal Medicine* (Katz).

Published Online: September 9, 2020. doi:10.1001/jamainternmed.2020.5415

Corresponding Author: Mitchell Katz, MD, NYC Health and Hospitals, 125 Worth St, Room 514, New York, NY 10013 (mitchell.katz@nychhc.org).

Conflict of Interest Disclosures: None reported.

1. Gasselli G, Greco M, Zanella A, et al. Risk factors associated with mortality among patients with COVID-19 in intensive care units in Lombardy, Italy. *JAMA Intern Med*. Published online July 15, 2020. doi:10.1001/jamainternmed.2020.3539

2. Guptas S, Hayek SS, Wang W, et al. Factors associated with health in critically ill patients with coronavirus disease 2019 in the United States. *JAMA Intern Med*. Published online July 15, 2020. doi:10.1001/jamainternmed.2020.3596

3. Cunningham JW, Vaduganathan M, Claggett BL, et al. Clinical outcomes in young US adults hospitalized with COVID-19. *JAMA Intern Med*. Published online September 9, 2020. doi:10.1001/jamainternmed.2020.5313

Outcomes of Contact Tracing in San Francisco, California—Test and Trace During Shelter-in-Place

Given the pressing need to reopen economic activity prior to the availability of a vaccine, the US and other nations are investing in contact tracing as a core component of the coronavirus disease 2019 (COVID-19) response.[1] An estimated 75% of infected contacts need to be quarantined to contain COVID-19.[2,3] We evaluated case investigation and contact tracing outcomes in San Francisco, California, during shelter-in-place restrictions.

Methods | San Francisco residents diagnosed with COVID-19 were routinely reported to the health department and assigned for case investigation and contact tracing.[4] On May 5, 2020, universal testing for COVID-19 contacts was recommended, regardless of symptoms. This study included cases diagnosed during shelter-in-place from April 13 to June 8, 2020. Cases identified through outbreak investigations in long-term care facilities were excluded (10% of cases).[5]

To evaluate the outcomes of contact tracing, we calculated the proportion of people who were interviewed, identified close contacts, and had at least 1 contact notified, tested, and newly diagnosed with COVID-19. A deterministic match based on personal identifiers was performed between contact and testing databases to (1) exclude contacts who were known to have COVID-19, (2) deduplicate previously named household contacts, and (3) ascertain testing results. We report the median number of days (with interquartile range [IQR]) taken to process each step. Analyses were conducted in SAS, version 9.4 (SAS Institute). Bivariate tests including χ^2 tests to compare categorical variables and *t*-tests for continuous variables were conducted, as appropriate, and a $P < .05$ identified statistical significance. This work was conducted as part of San Francisco Department of Public Health COVID-19 surveillance; institutional review board approval and informed consent were not required.

Results | Among 1633 cases reported, 1394 (85.4%) people were interviewed. Median (IQR) age was 37 (26-49) years; 972 (69.7%) were Latino (85% primarily Spanish-speaking), and 842 (60.3%) were male. Of the 603 (43.2%) interviewed people residing in a household with at least 5 persons, 510 (84.6%) were Latino. Half of interviewed people reported contact with someone diagnosed with COVID-19 (**Table**).

Among 791 people interviewed after recommending universal testing for close contacts, 404 (51.1%) identified a contact not previously diagnosed with COVID-19, 356 (45.0%) had at least 1 contact notified, 206 (26.0%) had at least 1

Notifications

COVID-19 Updates

- Alberta entered Stage 3 on July 1: Limited restrictions remain.
- Get vaccinated: Everyone 12+ can book first and second doses now.

THIS IS EXHIBIT " O " referred to in the Affidavit / Declaration of Dr. Deena Hinshaw affirmed Sworn/Declared before me this 12th day of July A.D., 2021
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public.
Heather L. Veale
Barrister & Solicitor

Alberta.ca

COVID-19 variants of concern

Find information on recently identified variant strains of the COVID-19 virus.

Overview

Variants are viruses that have changed or mutated while reproducing inside an infected person's cells. Variants can spread to others and may continue mutating as they move from person to person. It is normal for viruses to mutate over time.

Variants of concern can spread more easily. They can also cause more serious illness that could result in more hospitalizations and deaths as they become common in the community.

COVID-19 variants of concern were first identified in the United Kingdom, South Africa, Brazil and India. These strains have since been detected in Alberta and in countries around the world.

Alberta is monitoring for variants spreading in our province. Confirmed cases are updated daily.

See variant case data in Alberta

Reduce the risk

Variants of concern can be prevented the same way as the original virus:

- Follow all public health actions
- Prevent the spread: wash your hands, stay 2m apart, wear a mask, stay home if sick
- Get tested if you have any symptoms
- Know the isolation and quarantine requirements
- Get vaccinated

Variants in Alberta

To date, 4 variants of concern have been identified in Alberta. The B.1.1.7 variant is the dominant strain in Alberta.

Anyone who has been infected with a variant strain will test positive for COVID-19. Positive tests are screened again for all variants to determine the exact strain.

B.1.1.7 Variant (United Kingdom)

First identified in the United Kingdom, this is now the most common variant of concern in Alberta.

Research to date has shown this variant spreads more easily and can cause more severe illness in comparison to the original COVID-19 strain.

B.1.351 Variant (South Africa)

First identified in South Africa, research has shown this variant spreads more easily than the original COVID-19 strain and may be capable of re-infecting people who have previously tested positive for COVID-19.

P.1 Variant (Brazil)

First identified in Brazil, research has shown this variant spreads more easily than the original COVID-19 strain and is capable of re-infecting people who have previously tested positive for COVID-19.

B.1.617 (India)

First identified in India, research has shown this variant spreads more easily than the B.1.1.7 (UK) variant and may be capable of re-infecting people who have previously tested positive for COVID-19.

What we know

Knowledge and understanding of the COVID-19 variants is evolving rapidly. Scientists and public health officials around the world are studying variant strains and how the current vaccines may help protect against them.

Current evidence suggests the variants of concern have one or more of the following traits:

- are more contagious and spread more easily than the original strain
- cause more severe illness, which could result in more hospitalizations and deaths
- have the same symptoms as the original virus, including cough, fever, shortness of breath, runny nose, and sore throat (see the full list of symptoms)

Vaccine effectiveness and protection

The Pfizer, Moderna and AstraZeneca vaccines currently available in Alberta offer protection against infection and may offer protection against severe outcomes with variants. However, the level of protection may vary depending on the variant and the number of doses received.

Data on vaccine effectiveness against variants of concern in Alberta is updated regularly.

For more information on specific effectiveness of COVID-19 vaccines, refer to the National Advisory Committee on Immunizations.

The best defense against COVID-19 and all variants of concern continues to be:

- getting vaccinated as soon as you're eligible
- following all public health actions
- isolating or quarantining according to requirements if you test positive, are a close contact, or return from international travel

Case study: How one case turned into many

One Albertan returned from travel with a case of a COVID-19 variant of concern. Instead of quarantining alone for 14 days following return from travel outside Canada, the infected traveller socialized with a friend during quarantine.

It kicked off a chain of COVID-19 infections that spread far beyond that one case. This is a real case, discovered during contact tracing.

Government of Canada / Gouvernement du Canada

THIS IS EXHIBIT "P" referred to in the Affidavit / Declaration of Dr. Deena Hinshaw affirmed / ~~Sworn / Declared~~ before me this 12th day of July A.D., 2021
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public.
Heather L. Veale
Barrister & Solicitor

Coronavirus disease (COVID-19): Outbreak update

Outbreak update

Symptoms and treatment

Prevention and risks

Canada's response

Guidance documents

On this page

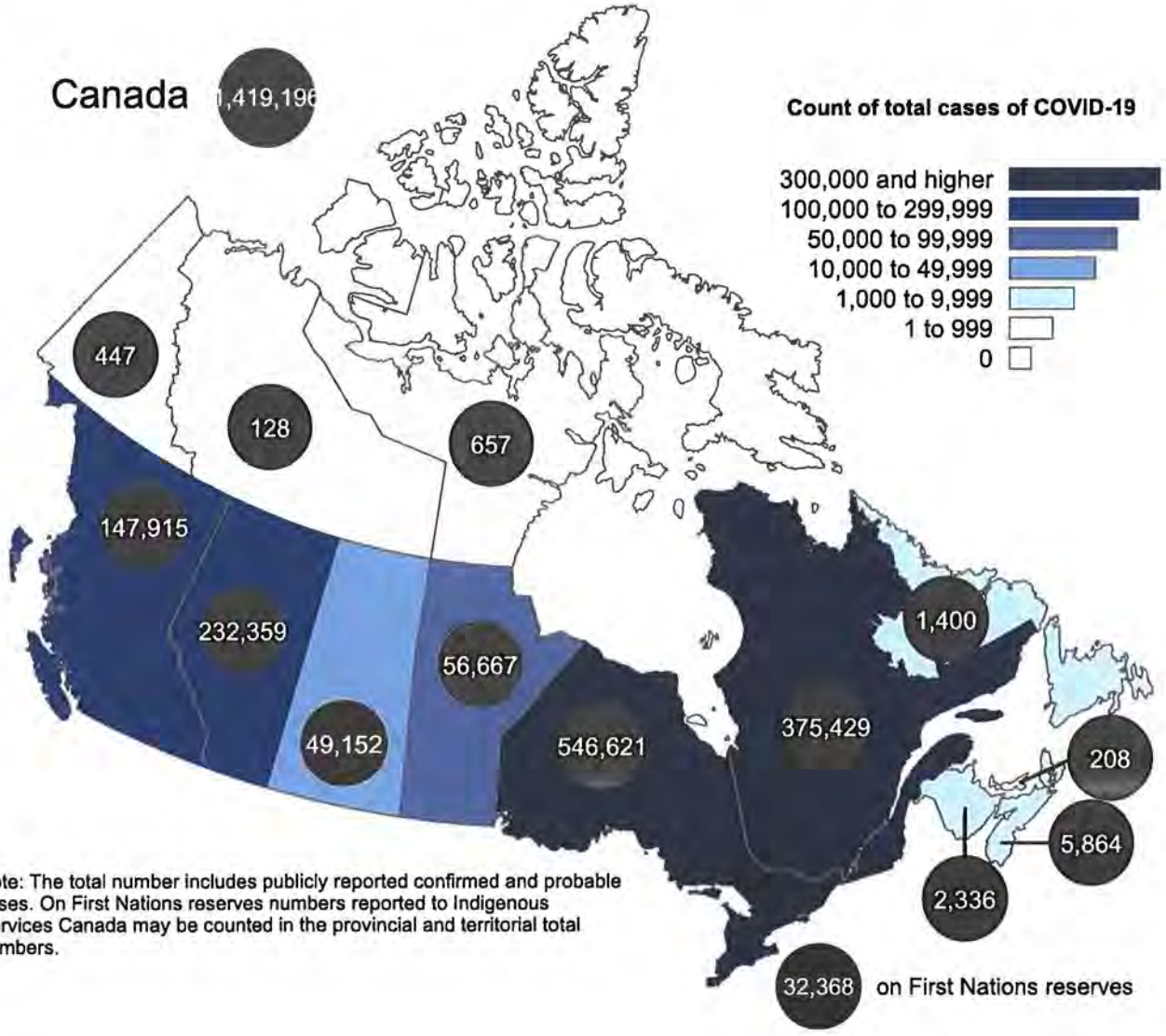
- Get email updates
- COVID updates

Current situation

Count of total cases of COVID-19 in Canada as of July 8, 2021

Last data update 2021-07-08 19:00 EST

ℹ Hover over provinces and territories to see total cases, active cases, recovered cases, tests performed or deaths in Canada over time. Click the play button to animate the map.



The count of total cases of COVID-19 in **Canada** was **1,419,196** as of July 8, 2021.

▶ Map - Total Number of COVID-19 Cases in Canada - Text Description

Additional national maps and data are available.

Additional COVID-19 case information:

- COVID-19 data trends
- Confirmed cases in First Nations on reserve in provinces
- Preliminary data tables related to confirmed cases (dataset)
- COVIDTrends: cases by area

Global

An international map and data are available.

Globally, efforts have focused on taking measures to contain the outbreak and prevent further spread.

An official global travel advisory and pandemic COVID-19 travel health notice are in effect: avoid non-essential travel outside Canada until further notice.

Risk to Canadians

COVID-19 is a serious health threat, and the situation is evolving daily. The risk varies between and within communities, but given the number of cases in Canada, the risk to Canadians is considered **high**.

We continue to reassess the public health risk based on the best available evidence as the situation evolves.

For more information, refer to our risk section.

How Canada is monitoring COVID-19

The Public Health Agency of Canada is working with provinces, territories and international partners, including the World Health Organization, to actively monitor the situation. Global efforts are focused on containment of

the outbreak and the prevention of further spread.

Canada's Chief Public Health Officer of Canada is in close contact with provincial and territorial Chief Medical Officers of Health to ensure that any cases of COVID-19 occurring in Canada continue to be rapidly identified and managed in order to protect the health of Canadians.

Canada's National Microbiology Laboratory is performing diagnostic testing for the virus that causes COVID-19. The laboratory is working in close collaboration with provincial and territorial public health laboratories, which are now able to test for COVID-19.

For more information, visit the COVID-19 daily epidemiology update.

COVID-19 variants

Genetic variations of viruses, such as the one that causes COVID-19, are common and expected.

SARS-CoV-2, the virus that causes COVID-19, will naturally develop mutations, which are changes to the genetic material in the virus over time.

When there have been several significant mutations to the virus then it's called a variant. A variant is of concern when it affects:

- disease spread
- disease severity
- tests used to detect the virus
- vaccines and treatments

Monitoring the variants

The Public Health Agency of Canada works with the provinces and territories, and other partners to monitor and identify variants of concern in Canada.

Monitoring for genetic changes in the virus allows us to better understand the potential impact of the mutations. Overall, variants of concern represent the majority of recently reported COVID-19 cases across the country.

Current variants of concern in Canada include:

- B.1.1.7 (Alpha)
- B.1.351 (Beta)
- P.1 (Gamma)
- B.1.617.2 (Delta)

The B.1.1.7 (Alpha) variant continues to account for the majority of variants in Canada.

Evidence demonstrates that the B.1.1.7 (Alpha) and B.1.617.2 (Delta) variants are at least 50% easier to spread. As well, the P.1 (Gamma), B.1.351 (Beta) and B.1.617.2 (Delta) variants each have certain mutations that may have an impact on vaccine effectiveness. However, the evidence is still limited.

Variants of concern reported publicly in Canada

About the new variants

These new variants of concern include mutations that seem to make the virus more infectious, allowing it to spread more easily. They may also affect the severity of the disease.

At this time, there's evidence that some variants may have an impact on certain drugs and vaccines. However, more research is needed to confirm these findings.

The variants don't currently affect diagnosis through authorized laboratory tests.

Given the limited data on the new variants, more research is needed to confirm these early findings. The Canadian and global medical, public health and research communities are actively evaluating these variants and other significant mutations.

Travel restrictions

We've put in place additional emergency measures to slow the introduction and spread of COVID-19 in Canada. Restrictions may change with little notice as the situation evolves. Refer to the latest travel restrictions in Canada.

Contact us

If you're looking for information on COVID-19, specific to your province, refer to our provincial and territorial resources page.

If you have additional questions that aren't answered on our website, contact the Public Health Agency of Canada.

Get email updates

Get COVID-19 email updates. Sign up to receive important information from the Government of Canada.

COVID updates

- Latest announcements, recalls and alerts
- Natural health products
- Medical devices
- Drugs

Related links

- Digital factsheets, printable posters and shareable videos on COVID-19 (multilingual products available)
- COVID-19: Social media and promotional resources for Health Canada and Public Health Agency of Canada
- Download COVID-19 apps, tools and data

What COVID-19 information do you need?

- Travel
  - Find out if you can travel to Canada
  - Testing and quarantine requirements
  - COVID-19 vaccinated travellers entering Canada
  - Travel restrictions in Canada
  - Compassionate exemptions
  - Registration of Canadians Abroad service
  - Check if you have been exposed during recent travel
  - Foreign workers coming to Canada
    - Arriving in Canada and mandatory quarantine
    - Health requirements and general guidance
    - Compliance and inspections
- Vaccines
  - COVID-19 vaccines overview

- How to get vaccinated or register
- Authorized vaccines
- Vaccine safety and possible side effects
- Reported side effects following vaccination
- What to expect at your vaccination
- Vaccine shipments and deliveries

- Health and safety
  - Prevention
    - Prevention for individuals
    - Prevention for communities
    - Wearing masks
    - Physical distancing and how it helps minimize COVID-19
    - Hygiene
    - Reduce the spread of COVID-19 in the workspace
  - Risks and spread
    - Difference between quarantine vs isolate
    - Overview of the risks of getting COVID-19
    - Surface contamination
    - How can I go out safely during the COVID-19 pandemic?
    - Which people are at risk of severe outcomes?
    - Pregnancy and risks related to COVID-19
    - Can my pet or other animals get sick from this virus?
    - How do I care for a person with COVID-19 at home?
  - Symptoms and treatment
    - Provincial and territorial self-assessment tools
    - What are the symptoms?
    - How long do symptoms take to appear?
    - Treatment?
    - Should I call my doctor?

- What can I do to care for my mental and physical health?
- Drug and medical device supply monitoring
- For clinical trial sponsors

- Income support
  - Get a list of benefits and support tailored to you
  - CERB has ended what happens next?
- Additional economic and financial support
  - Individuals
    - Individuals and families
      - Employment Insurance (EI) program
      - Canada Recovery Benefit (CRB)
      - Canada Recovery Sickness Benefit (CRSB)
      - Canada Recovery Caregiving Benefit (CRCB)
      - Mortgage payment deferral
      - Provincial and territorial support
  - Support for businesses
    - Avoiding layoffs, rehiring employees and creating new jobs
      - Canada Emergency Wage Subsidy (CEWS)
      - Extending the Work-Sharing program
    - Financial support, loans and access to credit
      - Canada Emergency Business Account (CEBA) interest-free loans
      - Canada Emergency Rent Subsidy (CERS)
      - Highly Affected Sectors Credit Availability Program (HASCAP)
      - Loan Guarantee for Small and Medium-Sized Enterprises

- Co-Lending Program for Small and Medium-Sized Enterprises
- Regional Relief and Recovery Fund (RRRF)
- Black Entrepreneurship Loan Fund
- Mid-Market Financing Program
- Mid-Market Guarantee and Financing Program
- Large Employer Emergency Financing Facility (LEEFF)
- Additional support by sector
- Provincial and territorial support

- Self-employed individuals
  - Canada Recovery Benefit (CRB)
  - Canada Recovery Sickness Benefit (CRSB)
  - Canada Recovery Caregiving Benefit (CRCB)
- Indigenous businesses
  - Relief measures for Indigenous businesses
  - Supporting business through the pandemic and into recovery

- Support for sectors
  - Agriculture and agri-food
    - Keeping workers in the food supply chain safe
    - Increasing credit availability
    - Protecting the health and safety of farm workers
    - Increasing interim payments from 50% to 75% through AgriStability
    - Expanding AgriInsurance to include labour shortage
    - Additional support for your business
  - Aquaculture and fisheries
    - Keeping workers in the food supply chain safe
    - Increasing credit availability

        - Assisting the fish and seafood processing sector
        - Changes to Employment Insurance (EI) fishing benefits
        - Additional support for your business
      - Cultural, heritage and sport
        - Support for Independent production companies
        - Additional support for your business
      - Energy
        - Launching the Emissions Reduction Fund
        - Additional support for your business
      - Infrastructure
        - Flexible funding for community resilience
        - Supporting communities: new ways to adapt spaces and services
        - Additional support for your business
    - Organizations helping Canadians
      - Vulnerable populations
        - Supporting women and children experiencing violence
        - Additional support for your organization
      - Indigenous organizations and communities
        - Addressing immediate needs in Indigenous communities
        - Additional support for your organization
- About COVID-19
    - E-mail updates on COVID-19
    - Current confirmed number of COVID-19 cases in Canada
    - More details about the cases reported in Canada
    - How does it spread?

- Where can I get information specific to my province or territory?
- How governments are working together
- Resources for parents and children
- Resources for youth, students and young adults
- Resources for seniors and their caregivers
- Resources for Indigenous communities
- People with disabilities

Date modified:
2021-06-15

Alberta Health Services

Healthy Albertans
Healthy Communities
Together.

2019-nCoV Scientific Advisory Group

Terms of Reference

Purpose

The Scientific Advisory Group (SAG) will use evidence and consider resource availability to provide recommendations to support policy and operational decision-making to the AHS Emergency Coordination Center for the 2019-nCoV incident response.

Reporting Relationship

SAG reports to the Operations Section Chief, Emergency Coordination Centre.

Scope

All requests for rapid evidence synthesis will come from the AHS Emergency Coordination Centre (or the Physician Co-leads), from the PPE Task Force (a subcommittee of the Operations Section of ECC) or from Alberta's Chief Medical Officer of Health. It is expected that questions may also arise from Alberta Zone Emergency Operations Centers – but those should be directed to SAG through the Physician Co-leads, Emergency Coordination Centre. Questions related to any aspect of COVID-19 are within scope, including risk for transmission, personal protective equipment, strategies for isolation, treatment strategies, and management of patients in hospitals.

Membership

SAG Co-chairs – Dr Braden Manns; Dr Lynora Saxinger

Public Health representative – Dr Alex Doroshenko

Infectious Disease / IPC Experts – Dr Nelson Lee; Dr John Conly

Critical care representative – Dr Shelley Duggan

General Internal Medicine – Dr Elizabeth Mackay

Respiratory representative – Dr Brandie Walker

Emergency department representative – Dr Andrew McRae

Pharmacy representative - Jeremy Slobodan

Provincial Laboratory – Dr Nathan Zelyas

Population, Public and Indigenous Health – Dr Melissa Potestio

Alberta Health Medical Office of Health representative – Dr Marcia Johnson

Other ad hoc external reviewers are added for each review based on the context of the ECC evidence synthesis requests.

Scientific Advisory Group
10301 Southport Lane SW
p: 587-774-5090
ScientificAdvisoryGroup@ahs.ca ahs.ca

Meeting Frequency

One to three times per week, 2 hours or on an as-needed basis as per the prioritized ECC evidence synthesis requests. All meetings to occur by Skype.

Member responsibility

(a) Co-chairs identify members. Each meeting must have one co-chair present.

(b) Each member is expected to attend meetings on a regular basis.

(c) Members are expected to:

- (i) Support the purpose and deliverables as outlined in the TOR
- (ii) Represent their subject matter expertise and bring their views and perspective to the meetings
- (iii) Participate in developing consensus by considering a diversity of opinions, ideas, and concerns and support decisions as a result of this collaborative process of developing recommendations;
- (iv) Consider evidence, resource constraints, and equity in decision making
- (v) Protect any AHS and/or Committee patient, clinical, or business information or records and not disclose the same outside of AHS without the written consent of the Committee Chair. This does not apply to information that is available to the public at www.ahs.ca or from other public sources.

(d) Members must recognize that uncertainty exists, but that recommendations are still required – based on best evidence and resource constraints

(e) Meeting agendas will be set by co-chairs

Decision making

SAG has no decision-making authority. Instead, SAG seeks to create high-quality evidence syntheses. To aid in decision making, SAG will also provide recommendations where possible based on quality and robustness of the evidence, as well as the resources available within Alberta. SAG will strive to ensure that recommendations are made by consensus where possible. Where recommendations are not unanimous, the anonymous results of voting will be recorded and provided to ECC or Alberta Health to enable their decision making.

Co-chairs do not vote. Given the need for frequent meetings, and the understanding that everyone is busy, quorum is 50%+1 member. Delegates are permitted, but must be briefed by the committee member they represent, and must bring a similar skillset / content expertise.

Resources

SAG will be supported by a Director (from AHS Health Systems Evaluation and Evidence) and rapid review services and knowledge synthesis (AHS Innovation Impact and Evidence and AHS SCN Scientific Offices). Where additional content expertise is required, SAG will draw upon AHS Strategic Clinical Network members, Operations and Clinicians. Where possible, the group will be guided by existing review resources (eg Oxford University COVID rapid evidence review service and other similar organizations).

SAG Process

There are three ways in which questions can be sent to SAG. The first is through Alberta's Chief Medical Officer of Health. The second is through the AHS ECC Operations Section Physician Co-leads. The third is through the AHS PPE Taskforce. Individuals outside the Chief Medical Office of Health at Alberta Health are asked to send SAG questions to the ECC Operations Section Physician Co-leads. After receiving questions, SAG Co-chairs will:

a) seek clarity on the question and determine which of the following is required:

- a rapid response brief (hours) (1-2 paragraphs with additional appended documents)
- a full rapid review and recommendation (24-96 hours depending on complexity)
- policy / guidance document – in which case the question will generally be delegated to a strategic clinical network where possible,

b) agree on review timelines, and

c) determine if a communication brief (for AHS staff or the public) is required (including determining the timelines for this separate document).

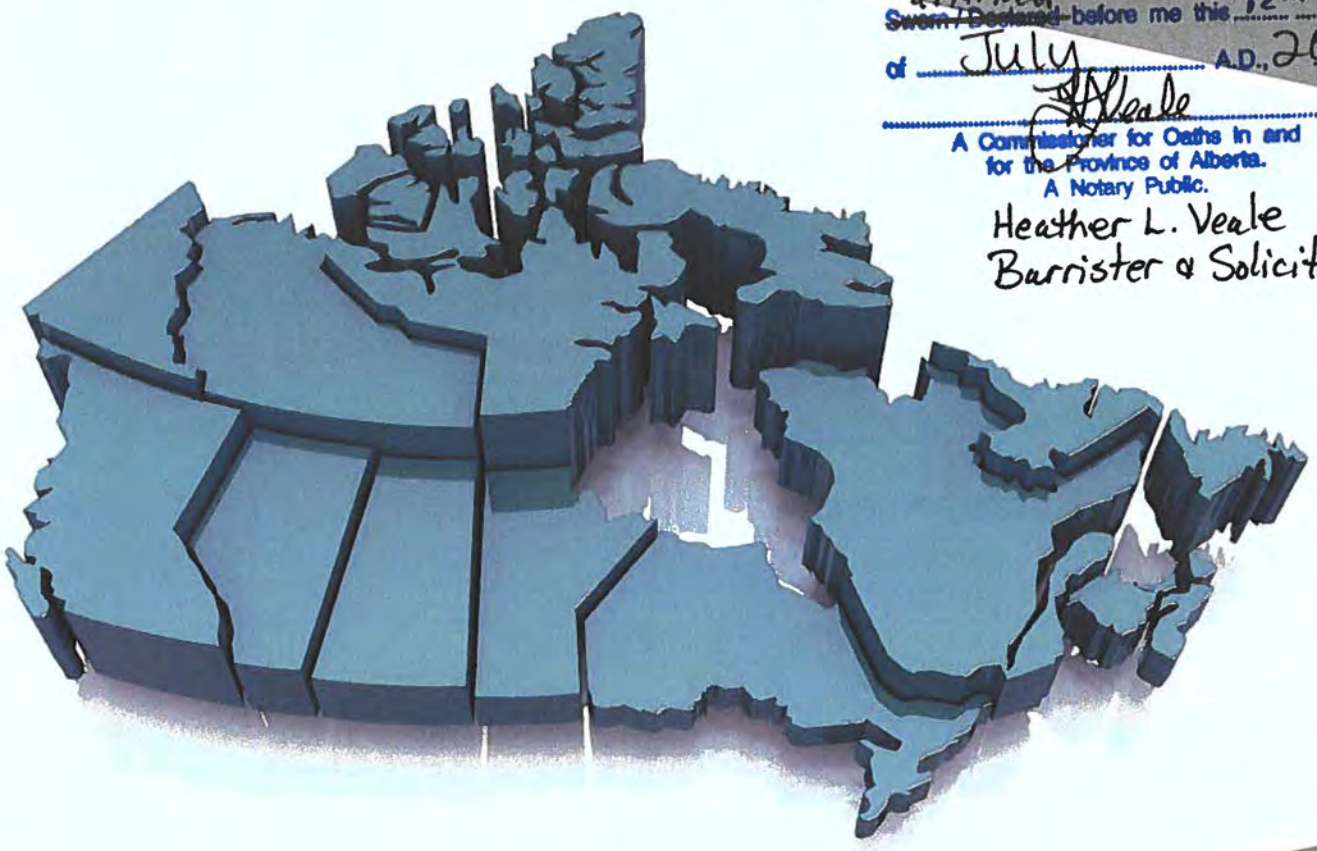
SAG Co-chairs will forward the final recommendation and evidence synthesis to Alberta Health / ECC for their approval and dissemination.

Date

December 11, 2020

Federal/Provincial/Territorial Public Health Response Plan for Biological Events

THIS IS EXHIBIT " R " referred to in the Affidavit / Declaration of
Dr. Deena Hinshaw
affirmed
Sworn / Declared before me this 12th day
of July A.D., 2021
H Veale
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public.
Heather L. Veale
Barrister & Solicitor



2018

Pan-Canadian Public Health Network
Partners in Public Health
Réseau pancanadien de santé publique
Partenaires en santé publique

TABLE OF CONTENTS

ADMINISTRATION AND AMENDMENTS

This document was prepared for the Federal/Provincial/Territorial (F/P/T) Public Health Network Council (PHNC) as an overarching governance framework to guide F/P/T public health responses to biological events. It was developed by an expert task group[1] comprised of experts in public health and emergency management, as identified by members of the Public Health Infrastructure Steering Committee (PHI-SC) and the Communicable and Infectious Disease Steering Committee (CID-SC). It was approved by PHN on October 17, 2017.

The Public Health Agency of Canada (PHAC), Centre for Emergency Preparedness and Response (CEPR) maintains the *Federal, Provincial, Territorial Public Health Response Plan for Biological Events* as an evergreen document on behalf of the PHNC.

The need to update the plan will be reviewed every three years at a minimum by PHI-SC and any changes will be tracked and noted as amendments in the plan. In addition, the need for revision will also be guided by after action reviews following the response to a real or simulated events requiring implementation of this plan, in whole or in part. The revision process will be coordinated on behalf of PHNC by the PHI-SC in consultation with CID-SC and led by CEPR. A time-limited joint task group may be established to conduct this work which may include recommendations for the development of new event-specific Annexes as required, to further support implementation of this plan.

Minor amendments will be approved by PHI-SC and CID-SC. Major revision, significantly altering the governance structure may require review and approval by PHNC.

Inquiries or comments on the *Federal, Provincial/Territorial Public Health Response Plan for Biological Events* should be directed to:

Director
Office of Situational Awareness and Operations
Centre for Emergency Preparedness and Response
Public Health Agency of Canada
100 Colonnade Road
A.L. 6201A
Ottawa, ON K1A 0K9

Email: HPOC_COPS@phac-aspc.gc.ca

Note to Readers

Henceforth, first occurrences in the text of terms that are listed in the Glossary are formatted in **bold**. Titles of plans, supporting documents and response levels are formatted in *italics*.

1 See Appendix M for task group membership

EXECUTIVE SUMMARY

This plan has been developed as a **response plan** for the Federal/Provincial/Territorial (F/P/T) health sector in order to facilitate formal coordination of F/P/T responses to **public health events that are biological** in nature and of a severity, scope or significance to require a high level **F/P/T response**. Informed by **lessons learned** from past F/P/T public health responses and best practices of current F/P/T structures (i.e., the Public Health Network structure and Special Advisory Committees), this plan focuses on the implementation of F/P/T responses led by senior-level public health decision-makers at the federal, provincial and territorial level in order to facilitate an efficient, timely, evidence-informed and consistent approach across jurisdictions to event-specific response activities. Improving effective engagement amongst **public health**, health care delivery and health emergency management authorities during a **coordinated F/P/T response** is a key objective of this plan. It is intended to serve as an F/P/T resource for F/P/T public health and **emergency management** authorities; specifically those who are involved in public health response preparedness and implementation. In order to further support coordination of public health events at a national level, this plan aims to build on the strengths of existing F/P/T tools and mechanisms while providing a single, overarching user-friendly response plan that is **scalable** and flexible enough to be utilized in full or in part for a range of F/P/T public health responses.

The concept of operations of the plan indicates how notification of public health events that potentially require a coordinated F/P/T response should be made to the Public Health Agency of Canada (PHAC), and how response needs are assessed to determine the appropriate level of F/P/T response coordination required. Four response levels that range from routine to **emergency** response are included to facilitate scaling of response activities as needed. The plan includes the details of a governance structure intended to be activated for those **events** in which a coordinated F/P/T response (i.e., led by senior-level decision makers) is deemed necessary and/or beneficial. The governance structure aims to: streamline response processes to a public health event; facilitate clarity on roles, responsibilities and approval processes; facilitate a high degree of situational awareness; and centralize risk management and task delegation. It incorporates three main streams: a Technical stream, a Logistics stream and a Communications stream. These streams are led by advisory committees/working groups and have been included in order to facilitate clarity regarding roles for issue management, response support, product development (e.g., recommendations, guidance, protocols), policy review and approval processes. "Cross stream" support and coordination will be essential to an efficient, informed and transparent response and therefore mechanisms for achieving this are also included.

Coordinated F/P/T responses will be conducted with each activated committee/group in the governance structure fulfilling the roles and responsibilities and decision-making processes as described in Section 4 of this plan and according to their respective terms of reference (included in corresponding appendices). Specifically, the Special Advisory Committee (SAC) will be the main approval/decision-making body for the duration of a coordinated F/P/T response under this plan, with governance structure products going to the Conference of Deputy Ministers of Health (CDMH) as required.

Public health emergencies involving multiple jurisdictions in Canada are relatively rare events. This plan is not exclusively an emergency response plan and therefore is expected to also be utilized for events not meeting the threshold of a public health emergency (i.e., for events requiring or that would benefit from enhanced F/P/T coordination); thus facilitating familiarity and opportunities to modify and improve this plan based on response experience.

This document is not intended to replace existing F/P/T health sector arrangements but rather is intended to complement and interact with the existing suite of plans and protocols currently in use by the health sector by providing an overarching governance framework with which the existing protocols will interact and/or align. Changes to those existing plans and protocols will be made following approval of this plan in order to clarify these linkages.

1 INTRODUCTION

Preface/Background

This document is a response plan for the Federal/Provincial/Territorial (F/P/T) health sector in order to facilitate formal coordination of F/P/T responses to public health events that are biological in nature. It is not intended to replace existing F/P/T health sector arrangements but rather is intended to complement and when applicable, be used in conjunction with the existing suite of plans and protocols currently in use by the health sector by providing an overarching governance framework that can be used to respond to a spectrum of public health events caused by **biological agents**. It is also expected that this plan will serve as the governance framework under which future and existing **hazard-specific** F/P/T health sector plans, protocols and guidance will be situated.

As required by legislation, all jurisdictions in Canada have plans that set out the steps to be taken in the event of an emergency or disaster. These plans identify linkages and channels of communication to other ministries, programs and agencies of the Government and contribute to a coordinated, system-wide approach to emergency management that can be applied if necessary in a **whole of government response**. In addition, the F/P/T health sector has in place well established hazard-specific tools that are routinely used to effectively plan for and manage public health events, including the *Canadian Pandemic Influenza Preparedness: Planning Guidance for the Health Sector* (CPIP) and *Food-borne Illness Outbreak Response Protocol* (FIORP) and others. In order to further support coordination of public health events at a national level, this plan aims to build on the strengths of these existing tools and mechanisms while providing a single, overarching user-friendly response plan and **F/P/T governance structure** that is scalable and flexible enough to be utilized in full or in part for a range of F/P/T public health responses to **biological** events. For a further description of the interface and relationship between this plan and other key plans at the F/P/T level, see *Appendix L: Relationship of the F/P/T Public Health Response Plan to other F/P/T Coordinating Instruments*.

Aim

The aim of this plan is to outline how F/P/T responses to public health events caused by biological agents will be conducted and coordinated. This response plan will provide clarity with respect to: considerations for F/P/T responses; response objectives and corresponding activities; governance mechanisms that support F/P/T response efforts and deliverables; and roles, responsibilities and accountabilities within those governance mechanisms.

This plan is intended to serve as a resource for F/P/T public health and emergency management authorities; specifically those that are involved in public health response preparedness and implementation. Those working in particular public health program areas can focus on hazard-specific preparedness activities (e.g., the CPIP) and response protocols (e.g., FIORP), knowing that if transition to a high level coordinated F/P/T response is needed this plan exists and would be used to provide that function.

Scope

The focus of this plan is on public health events that are biological in nature and require a public health response at both the P/T and federal levels. While the focus of this plan is public health, it should be emphasized that any public health event will be health system-wide and will require coordination between public health and health care delivery and other sectors. Details regarding response coordination with the respective health care systems of the provinces and territories are outside the scope of this plan.

Further, as a response plan, issues regarding **mitigation, preparedness** and **recovery** are also beyond the scope of this document. Activities relating to mitigation, preparedness are dealt with through the activities of existing committees and task groups within the Public Health Network that are actively engaged in health emergency management. However, should there be a need for enhanced F/P/T coordination in the recovery of a public health event (e.g., continued psychosocial response to a bioterrorism event or **pandemic**), consideration may be given to leveraging the governance components of this plan to support recovery activities.

Biological agents are the cause of biological events and include bacteria, viruses, fungi, other microorganisms and their associated toxins. They have the ability to adversely affect human health in a variety of ways, ranging from relatively mild, allergic reactions to serious medical conditions and death. These organisms are widespread in the natural environment; they are found in water, soil, plants, and animals.

Biological events can be naturally occurring disease outbreaks at national and international levels, accidental exposure to **pathogens** (disease causing agent) in the context of biomedical diagnostics and research, significant shortages of drugs and biologics or intentional use of pathogens or biotoxin (poisonous substance produced by a living organism) against humans, plants, or animals for harmful purposes. The scope of this plan is intended for the situations where the principle issue is human health and includes biological agents found in the environment, or diagnosed in animals, that have the potential for transmission to humans (zoonosis).

The following are examples of the range of scenarios where this plan may be applicable. It may be applied for a biological public health event in a single P/T with the potential for spread/involvement to another P/T, to multijurisdictional outbreaks that require coordination with federal and P/T partners (e.g., large and complex foodborne outbreak requiring significant coordination at a senior level beyond the scope of the FIORP), to shortages of **medical countermeasures** (e.g., **vaccine** shortage), to **public health emergencies** in Canada (e.g., H1N1 pandemic influenza). The management of large-scale public health events with international implications in which federal coordination is necessary (e.g., ebola, zika) are also within the scope of this plan. Biological events that are restricted to animal, plant, or food health or safety are outside the scope of this plan.

It is recognized that public health events that are intentional in nature (e.g., bioterrorism) will require a law enforcement/security response in addition to a public health response. While the elements of the public health response to an intentional event may not significantly differ from those described in this plan (and therefore this plan may be utilized for the public health **consequence management**), the linkages to the law enforcement/ security response are not within the scope of this plan. It is expected however, that the governance structure for a biological event where the intent is malicious, would be similar to that as described in this plan.

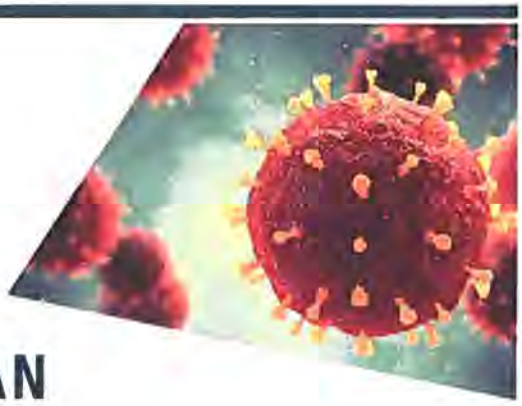
Following endorsement, training and use (i.e., proof of concept), this plan will become a model for development of an **all hazard** F/P/T governance for the health sector that can be applied if required for F/P/T coordinated responses to other events such as natural disasters or **Chemical, Biological, Radiological/Nuclear, Explosive (CBRNE) events**.

Objectives

The specific objectives of this plan include:

- defining a flexible F/P/T governance mechanism that can be used consistently for a coordinated response to all biological public health events that would benefit from high level F/P/T collaboration;
- identifying escalation considerations and response levels for a scalable response, and
- improving effective engagement amongst public health, health care delivery and health emergency management authorities during a coordinated F/P/T response.

Through the achievement of these objectives it is expected that, at the time of a response, notification processes and inter-jurisdictional information-sharing will be enhanced; public and professional communication expectations will be addressed; and advanced planning and decision-making between and amongst multiple jurisdictions will be facilitated.



2 CONTEXT FOR THE PLAN

Risk Environment

This plan has been developed at a time when **public health risks** have been relatively well defined and assessed, and risk mitigation activities are ongoing. However, it is recognized that many risk drivers are so broad and expansive that even coordinated public health interventions are unlikely to mitigate those risks. Some of the risk drivers associated with emerging infectious disease are: globalization of people and animals, climate change, changes in land use, movement/displacement of people, population density and urbanization, and changes in farming practices and antibiotic use. Many of these risks are manifesting outside of Canada but have a real or potential impact on the health of the public in Canada. It is in this risk environment that health authorities in Canada must be prepared to respond to biological **hazards**.

Previous and ongoing public health responses have addressed everything from **epidemics** of novel respiratory pathogens (e.g., Severe Acute Respiratory Syndrome—SARS) and pandemics (e.g., H1N1 influenza), to emerging infections (e.g., west nile virus, lyme disease) and international or travel-related public health threats (e.g., ebola, zika).

Throughout 2013-14, the Council of Chief Medical Officers of Health (CCMOH) was involved in the response to a number of significant public health events including infectious disease: (H7N9; MERS-CoV; H5N1; H1N1, seasonal influenza), food-borne illness: (E coli O157:J7 (XL Foods, Inc.), and vaccine supply issues: (2014 influenza vaccine shortage). The CCMOH subsequently identified inconsistencies in the management of these events and requested the development of a plan for response to public health events of national concern to ensure consistency, timeliness and scalability of F/P/T response activities.

It is within the context of experiences from past public health events that the guiding principles used for the development of this plan and anticipated response activities associated with this plan were derived. Specifically, lessons learned from an intensive review of the governance structure utilized during the F/P/T response to the H1N1 influenza pandemic in 2008-9 identified the need for a nimble, flexible governance that can be applied consistently, in whole or in part, to a range of public health scenarios and the need to clarify roles and responsibilities as well as decision-making and approval processes at various levels.[2]

2 Lessons Learned Review: *Public Health Agency of Canada and Health Canada Response to the 2009 H1N1 Pandemic:* www.phac-aspc.gc.ca/about_apropos/evaluation/reports-rapports/2010-2011/h1n1/pdf/h1n1-eng.pdf

Guiding Principles

The guiding principles used for the development of this plan and anticipated response activities were based on lessons learned or identified from previous public health responses and best practices. They include:

- Efficiency
- Timeliness
- Transparency
- Commitment
- Engagement
- Representativeness
- Health Equity
- Flexibility
- Effectiveness, and
- Ethical and Evidence-Informed Decision-Making.

More details regarding these principles are located in *Appendix B: Plan Development Guiding Principles*.

The contents of this plan and in particular the governance structure and concept of operations, aim to facilitate the following of these principles in order to appropriately operationalize best practices (such as the activation of the Special Advisory Committee) and other learnings from previous public health responses.

During a response there will be a need for a consistent, coordinated approach that is both scalable and flexible. Throughout the response it may be necessary to modify guidance, protocols, or recommendations in order to adapt the response to the evolving circumstances. Ideally, any significant changes will be made in conjunction with an articulated change in response objectives (e.g., preventing introduction into Canada vs. preventing spread of illness within Canada). It is recognized that at any one point during the response the objectives of the response may vary from jurisdiction to jurisdiction within Canada depending on the local impact of the public health event and **risk assessments**; however, F/P/T governments should aim to work collaboratively to facilitate a common set of F/P/T public health response objectives to every extent possible, recognizing roles and responsibilities differ, the impact of the event will likely be different in each jurisdiction and F/P/T health care systems function differently.

Public Health and Emergency Management Roles

Public Health authorities conduct and manage responses to public health events via:[3]

- monitoring and surveillance activities,
- risk assessment,
- **public health measures** (e.g., public education, case and contact management, trace-back/trace-forward, travel/border measures, vector control, mitigation of risk from animals, etc.),
- laboratory networks,
- connections with a clinical research network and other health care delivery partners,
- vaccine (and other medical countermeasures) programs,
- the provision of specific health services and evidence-informed recommendations,
- engagement with key stakeholders (e.g., occupational health authorities, health care institutions, law enforcement), and
- risk communications.

3 Not all examples are applicable in Québec or are the responsibility of public health authorities in in Québec where the concept of *public health* is distinguished from the *public health system*.

Emergency Management authorities facilitate and support coordination of responses to public health events by:

- using a platform and tools for planning and coordination of integrated response activities,
- addressing issues regarding mutual assistance/aid (e.g., via the *Operational Framework for Mutual Aid Surge Requests* [OFMAR]),
- providing logistical guidance and support, and
- expediting and facilitating the sharing of information and other resources across the health sector and with other relevant sectors domestically and internationally.

The response activities implemented and coordination required will vary depending on the type of public health event and response objectives (which may change over the course of the response). Therefore this plan includes references to potential response activities in conjunction with response objectives, a governance structure that is flexible and scalable, and a concept of operations that facilitates awareness of the entire response process.

F/P/T Authorities/Roles and Responsibilities

The main roles, responsibilities and authorities of the federal Health Portfolio and the provincial and territorial public health authorities during a public health response to a biological hazard are listed in *Appendix C: Main F/P/T Roles and Responsibilities*. A coordinated F/P/T response requires collaborative and inter-operable infrastructures, response capacities and harmonized activities. During a public health response, the role of the F/P/T governments will be to work collaboratively to establish an overall agreed upon strategy that articulates, why, what and how. The 'what' are interventions that can be implemented as needed across Canada and that correspond to response needs and objectives, recognizing that some or all jurisdictions may implement them dependant on the roles and responsibilities of the jurisdiction and circumstances of the event. These interventions may include: developing/modifying protocols for surveillance and laboratory testing, providing recommendations for public health measures and the use of medical countermeasures, identifying research needs and developing and implementing an F/P/T communication strategy that allows P/T governments to develop harmonized communication plans and stakeholder engagement strategies.[4]

If a coordinated F/P/T response is implemented under this plan, the federal Health Portfolio will facilitate the coordination of the response through the Health Portfolio Operations Centre (HPOC) including participation on the F/PT governance structure committees/groups as described in this document and through its support of the F/P/T Special Advisory Committee Secretariat. See Section 4 *F/PT Governance* for more specific information on the HPOC's role.

4 In Québec, public health is responsible for medical countermeasures for immunization and prevention activities, not for treatment or medication.

Government of Canada / Gouvernement du Canada

Public health ethics framework: A guide for use in response to the COVID-19 pandemic in Canada

THIS IS EXHIBIT "S" referred to in the Affidavit / Declaration of Dr. Deena Hinshaw affirmed Sworn / Declared before me this 12th day of July A.D., 2021
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public.
Heather L. Veale
Barrister & Solicitor

On this page

Introduction

The public health threat posed by the COVID-19 pandemic has led all levels of government to take unprecedented measures to help slow the spread of COVID-19 and thereby minimise serious illness, death and social disruption resulting from the pandemic. Difficult choices are being made in a context of considerable uncertainty, as knowledge about COVID-19 and the impact of unprecedented public health measures evolves rapidly. Examples include decisions about allocation of scarce resources, prioritization guidelines for vaccines and medical countermeasures, curtailment of individual freedoms, and closing or re-opening public spaces, schools and businesses. Recognizing the fundamental ethical nature of these choices

can help decision makers identify competing values and interests, weigh relevant considerations, identify options and make well-considered and justifiable decisions.

Intended audience

This Framework is intended for use by policy makers and public health professionals making public health decisions in the context of COVID-19.

Intended application

This document is a guide to support ethics deliberation and decision-making in the public health response to the COVID-19 pandemic, including the transition to a new normal. It is based on several guidance documents and frameworks developed in Canada and internationally. Section 1 articulates ethical principles and values for public health authorities to consider, and Section 2 sets out a framework to help clarify issues, analyse and weigh relevant considerations, and assess options, in order to support decision making in real situations.

Ethical values and principles

Trust and Justice are the two key guiding values that underpin this framework. The ethical principles and procedural considerations that follow contribute to upholding and promoting trust and justice. Given that it may not be possible in some circumstances to uphold all values and principles equally, it will be important for decision makers to explain how they prioritised them, and to justify the trade-offs made in each situation.

Trust

Trust is the foundation upon which rest all relationships, whether between persons, persons and organisations, or citizens and government. Trust is essential to the success of the response to COVID-19. The effectiveness of many public health measures depends on the active cooperation of the public, and such cooperation is more likely if the public trusts the advice of public health authorities. Evidence that public health measures are achieving their intended outcomes, or alternatively, timely and transparent explanations of why they have not, also help to maintain and promote public trust. Without this trust, individual choices could contribute to the spread of COIVD-19 within the community. In the current context of uncertainty, being open, truthful and transparent in decision making and communication is essential to establishing and promoting trust.

Justice

Justice entails treating all persons and groups fairly and equitably, with equal concern and respect, in light of what is owed to them as members of society. This does not mean treating everyone the same, but it does mean considering who benefits and who is burdened by measures, avoiding discrimination, and minimising or eliminating inequities in the distribution of burdens, benefits, and opportunities to preserve health and well-being. In the context of COVID-19, it also means carefully considering the impact of decisions and their implementation on those who have the greatest needs, are especially vulnerable to injustice or are disproportionately affected by the pandemic and public health response measures, both in Canada and in the global context. A conscious and deliberate questioning of assumptions is essential in ensuring that responses and decisions do not reproduce the biases and stereotypes that are further entrenching inequalities in this pandemic.

Respect for persons, communities and human rights

Respect for persons and communities means recognizing the inherent human rights, dignity, and unconditional worth of all persons, regardless of their human condition (e.g., age, gender, race, ethnicity, disability, socioeconomic status, social worth, pre-existing health conditions, need for support). This entails recognizing the unique capacity of individuals and communities to make decisions about their own aims and actions, and respecting the rights and freedoms that form the foundation of our society. The right to autonomy is not absolute however. In the context of the response to COVID-19, respecting autonomy may entail: recognizing the importance of public consultation and of explaining the basis of decisions; providing information in a manner that is truthful, honest, timely and accessible; and providing individuals with the needed personal supports and the opportunity to exercise as much choice as possible when this is consistent with the common good. Respect for communities requires considering the potential impact of decisions on all communities and groups that may be affected, and respecting the specific rights of, and responsibilities towards, Indigenous Peoples.

Promoting well-being

Individuals, organizations and communities have a duty to contribute to the welfare of others. In the context of COVID-19, public health authorities' decisions and actions should promote and protect the physical, psychological and social health and well-being of all individuals and communities to the greatest extent possible. They should also consider the specific needs of, and duties towards, those who are marginalised, disadvantaged or disproportionately affected by response measures.

Minimising harm

Public health authorities have an obligation to avoid causing undue harm and, given that some harm is likely unavoidable, to minimise risk of harm and to reduce suffering associated with COVID-19 and public health response measures. This requires taking into consideration the variety of harms and suffering that may result from the current pandemic (such as ill health, increased anxiety and distress, isolation, social and economic disruption), as well as the differential impact of these harms on different groups and populations.

In order to promote well-being and minimise harm, the following must be considered when weighing options:

- **Effectiveness:** there should be a reasonable likelihood that the proposed decision or action will achieve its goals, and that its implementation is feasible. If scientific evidence is available, the proposed action or decision should be supported by the evidence;
- **Proportionality:** potential benefits should be balanced against risks of harm. Measures should be proportionate to the relevant threat and risks, and the benefits that can be gained. If a limitation of rights, liberties or freedoms is deemed essential to achieve an intended goal, the least restrictive measures possible should be selected, and imposed only to the extent necessary to prevent foreseeable harm;
- **Reciprocity:** those who are asked to take increased risks or face greater or disproportionate burdens in order to protect the public good should be supported by society in doing so, and the burdens they face should be minimised to the greatest extent possible;
- **Precaution:** scientific uncertainty should not prevent decision makers from taking action to reduce risks associated with COVID-19. The continued search for scientific evidence should nonetheless be a goal.

Working together

Because individuals are part of a greater whole, whether an organization, a local community, a nation or the global community, collective action in the face of common threats is justified. Helping each other and working together to plan for, respond to, and recover from, the pandemic is important because the pandemic affects all of society. It implies strong links between all jurisdictions within Canada, and at the international level.

Procedural considerations

Ethical decisions are based on the best information available and a solid, shared understanding of what values, principles and considerations are important. A good decision-making process helps to build trust, to increase legitimacy and acceptability of decisions, and to effectively implement them. Its hallmarks are:

- **Accountability:** decision makers are answerable to the public for the type and quality of decisions made or actions taken;
- **Openness and transparency:** decisions are made in such a way that stakeholders know, in a full, accurate and timely manner, what decisions are being made, for which reasons, and what criteria were applied, and have the opportunity to provide input;
- **Inclusiveness:** groups and individuals who are most likely to be affected by a decision are engaged in the decision-making and planning processes to the greatest extent possible;
- **Responsiveness:** decisions are revisited and revised as new information emerges;
- **Intersectionality:** an intersectional lens is applied to deliberation and decision making.

Ethical framework

This framework consists of five steps. It sets out questions to guide the systematic analysis of ethical issues – using the values and principles articulated in Section 1 – and the assessment of options, in order to support decision-making.

Step 1: Identify the issue and gather the relevant facts in order to clearly understand the problem

- What is the issue that needs to be addressed?
- What are the relevant facts, scientific evidence and other contextual factors? What misinformation surrounds the issue? What is not known?
- Who is affected by this decision? How can all stakeholders be engaged throughout the decision-making process?
- How do the different stakeholders view the issue, and what are their concerns?

Step 2: Identify and analyse ethical considerations, and prioritise the values and principles that will be upheld

- What ethical values, principles and considerations are involved in this issue?
- Are any of these values and principles in conflict?
- Which of these values or principles are most important?

Step 3: Identify and assess options in light of the values and principles

- What are the options (including doing nothing)?
- In light of the prioritised values and principles, what are the pros and cons of each option (e.g. potential benefits, harms, fair and equitable distribution, relative impact on disadvantaged individuals or groups,

intended and unintended consequences, level of certainty about effectiveness, respect for rights and interests)?
- What uncertainties exist for each option?

Step 4: Select best course of action and implement

- Which option best aligns with the prioritised values and principles?
- Are the decision makers and stakeholders comfortable with the decision?
- Who will implement the decision? How can it be implemented fairly?
- How, when and by whom will the decision be communicated?

Step 5: Evaluate

- What are the lessons learnt from implementation of the decision?
- Were the results of the decision consistent with the objectives? Were there any unintended consequences? Did its implementation create or exacerbate inequalities?
- Should the decision be revisited?

Selected resources

- World Health Organization, *Guidance for Managing Ethical Issues in Infectious Disease Outbreaks* (2016)
- UNESCO International Bioethics Committee and World Commission on the Ethics of Scientific Knowledge and Technology, Statement on COVID-19: Ethical Considerations from a Global Perspective (2020)
- Public Health Agency of Canada, *Framework for Ethical Deliberation and Decision Making in Public Health: A Tool for Practitioners, Policy Makers and Decision Makers* (2017)

- Alberta Health, *Alberta's Ethical Framework for Responding to Pandemic Influenza* (2016)
- British Columbia Ministry of Health, *COVID-19 Ethical Decision-Making Framework* (2020)
- Northwest Territories Health and Social Services Authority, *Territorial Ethical Decision-Making Framework* (2019)
- Québec, Comité d'éthique de la santé publique et Commission de l'éthique en science et en technologie, *Cadre de réflexion sur les enjeux éthiques liés à la pandémie de COVID-19* (2020) (in French only)
- University of Toronto Joint Centre for Bioethics Pandemic Influenza Working Group, *Stand on Guard for Thee: Ethical considerations in preparedness planning for pandemic influenza* (2005)
- Trillium Health Centre, *IDEA: Ethical Decision-Making Framework* (2013)
- Status of Women Canada, *Government of Canada's Approach: Gender-Based Analysis Plus* (2018)

Acknowledgements

The *Public Health Ethics Framework: A Guide for Use in Response to the COVID-19 Pandemic in Canada* was developed by PHAC's Public Health Ethics Consultative Group and its Secretariat with input from the Canadian Pandemic Influenza Task Group, the Federal/Provincial/Territorial Special Advisory Committee on COVID-19 and the COVID-19 Disability Advisory Group. PHAC greatly appreciates the time and effort that all contributed to this endeavour.

Related links

- Points to consider: Public disclosure of outbreaks and cases of infectious diseases

Date modified:

2021-02-16

COVID-19 Scientific Advisory Group Rapid Response Report

Key Research Question: What is the evidence supporting the possibility of asymptomatic transmission of SARS-CoV-2? [Updated July 13, 2020]

Context

- Significant asymptomatic transmission of SARS-CoV-2 would reduce the effectiveness of public health control measures that are related to symptom onset (isolation, face masks and enhanced hygiene for symptomatic persons, and parameters of contact tracing).
- There is a lack of clarity and common usage of the terms asymptomatic, presymptomatic, and paucisymptomatic states in the COVID-19 literature.
- Concerns regarding asymptomatic transmission are driven by select early reports suggesting high proportions of people with positive RT-PCR in various outbreak settings were asymptomatic at the time of testing, and subsequent epidemiologic modelling suggesting that these cases may be responsible for potentially significant transmission. However, these studies generally did not exclude paucisymptomatic and presymptomatic states, and prolonged RTPCR positivity was not well understood earlier in the pandemic. New data are synthesized here.
- Even a small rate of asymptomatic or presymptomatic transmission could impact communities as public health measures are relaxed, if core control measures are neglected (including physical distancing, hygiene, appropriate use of face masks as recommended by current public health guidelines).
- There is new data emerging around diagnostic test utility, sensitivity and specificity, and the role of community based serologic testing to ascertain seroprevalence within communities and better delineate the fraction of undetected infections, and the possibility of asymptomatic and presymptomatic transmission as a community risk.
- Between the updated literature search date and the release of this update repeated searches were carried out to include high profile publications in this topic area, including the recent WHO Transmission Scientific Brief, released July 9, 2020. The author of the report reviewed this document in detail and there are no significant discrepancies or new information between this rapid review and the WHO updated scientific brief although it adds information on short range aerosols and the theoretic risk of fomite transmission, which are outside the scope of this document.

Key Messages from the Evidence Summary

1. Evidence thus far has not adequately defined or assessed "asymptomatic" individuals who test positive for SARS-CoV-2 by RT-PCR, making much of the current data unreliable. A single positive RT-PCR without current symptoms could be classified as 1) Presymptomatic, 2) Asymptomatic (or paucisymptomatic), or 3) Positive after infection (regardless of symptoms) or rarely, a false positive result (which cannot transmit infection.) Transmission might occur from only the first two types of individuals (pre and asymptomatic infected persons).

Interpretation of existing data (including that used in modeling studies) is clouded by a lack of clarity in 1) definition of "asymptomatic" (whether defined by Influenza Like Illness screening (absence of cough and fever) or a more comprehensive symptom list was used) and 2) lack of reporting of symptoms for 4 weeks prior to, and 2 weeks after the test.

There is evolving data on viral kinetics in asymptomatic, pre-symptomatic, and paucisymptomatic SARS-CoV-2 infection. One series documented higher viral loads (by 60 fold) and a longer time to RT-PCR clearance in patients with severe illness, and a median of 24d to become RT-PCR

negative (with 32.1% still positive at 1 month post onset). Importantly, other studies have shown that SARS-CoV-2 RT-PCR can remain positive for 4 weeks in patients with milder outpatient managed COVID-19 as well.

- Therefore a RT-PCR positive result in a currently asymptomatic person is of unclear significance and RT-PCR positive status cannot be used to infer potentially infectious status.

2. Studies suggest that levels of SARS-CoV-2 can be high by RT-PCR and detected by virus cultivation early in infection, prior to symptom onset, with replication in upper respiratory (nasal lining) and respiratory cells. This is distinct from SARS-CoV and would support the potential importance of presymptomatic transmission. Two publications demonstrate a lack of viable virus detected after day 8 of symptoms, with another suggesting a possible longer duration of shedding of viable virus in severe illness.

In addition, the RT-PCR CT (threshold cycle) value may eventually become useful as a proxy for cultivatable virus - one source suggested <24 is associated with cultivatable virus. However development of validated methodologies to use SARS-CoV-2 CT as a quantification assay would be required.

3. To define the role of asymptomatic transmission, processes to rule out post infectious and presymptomatic RT-PCR positive states are required, as the proportion of people with truly asymptomatic infection cannot be accurately inferred from studies that report "asymptomatic" status at the time of testing. Prevalence studies carried out after epidemics in high risk closed populations are potentially more likely to include post infection RT-PCR positives, and overestimate the proportion of people who may transmit infection.

To establish asymptomatic SARS-CoV-2 infection:

- Post symptomatic PCR positivity should be ruled out by documentation of a negative 4 week symptom history and potentially with concurrent serologic testing, where available, for the presence of SARS-CoV-2 antibodies. Current evidence suggests that a positive PCR with positive antibody test would suggest past infection and low likelihood of current transmission potential.
- Presymptomatic PCR positivity should be ruled out by documenting absence of compatible symptoms over a 14 day period from test collection.
- If an asymptomatic person who is RT-PCR positive is seronegative, documentation of seroconversion at 3-4 weeks after the initial test should be considered.

4. The best individual studies of the true asymptomatic proportion in high risk populations suggest a range of 15 to 20%, in studies of individuals who were close contacts isolated in centralized quarantine facilities. Similarly, a well conducted RT-PCR and serology based study of US service members aboard an aircraft carrier reported an asymptomatic proportion of 18.9%, raising the possibility that younger people may be more likely to be paucisymptomatic or asymptomatic. Finally, a pre-print metaanalysis of these epidemiologic data suggested the asymptomatic proportion is 15% (12-18%). Uncertainty in these studies is related to the possibility of prior infectious contacts in the community during exponential growth rate epidemics in some of these reports, coupled with a lack of detailed symptom history prior to the positive test, which would tend to overestimate the asymptomatic positive proportion through inclusion of post symptomatic positive cases. Importantly, a population of close contacts to documented cases are at higher risk of infection (symptomatic or asymptomatic) compared to the general population so observing that a proportion of 15% positives in high risk populations are asymptomatic does not suggest that 15% of asymptomatic people in the community are infected.

5 The efficiency of observed transmission of infection from asymptomatic RT-PCR positive people appears to be low (two studies reported no transmission from asymptomatic cases, one quarantine center series reported an incidence of secondary infection of 0.3%, which was 20 fold lower than transmission to contacts from severe cases, and another reported transmission to 2.2% of traced contacts of

asymptomatic people. A preprint systematic review (including many of the papers reviewed here) estimated that secondary attack rates were 2.5X higher from symptomatic versus those who were symptom free at diagnosis.

6. Presymptomatic transmission merits separate consideration from asymptomatic transmission, because of more robust documentary data and because of practical contact tracing implications. Presymptomatic spread has been well documented in individual case reports and reported case series, usually involving close/household contacts. Newer data suggests that presymptomatic transmission may in some circumstances be considerable, although it is unclear whether these events are related to characteristics of the index case, the setting of transmission, or both. Case series have shown relatively high secondary attack rates with exposure just prior to symptom (for example, presymptomatic cases transmitted to 0.7% of contacts compared to while presymptomatic versus symptomatic cases transmitting to 1.1% of contacts). In another household study where index cases isolated themselves and masked within the household upon symptom development, however, there were no household transmissions versus a 17% attack rate in other households. Contact tracing studies overall suggest that most transmission risk occurs before day 6 of symptoms, with no nosocomial transmissions among 852 hospital contacts after day 6 of symptoms, although the contribution of presymptomatic spread was not clarified in that study.

7. Modeling data has suggested the possibility that presymptomatic or asymptomatic transmission could contribute to significant community transmission, but models have generally been based on data with the discussed shortcomings. Existing models are based on assumptions generated from studies in high risk populations that that did not rule out postsymptomatic and presymptomatic RT-PCR positives in the reported proportions of asymptomatic cases, as previously discussed. As such, these models establish an upper range of potential community transmission from asymptomatic and presymptomatic cases.

8. The role of paucisymptomatic individuals in COVID-19 transmission is very unclear, as on detailed review this group may have been called either "asymptomatic" or "mildly symptomatic" in previous studies. There is some suggestion that less severe disease is associated with a shorter duration of shedding of infectious virus.

Recommendations

1. The office of the Chief Medical Officer of Health, Alberta Health should develop and use standardized definitions for Asymptomatic, Presymptomatic, and Paucisymptomatic COVID-19 cases to support data collection and case classification, to clarify the assessment of transmission dynamics in Alberta.
2. All COVID-19 RT-PCR positive patients should be administered a brief global symptom history for current or recent symptoms suggestive of COVID-19 and if no current symptoms are documented, a specific symptom history over the previous 6 weeks should be recorded as a searchable data field. Patients with prior symptoms would be able to be assigned "possible post-symptomatic" status.
3. A pilot of periodic administration of this current/previous 6 weeks symptom history questionnaire should be resourced to allow data collection on a sample of all patients presenting for testing at assessment centres to document the baseline prevalence of these symptoms in the Albertan population and the association with COVID-19 testing results.
4. If an asymptomatic person is documented to be RT-PCR positive, they should be monitored during self isolation and reclassified as "presymptomatic RT-PCR positive" if symptoms develop.
5. When serologic testing is available, the Serology working group of the provincial laboratory and Public Health should consider a pilot of serologic testing in asymptomatic RT-PCR positive patients to evaluate what proportion of test positive asymptomatic people are seropositive, suggesting past infection and likely noninfectious status. If seronegative, the serology should be repeated 3-4 weeks after the RT-PCR test to document if seroconversion has occurred.
6. The office of the Chief Medical Officer of Health, Alberta Health should consider further public education in two main areas:

a) Identification of symptoms and prompt self isolation: Topics may include the importance of recognition of mild possible COVID-19 symptoms, the need to self isolate/get tested, and reinforce employer responsibilities to support employees with adequate sick leave policies.
b) Highlight need for contact tracing: Topics may include the need for individuals to be able to list their contacts if subsequently identified as potentially infectious, to reduce further spread of infection. Therefore, if a contact tracing app is not used, people should be encouraged to keep a running diary of their daily contacts/types of contacts with others in the event that contact tracing is required.

7. Based on evidence identified in this review, it is suggested that adequate resources and infrastructure adaptation are currently required to prioritize specimens for COVID-19 RT-PCR testing in the following order: symptomatic (highest priority), asymptomatic people who are close contacts of known cases (high priority due to high pre-test probability), and then asymptomatic people without high risk contacts. Testing of asymptomatic people who are not identified case contacts should not delay testing, reporting and contact tracing efforts for people who are symptomatic or close contacts to known COVID-19 cases.
8. To clarify the utility of widespread testing of people who are asymptomatic, a pilot of strategic testing of asymptomatic people (with symptom documentation as above) should be considered to better describe population infections dynamics, with consideration for
    a. RT-PCR testing programs for those potentially at higher risk of exposure to infection (essential workers, those with higher numbers of community contacts, teachers, staff and children upon return to school), and those of higher risk of severe disease if acquiring infection (older persons, comorbidities).
    b. Population based prevalence studies using representative sampling, and both RT-PCR and serologic testing.

Committee Discussion

Third Revision:

This revision saw reasonable committee agreement that presymptomatic spread has evolved to have a more supported role in community transmission and that existing data on the proportion of transmission for completely asymptomatic persons is unclear. Committee members supported a recommendation to better delineate this in an Albertan context, primarily though documenting an expanded symptom history at the time of swabs and ensuring a 6 week retrospective history review is documented in those who are positive. The recommendation was originally 4-6 weeks but 6 weeks was felt to be better operationally. Use of serology in conjunction with RT-PCR in people who are truly asymptomatic and not post symptomatic was seen as potentially promising but committee survey suggested that this should not be recommended directly given the nascent state of serologic testing so the recommendation was changed to request that the COVID-19 Serology provlab group to work with Public Health to consider a pilot of this approach.

Second revision:

The SAG did not reach a consensus recommendation based on available evidence after discussion of this update. The new data considered was seen as supportive that asymptomatic and presymptomatic persons may test positive for SARS-CoV2 and that there are case reports of transmission without overt symptoms. The degree to which this may drive transmission in various settings (outside of close or household contact as has been reported) was debated. There were considerably varied opinions on the likelihood of asymptomatic transmission as a major contributor to transmission. That said, some committee members felt that the lack of concrete evidence to show cultivatable virus, and/or transmission in community or healthcare setting (versus close household settings) from presymptomatic cases is currently a critical evidence gap. Committee members felt that further data on asymptomatic cases may become available shortly, which would support a potential evidence based consensus recommendation. Seven committee members were in agreement with the key messages while two committee members felt that the current epidemiological situation supported that asymptomatic or presymptomatic transmission is

occurring to a significant degree, which would have implications for risk assessment, and control measures.

The evidence for this topic is changing very rapidly. It is necessary to monitor the literature for new estimates of spread from asymptomatic persons, information around rapid potential screening of asymptomatic persons, efficacy of face shields, masks, and cloth masks, alone and in combination. This brief should be re-visited frequently to ensure all evidence is accounted for.

Summary of Evidence

The literature searches were conducted by KRS within the Knowledge Management Department of Alberta Health Services. Critical appraisal was conducted using an adapted Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018). A key limitation of this review is that some of the evidence is preprint, which has not been subject to peer review, published as correspondence not subject to peer review, or are observational studies, with lower rigor than formal epidemiological studies.

Research Gaps

There is not yet a reliable estimate of the burden of truly asymptomatic infection and its consequent transmission potential. Existing studies have failed to report methods, sampling frames, case definitions, extent of contact tracing, followup periods, and clear separation of asymptomatic, presymptomatic and mildly symptomatic/paucisymptomatic cases. Future studies should seek to fill this gap. In addition, modelling studies using newer estimates of the proportion of, and transmissibility from asymptomatic SARS-CoV-2 infected people are needed.

Population serosurveys should also include symptom documentation over the course of the potential exposure period recognizing increasing risk of recall bias.

Methodologies for laboratories to quantitatively report SARS-CoV-2 RT-PCR results from respiratory specimens should be developed. It is recognized that cycle threshold (Ct) values may assist clinicians and PH personnel in assessing cases in the overall clinical context of cases but that validation and controls for this reporting are not developed.

Detailed Evidence Review: What is the evidence supporting the possibility of asymptomatic transmission of SARS-CoV-2?

Data informing an assessment of symptomatic transmission has been collated from studies in 4 main categories: 1) virologic studies, 2) epidemiologic observations (outbreak investigations and transmission chain analysis), 3) modelling studies, and 4) high quality population serologic surveys which include symptom questionnaires.

1. SARS-CoV-2 viral testing kinetics

1.1 Viral load data and culture data, in humans

Small studies have demonstrated very high viral loads (by RT-PCR) in patients identified as presymptomatic, asymptomatic, or mildly symptomatic, making this a plausible concern (Kimball et al., 2020; Pan et al., 2020; Zou et al., 2020). Two reports described successful culture of virus from presymptomatic (Arons et al) and asymptomatic (Hoehl et al) people, although in both of these reports, it was unclear that postsymptomatic RT-PCR positivity was excluded. There is emerging data suggesting that infectiousness may be inferred from cycle threshold (Ct) levels, where a higher number suggests that more cycles were required to detect the SARS-CoV-2 RNA, and thus a lower value would suggest a higher viral load. In a study in a long term care home, 13 of 23 individuals who tested initially positive by RT-PCR were asymptomatic at the time of testing (Kimball et al., 2020). In a detailed laboratory publication from this care home with prevalence surveys, high amounts of viral RNA based on RT-PCR was detected in people who were identified as asymptomatic, presymptomatic or symptomatic at the time of testing, with no significant differences between the three groups. Prevalence testing was performed 23 days after the first identified case with 48/76 residents were positive, of which 27 (56%) were

asymptomatic. Twenty four (89%) subsequently developed symptoms (median onset at 4 days). Seventeen (71%) of these presymptomatic patients had viable virus recovered. The mean Ct value was 24.2 for presymptomatic and 27.3 for asymptomatic patients (Arons et al 2020). In this study the highest cycle threshold of RT-PCR in samples where virus was culture positive was 34, with 2 over 30, and the culture were positive over a range from 6 days before onset of fever, cough, or shortness of breath through to 9 days after symptom onset. A significant flaw is that the earliest non ILI symptoms were not recorded, and the accuracy of symptom assessment in this patient population may be limited.

A recent retrospective cross sectional study attempted Vero cell culture from RT-PCR positive samples, with 26/89 (29%) demonstrating growth. In this paper there was no viral growth from specimens with a Ct of >24, or symptom onset to test time of >8 days (Bullard et al, 2020). Similarly, an earlier paper suggested that no replicating virus (assessed by subgenomic RNA) was detectable after day 8 in a detailed virological assessment was carried on nine patients with early symptoms (Wolfel et al., 2020). Patients demonstrated high virus shedding by RT-PCR, peaking at day 4, and live virus was isolated during this time frame. They also used sub-genomic RNA to demonstrate active viral replication in the upper respiratory tract. Seroconversion occurred by day 7 in 50% of patients and by day 14 in all patients. Shedding of viral RNA based on RT-PCR with high quantitative burden continued into the second week even though (Wolfel et al., 2020), indicating that RT-PCR positivity does not confirm live virus shedding.

Congruent findings from 82 people in Beijing were reported in a correspondence that reported the viral load peak at five to six days after symptom onset (Pan et al., 2020a). There were two people in this group with known exposure to an infected individual who were RT-PCR positive one day before symptom onset (Pan et al., 2020a). In another study of18 patients, those with early symptoms had high viral RT-PCR values, as did 1 asymptomatic patient, which was distinguished from SARS-CoV infection which had higher loads (also based on RT-PCR not cultivation) later in illness (Zou et al., 2020; World Health Organization, 2020b). Interestingly, a letter to the editor by Xu et al. (2020), suggests that the salivary glands may be important in asymptomatic infections due to the high expression of ACE2 receptors in the salivary gland. They discuss other literature where SARS-CoV viral RNA was detected in the saliva prior to identification of lung lesions, and COVID-19 saliva positivity by RT-PCR can be over 90% and virus can be cultivated, suggesting this should be further investigated (Xu et al., 2020).

A variety of additional publications have confirmed prolonged PCR positivity, with a paper by Xiao et al. (2020) describing 56 hospitalized patients, in which severe illness was associated with higher viral loads (by 60 fold) and a longer time to RT-PCR clearance in patients. Viral RNA shedding was prolonged with a median of 24d to become SARSCoV-2 RT-PCR negative (and 32.1% still positive at 1 month post onset). A preprint study of 1343 probable and confirmed outpatient COVID19 cases in New York were assessed with serologic and nasopharyngeal RT-PCR testing. 249/584 participants with antibody and PCR testing were RTPCT positive at 20 days (11-42 days) from symptom onset and 12 days (5-28d) from symptom resolution. In this cohort, 19% of survey participants with previous self reported symptoms were PCR positive at testing (Wajnberg et al).

The severity of disease may affect the duration of infectious virus shedding, and antibody testing may be useful to guide infection control measures as assessment of likely infectivity. A preprint study from van Kampen et al, of critically ill patients suggests that a higher viral load (>7 log/ml) in respiratory tract specimens was associated with isolation of infectious SARS-CoV-2, and the presence of neutralizing antibody was associated with absence of infectious virus. In these patients infectious virus could be isolated for up to 20 days (median 8 days, <5% probability after 15,2d of symptoms), which is longer than the 8 day duration of viable virus shedding in less ill patients described by Wolfel et al.

1.2 Viral load data and culture data, in animal studies

In experimental SARS-CoV-2 infection of four macaques, early and prolonged virus excretion (through RT-PCR and virus isolation from the nose and throat in the absence of clinical disease was seen. Higher nasal shedding of SARS-CoV-2 virus RNA was identified in older animals, peaking at day 4 after infection

compared to young (peaking at day 2) (Rockx et al). There was shedding for up to 10 days by RT-PCR, and no infectious virus was detected after day 4. Viral replication was suggested by RTPCT positivity in respiratory tract tissues including ciliated nasal mucosal tissue, with urinary, cardiac, endocrine and CNS tissues negative, and an ileal specimen positive. The early viral shedding in this study is suggested similar to what is seen with influenza virus kinetics in both humans and macaques. This similarity to influenza is also suggested by other authors (Pan et al., 2020; Zou et al., 2020).

1.3 Summary- virologic data

In summary, there is a reasonable body of literature that supports early viral presence in saliva and in upper aerodigestive tract specimens in early infection, including in asymptomatic and presymptomatic states. The factors affecting transmission and likelihood of transmission in these states of "unapparent positivity" remain less clear, however. Detection of viable virus drops rapidly over the first 8 days of infection, but may be prolonged with a suggestion this may be more common in the elderly (based on macaque study, and a LTC study in which virus was cultivated after 9 days or symptoms in one patient). Prolonged RT-PCR positivity is well documented (not uncommonly for 3-6 weeks from onset) so a positive laboratory result without a detailed symptom history is of limited value in assessing whether and "asymptomatic infection" is associated with possible transmission.

2.0 Epidemiologic Data from human COVID-19 clusters and cohorts

Reported rates of positive RT-PCR screening in patients without symptoms at the time of testing range considerably. Some of this variability could be related to differences in how "asymptomatic" status was assessed: some groups included a variety of generalized mild symptoms as "asymptomatic." In a report of 16749 hospitalized COVID-19 patients in the UK, 7% of hospitalized patients would not meet an ILI case definition and 4% had enteric symptoms only (Docherty et al, 2020). In addition, many reports potentially fail to exclude paucisymptomatic or symptomatic infection in the previous 6 weeks. See Appendix A for a complete table of "asymptomatic" RT-PCR positive series/studies. A summary of representative studies is extracted below, favoring studies where contacts of cases or cases were monitored with serial testing, with reasonable exclusion of presymptomatic or postsymptomatic status (Bi, Cheng, and Tian et al). These report a range of the proportion of truly asymptomatic cases of 5-20%. Some reports of "asymptomatic" transmission clearly outline probably presymptomatic transmission, including a 2 family cluster of 7 patients with presymptomatic and postsymptomatic contact over a 5 day period (Li. Ji et al, 2020). Most reports have come from China, where undetected community transmission could not be ruled out, describe household, family, and meal sharing contact (Bai et al, 2020, Hu et al, 2020)

2.1 Quarantine Centre Studies

Two papers explicitly mention asymptomatic over presymptomatic transmission, one familial cluster which suggested an asymptomatic person infected 1 household contact, and one contact tracing/centralized quarantine series (preprint, Luo) which noted transmission from asymptomatic cases to 0.3% of contacts. This latter study yields other interesting transmission data: 2950 contacts of 347 cases were placed in 14 days of quarantine with RT-PCR monitoring every 2 days. There were 129 secondary cases within the contacts. Of the contacts, 0.2% developed asymptomatic infection, and 2.4% developed symptomatic infection over the 14 day quarantine period. In this paper, older contacts had increased risk of infection with a gradient across age (1.8% in <18y through 4.2% in 60+ years). Seventy percent of the contacts were in a household setting with 10.2% acquiring COVID-19, with healthcare contact risk of 1.0% and public transport risk at 0.1%. Clinical severity of source case data was reported for 2610 contacts, of which 305 had an asymptomatic source case (based on incomplete data), and one secondary case was attributed to this group (1/305=0.3%) There was a gradient of risk from there was 0.3% risk to contacts of asymptomatic COVID-19 cases through 6.2% of contacts acquiring disease from index patients with severe symptoms (Luo et al., 2020).

In a Taiwanese report of 100 patients, 2761 contacts were traced, tested, monitored for 14 days, and tested again if symptoms developed. Twenty two secondary cases were found, all with exposure within 5 days of the index cases symptom onset, with an attack rate of 0.7% (2 secondary cases of 277 contacts) for exclusively presymptomatic contacts and 1.1% (12/1083) in those exposed at or after the day of

symptom onset. Where exposure started in the presymptomatic period (not restricted to exclusively presymptomatic contact), the attack rate was 4/100 (4%) for household, 1/10 (10%) for nonhousehold family, 2/236 (0.8%) for health care contacts, and 0/389 for other contacts. However, contacts prior to symptom onset were not completely ascertained and a suggestion to extend to 4 days prior to onset was made. There was no transmission to 852 contacts exposed after day 6. None of the 9 asymptomatic case patients transmitted a secondary case (to 91 contacts). The attack rate from those with mild illness was 0.4%, severe 1.4%, and ARDS/Sepsis 1.5%. Detailed review reveals that four asymptomatic secondary cases were identified, all of which were household or nonhousehold family contacts, out of 227 household and nonhousehold family contacts followed, suggesting that 1.76% of all identified household-family contacts developed asymptomatic infection, versus 4.8% (11/227) with symptomatic infection. Overall household and nonhousehold family contact secondary attack rates were 4.6% and 5.3% respectively (Cheng et al, 2020).

In a report of 392 household contacts of 105 index cases who were exposed in Wuhan, family contacts were quarantined and monitored daily, and 14.1% of contacts found to be RT-PCR positive were asymptomatic. A proportion (13.3%) of index patients had quarantined themselves at home after symptom onset with masking, sleeping and eating separately within the house. Importantly, the attack rate from those who self isolated at home with onset of symptoms was 0% versus a 16.9% attack rate in households in which the index case did not isolate within the home, so no presymptomatic transmission occurred in this cohort, and transmission was prevented by home self isolation. The secondary attack rate was highest to spouses at 27.8%, and transmission to children was 4% versus 17.1% to adult household contacts adults overall. (Li et al, CID).

In a report of 262 confirmed cases in Beijing, 13 (5.0%) were asymptomatic close contacts, and an asymptomatic case was defined as "a confirmed case with normal body temperature or minor discomfort", with cases comprised of all positive COVID-19 cases, who were referred to centralized hospitals for therapy or monitoring. The vast majority of cases in this series were (92%) were identified in contact tracing, and 67.2% were cluster cases (Tian et al, 2020).

A research letter from Wuhan by Yang et al described close contact screening and quarantine (December 25 to February 24,2019) followed all COVID-19 RTPCT patients who were admitted to hospital after contact tracing 26 clusters of infection. In this series, 42.3% of patients 33/79) were asymptomatic at testing, However, a symptom checklist and "asymptomatic" definition was not provided and pre test symptom history was not described, and CT scans were abnormal in a proportion of "asymptomatic" cases. The "asymptomatic" cases were more likely to be younger (27 versus 56 year old), female (67 versus 31%), and had shorter duration of viral shedding (8 versus 19 days). Clinical variables were less severe including improvement of CT scan abnormalities (9 versus 15 days), CD4 count (720 versus 474), and abnormal liver biochemistry (3% versus 20 percent.)

A prospective study by Chau et al, at a quarantine centre in Hi Chi Min City, Vietnam enrolled and followed PCR positive cases. Between March 10 and April 4, 49 of about 14000 people were positive, of which 30 were enrolled. Thirteen (43%) had no symptoms (the history duration and data collection instrument were not defined). A cluster of 11 participants was described with a suggestion of possible asymptomatic transmission, although insufficient detail is provided to assess this. Despite initially similar RTPCT Ct values, the there was a suggestion of faster viral clearance from the respiratory tract in asymptomatic persons,

2.2 Other Studies of Close Contacts

A recent US publication has been suggested to support asymptomatic transmission, describing positivity rates in household contacts of the first 229 cases in New York State during an exponential phase epidemic. The household infection prevalence was much higher than in other series at 38%, with an age gradient from 23% among those <5 years to 68% among those over 65, on a background of a percent positivity of all tests in NYS in March of 33%. There were 498 household members tested, of which 148 had symptom data recorded. Of these, 82.6% reported "any" symptoms, suggesting that 27.4% were

asymptomatic at testing. Transmission chains were not assessed. Antecedent symptoms or subsequent symptoms were not assessed. As such, this report has the same weakness of others where previous infection was not excluded (Rosenberg et al, 2020). Similarly, a study on an "asymptomatic" hospitalized case suggested that there was no transmission to 455 contacts, however, post symptomatic RT-PCR positivity was not ruled out: the individual had been short of breath (due to proposed CHF from congenital heart disease) for a month prior to admission, was admitted for the same then screened after being in hospital for 4 weeks (screened by RT-PCR for an in hospital transfer). Multiple patients, patients' family members and hospital staff were tested an observed in quarantine (Gao et al, 2020).

Chaw et al describe a superspreading event in Brunei, at a religious gathering in Malaysia on February 28-March 1st. Of 75 attendees, 19 tested positive, with 52 secondary cases identified. Attack rates were 14.8% at a subsequent religious gathering (March 5th), and 10.6% in households. The household AR from symptomatic cases was 14.4%, versus 5.4% from asymptomatic or presymptomatic cases, with very low transmission in social or workplace settings. Symptom assessment was only performed at the time the swab was collected and during the followup period.

A report from Huang et al described transmission of COVID-19 from a presymptomatic youth starting 3 days before symptom onset, with 7/22 contacts developing infection (food sharing, indoor restaurant, karaoke) developing infection, highlighting significant presymptomatic spread among young people in social environments.

2.3 Prevalence Studies and Outbreak investigations

A comprehensive analysis of 382 service members (of 1417 total exposed) involved in an outbreak aboard an aircraft carrier was reported by Payne et al, with symptom questionnaires, serologic assessment and 267 (70%) also providing NP swabs. The investigation took place April 20-24 (the outbreak was in March,) 60% were antibody positive, and symptoms were assessed as Category A (Cough, shortness of breath) or Category B (2 or more fever (measured or subjective), chills, rigors, myalgia, headache, sore throat, new olfactory and taste disorder(s) (Council of State and Territorial Epidemiologists, 2020) Twenty three of 154 (15%) of those with negative serology had a previous PCR positive result, and 82 of 131 (63%) of seronegatives without previous positive PCR were tested by PCR and 4 (5%) were RT-PCR positive. Overall, 238 of participants had documented previous or current SARS-CoV-2 infection, of which 18.5% were asymptomatic. Taste and smell alterations were strongly associated with infection (OR 10.2). Self reported distancing, avoidance of common areas, and face covering use were potentially protective. Level of antibody was not reported in asymptomatic versus symptomatic confirmed positive cases. Specimens were collected that were RT-PCR positive to 48 days after symptom onset.

The perils of interpretation of RT-PCR positive results and absence of current symptoms at the time of testing are illustrated in correspondence in the Lancet, which described screening of asymptomatic HCW in a hospital in London, with collection of nasal swabs, health questionnaires and blood samples over 16 weeks. The first 400 tests yielded 44 SARS-CoV-2 positive HCW (11%) of which 12 (27%) reported no symptoms of COVID-19 during the week before or after their positive test(s). During the study, 7 HCW tested positive on two consecutive weeks and 1 tested positive on three consecutive weeks by RT PCR (Treibel et al., 2020), and the rates mirrored the epidemic curve in the community. However, this is a short correspondence and many details of methodology are not available for review. To exclude prolonged shedding in this cohort, symptom assessment for 4 weeks prior to testing and observation for symptom for two weeks post testing would have been optimal. No serologic assessments, or attempts to cultivate virus were performed.

A call centre outbreak investigation in South Korea described by Park et al investigated all workers, inhabitants and visitors to a commercial/residential building between February 21-March 8 2020, with testing March 9-12 (17 days from start of exposure risk period). There is no documentation that history of previous symptoms was sought, and asymptomatic cases were followed for 14 days from testing. Testing was performed for 1143 of the 1145 persons under investigation, was 8.5% documented positive, 94/97

of these were in the 11th floor call centre. The attack rate in the call centre was 43.5%. Of the case patients, 89/97 (91.7%) were symptomatic, and 4 developed symptoms, and a further 4 remained asymptomatic (4.1%) The case patients had 225 household contacts with a household attack rate of 6.2%, with no transmission from presymptomatic or asymptomatic cases.

A followup study on a subset of the highly described Diamond Princess cruise ship cohort has been published by Sakurai et al, in which 712 of 3711 passengers and crew were documented RT-PCR positive, and 410 (58%) asymptomatic at testing, Ninety six of the asymptomatic positive cases and 36 cabinmates were quarantined and observed in hospital, with 11/96 (11.5%) developing symptoms at a median of 4 days from testing positive, with 8/32 (25%) of cabinmates also testing positive after an initial negative test but remaining asymptomatic. This study described becoming RT-PCR negative as "resolving infection", which is arguably inaccurate, and this occurred 15 days after the initial positive test in 90%. The likelihood of developing symptoms, and of remaining PCR positive for longer periods increased with age. Previous symptoms, symptom assessment, and serology results are not reported.

A final study described screening of all passengers and crew on an isolated Antarctic cruise: a passenger developed fever on day 6, and on day 20 of the cruise 128/217 (58.9%) of people tested were positive, of which 81 (64%) were asymptomatic at testing. There was no description of how symptom history was assessed or of followup post testing for symptom development (Ing,et al 2020). There was no description of symptom assessment, followup, and no serology was done.

The role of pediatric SARSCoV-2 in transmission remains unclear, and given the apparent lower rates of infection in chidren there is interest in assessing the possibility of asymptomatic children as transmission sources.In a preprint evaluating reported household transmission clusters, 9.5% of the clusters had a pediatric index case. To reduce the possibility that an asymptomatic index case child was overlooked, cases in which a symptomatic adult was identified as the index case in a household with an asymptomatic positive child was also identified were reviewed, with the results that up to 21% of the household MAY have had an asymptomatic child as the index case. In comparison, H5N1 influenza transmission cluster analysis revealed children as index case in over half (Zhu et al, 2020).

Presymptomatic transmission merits separate consideration from asymptomatic transmission, because of more robust data and because of different practical contact tracing implications. Presymptomatic spread has been well documented in individual case reports and reported case series, usually involving close/household contacts. Newer data suggests that presymptomatic transmission may in some circumstances be considerable, although it is unclear whether these events are related to characteristics of the index case, the setting of transmission, or both. Multiple case series have shown high secondary attack rates with exposure just prior to symptoms. In one study, the attack rate among exclusively presymptomatic close contacts was 0.7% (versus 1.1% overall). However, in another study of contacts and household transmission, there were no household transmissions when the index patient self isolated (masked, resided separately) within the home versus 17% attack rate in other households contacts, weighing against significant presymptomatic transmission. Contact tracing studies further suggest that most transmission risk occurs before day 6 of symptoms, with no nosocomial transmissions among 852 hospital contacts after day 6 of symptoms.

Thus, although it seems a proportion of people may remain asymptomatic but PCR positive, transmission from presymptomatic cases is currently more clearly supported by these data. The relative contribution of presymptomatic spread to community transmission was detailed in am epidemiologic report from Singapore, in which all 243 cases of COVID-19 between Jan 23 and Mar 16, 2020 were investigated. Seven clusters of cases with probable presymptomatic transmission were identified, and the overall proportion of transmission from these cases comprised 6.3% of overall documented transmission. Diagnostic testing was correlated with clinical signs and thoracic CT scans. Individuals were thought to be infected from contact presymptomatic cases, not unidentified asymptomatic cases, as strong surveillance was in place and minimal community transmission was occurring. Two of these clusters involved people who gathered together to sing. (Wei, 2020).

2.4 Reviews and Meta Analyses

Finally, three preprint systematic reviews and meta-analyses addressing this topic have been identified, as well as a narrative review. The first, a rapid living systematic review and meta-analysis on asymptomatic transmission (Buitrago-Garcia et al) gave the overall estimate of the proportion of people who become infected with SARS-CoV-2 that remain asymptomatic throughout infection as 15% (95% CI 10 to 22%) This review did not evaluate the possibility that some of the studies included did not rule out postsymptomatic shedding. A systematic overestimation of the proportion with asymptomatic infections due to the inclusion of asymptomatic cases in contact investigations was also noted.

The second systematic review and metaanalysis preprint specifically included only studies where the sample frame included the at risk population and there was adequate followup to identify presymptomatic cases, as is assessed as higher quality. It should be noted that this review excluded 25 studies which were included in the above metaanalysis, which were felt to be at high risk of bias, and missed 6 of the articles included in this report. Review of 998 articles identified 9 studies for inclusion, with 21035 people tested, of which 559 (2.7%) were positive and 83 (14.8% of those positive) were asymptomatic. The proportion of asymptomatic cases ranged from 4-41%, and metaanalysis gave the proportion as 15% (12-18% overall.) Transmission from asymptomatic cases was suggested in 4 studies, at a lower rate than symptomatic cases (Byambasuren et al, 2020). Two studies documented zero transmission from asymptomatic cases, and the other two risk estimates were .06 and .79.

A recent narrative review, by Oran and Topol is a significant outlier in interpreting the extant literature. The authors suggested that 40-45% of SARS-CoV-2 infections are asymptomatic and that asymptomatic people can transmit to others for >14 days. Studies felt to be at high risk of bias were included, with prevalence sampling, and studies without definition of asymptomatic, or symptom assessment pre and post test. Serosurveys and PCR testing were both included in aggregate estimates. This is therefore not felt to be a useful synthesis. A recent open latter to Oran and Topol, and the Annals of Internal Medicine highlighted the lack of clear definition of asymptomatic infection and the selective inclusion of cross sectional studies, with the suggestion that this overestimate of asymptomatic infection could misinform policy response (Cevik et al).

Table 1. Select Studies –COVID-19 Cases - Asymptomatic at Testing (See appendix for complete list)

Setting	Author	Total Positive cases	Number (%) with no symptoms at testing	% who remained asymptomatic	Comments
Long Term Care	Arons	48	27 (56%)	6.3%	Symptom Screening for -14d to +14d of test, outbreak started 23 days prior – poss post Sx
Monitored Contact Quarantine	Bi	98 (of 1286 contacts)	17 (20%)	Unknown	Well defined symptom list, did not clinically report if developed Sx
Monitored Contact Quarantine	Cheng	22 (of 2761 contacts)	4 (18%)	NR but monitored 14 day quarantine	Contact with presymptomatic case attack rate 0.7% (versus 1.1% contact in in first 5 days). Contacts to severe/critical cases higher risk.
Pediatric cases (Chinese CDC)	Dong	731 PCR confirmed cases	94 (12.8%)	NR	Did not exclude presymptomatic or postsymptomatic
Contact tracing (conference)	Hijnen	10 (of 12 contacts)	2 (175)	NR	Presymptomatic transmission 2-3 days after index case exposure

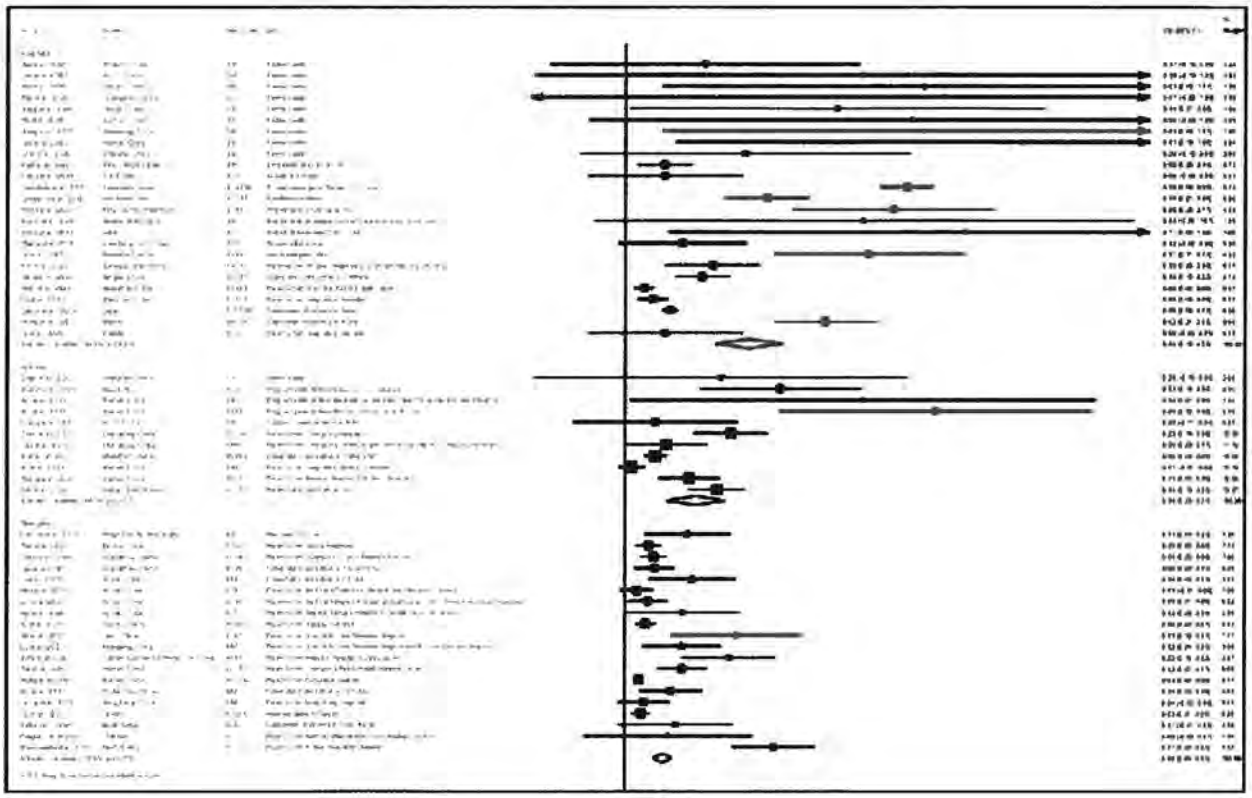
Airline flight	Hoehl	114 airline passengers with RT-PCR results	2 (1.8%)	1 (50%)	Mild rash/sore throat
Contact Tracing (Fitness class)	Jang	112 contacts pf 8 positive instructors (12 facilities)	30 (26.8%)	NR	Did not exclude presymptomatic or postsymptomatic
Long Term Care	Kimball	23 residents	13 (56.5%)	13%	Did not exclude presymptomatic or postsymptomatic,tested 16d after introduction
Prevalence survey, community based	Lavezzo	I. 73 cases (of 2812) 14 days later, II.29 cases (8 new) of 2343	30 (41%) 13(29%) (unclear if new or old)	NR	Did not exclude presymptomatic or postsymptomatic
Monitored Contact Quarantine	Li	64 (of 392 household contacts)	9 (14.1%)	9 (14.1%)	Close monitoring for 14 d from exposure, no transmission in index case self isolation households
Monitored Contacts, Quarantine	Luo	129 cases (in 4950 contacts)	8 (2.5%)	8 (2.5%)	Incidence of secondary infection 6.2% from critical, 3.3% from mild, and 0.33% from asymptomatic cases.
Cruise Ship	Mizumoto	634	113 (17.9%)	NR	Did not exclude presymptomatic or postsymptomatic., testing 10-17 days after outbreak start
Evacuees from Wuhan	Nishuira	13	4 (31%)	No	Testing long after Wuhan departure. Did not exclude presymptomatic or postsymptomatic
Centralized assessment - all cases Hospitalized, Beijing	Tian	262	12 (5%)		Asymptomatic – included confirmed case with normal temperature or minor discomfort

Finally a very recent preprint systematic review and metaanalysis by Koh et al. included analysis of transmission and secondary attack rates, serial intervals, and asymptomatic data. They and estimated that 25.8% of CIVD-19 cases were asymptomatic at diagnosis, and given the observation from multiple settings that 2/3 develop symptoms on monitoring suggested the "true asymptomatic" proportion to be 5.4%. From observational studies, the RR of transmission was 2.55 from symptomatic index cases, suggesting that testing strategies should prioritize symptomatic persons when resources are constrained. However, given the difficulty in rapid detection of asymptomatic infections, it was noted that some degree of physical distancing is likely required to account for this.

However, it is noted the evidence base included many of the studies reviewed here, that failed to account for post symptomatic shedding in epidemic situations, where the RTPCR prevalence testing was carried out late in the epidemic, where positive RTPCR would be less likely to indicate transmissible infection. The forest plot of asymptomatic cases from this paper is below, provided with the caution about the lack of standardized case definitions for asymptomatic infections and also acknowledging the possibility of

publication bias related to media attention to this particular topic. The findings of this paper suggested that setting specific transmission risk should guide control measures with quarantine more appropriate for congregate living community settings such as workplaces and dormitories, and contact tracing utilized to identify hotspots and vulnerable populations.

Figure 1. Koh et al, Forest plot of the proportion of asymptomatic cases. ES is the estimated asymptomatic proportion, with 95% confidence intervals (CI). I-squared is the squared percentage of between-study heterogeneity that is attributable to variability in the true effect, rather than sampling variation.



2.5 Summary

Higher quality epidemiologic studies from centralized quarantine facilities, in which close contacts (a high risk population) have been monitored and serially tested, AND methods suggest better exclusion of presymptomatic and post symptomatic cases suggest that 2.5 to 20% of RT-PCR positive contacts remain asymptomatic. A good quality preprint metaanalysis of these epidemiologic data suggested the asymptomatic proportion is 15% (12-18%), and another estimated that 25% could be positive-asympotmatic but that the true asymptomatic proportion was likely 8.6% (excluding presymptomatic). Uncertainty in this proportion is related the possibility of prior infectious contacts in the community during exponential growth rate epidemics in some reports, and in addition, a population of close contacts to documented cases may tend to overestimate compared to the general population. Data from an aircraft carrier outbreak and multiple household transmission studies suggests that asymptomatic and paucisymptomatic infection status may be more common in younger people and children. In these studies **the efficiency of observed transmission of infection of asymptomatic** infection appears to be low (two studies reported no transmission from asymptomatic cases, one quarantine center series reported an incidence of secondary infection of 0.3%, 20 fold lower than transmission to contacts from severe

cases, another reported 2.2% transmission from asymptomatic cases, and the RR of transmission as 2.5 in symptomatic compared with asymptomatic in another.)

So, although existing data have significant shortcomings it appears that transmission from presymptomatic, pauci-symptomatic or asymptomatic people, particularly in close contact settings may occur, with more data supporting that transmission from presymptomatic cases may be more substantial. Close contact settings such as household exposures or possibly long term care facilities appear to be higher risk, and limited data suggest that transmission risk from asymptomatic persons is much less efficient (0.03% of contacts of asymptomatic COVID-19 cases compared with 6.2% in contacts of severe cases in one study). Physical distancing, masking and hand hygiene would be expected to mitigate some of this risk. Standardizing definitions, and protocolizing assessment of "asymptomatic" cases to differentiate these from paucisymptomatic, and presymptomatic is important to both clarify the evidence around transmission potential and because the latter conditions may still allow testing and rapid contact tracing to have a beneficial effect. This will require public education around paying attention to and documenting timing of even mild symptoms, seeking testing, mindfulness and documentation of exposures and contacts to assist possible contact tracing, and seeking history of symptoms from -4 weeks to +2 weeks after testing.

3.0 Epidemiologic modelling

If the mean interval estimate (the time between symptoms developing in the infector and infectee) is shorter than the mean incubation period, presymptomatic transmission is suggested, and would support that transmission can occur early after infection and possibly before symptoms. Modelling the serial interval estimate (efficiency of propagation) suggests that the serial interval estimate for SARS-COV2 is 4 days (95% CI 3.53 – 4.39) which is significantly shorter than SARS-COV1 (8.4 days) or MERS-COV (14.6 days) (Bi et al. 2020; Zhao et al., preprint; Nishiura, Linton & Akmetzhanov, 2020), suggesting presymptomatic transmission. However, estimates of the serial interval vary. In a description of 468 confirmed cases in China, presymptomatic transmission was suggested in up to 13% of transmission chain cases (serial intervals were negative, with the infectee developing symptoms before the infector) (Du et al., 2020). In another preprint article that described viral shedding and modeled transmission chain data, the mean interval estimate was longer at 5.8 days, with infectiousness estimated to start at -2.5 days before symptom onset, and peak at -0.6 days before symptom onset with decline over 7 days. These studies of primary and secondary cases may be limited by recall bias, as secondary cases are more likely to remember recent exposures.

In a study modeling infectiousness from 77 predominantly household based transmission pairs, He et all observed infectiousness peaked at or before symptom onset and that 44% of cases were infected during the index cases presymptomatic stage (in predominantly household clusters). The relative proportion of post symptom transmission was reduced by isolation (He et al.2020).

In a preprint of a statistical transmission model applied to contact tracing data from Guangzhou, 249 cases forming 195 unrelated clusters were examined, with cluster sizes from 1-274 (median 6). Most transmissions occurred among household members. Modeling the spatial and temporal epidemiology suggested the daily transmission probability during the incubation period was similar to that in the illness period (Jing et al).

There are a number of new studies looking at serial intervals in different countries, with different testing strategies. A preprint of a modelling study by Tindale et al. from Simon Fraser University, based on outbreak information from Singapore and Zianjin, China estimated the mean serial interval at 4.56 (2.69, 6.42) days in Singapore and 4.22 days (3.43, 5.01) in Tianjin using a mixture model approach, with the mean serial interval 2-4 days shorter than the incubation, suggesting that presymptomatic transmission was occurring. Limitations include variability in exposure time, presumed infectors and incubations period as well as the lack of uncertainty in the model around symptom onset (Tindale et al., 2020).

A March 30, 2020 report from the Imperial College COVID-19 Response Team also estimated that the percentage of total population infected is orders of magnitude higher than case counts, related to mild and asymptomatic infections as well as limited testing capacity, with the model suggesting attack rates ranging from 0.7% of the population in Germany through to 15% in Spain however the relative proportion of asymptomatic infection was not discussed (Flaxman et al., 2020). In contrast, a preprint by Zhou investigates dynamics and spread of the outbreak using a modified Susceptible-Exposed-Infected-Resistant (SEIR) model with empirical data from the people evacuated from Wuhan from Jan 29 to Feb 2, 2020. The model provided little support for asymptomatic transmission although findings are subject to assumptions used, and the subgroup studied has low case confirmation and perhaps different social behavioural and environmental factors. (Zhou et al, Preprint). Reassuringly, in this paper, the reproductive number (R0) was found to be 2.12 which is consistent with the majority of the findings globally of an R0 range between 2.0 to 3.0.

Ferreti et al (2020) describe a compartmental mathematical model based on linked case data from Hubei, assuming a fraction of 46% asymptomatic SARS-CoV-2 infections and reduced infectiousness from asymptomatic cases) that pre-symptomatic patients account for 47% (95% credibility interval 11 to 58%) of the total transmission, and asymptomatic transmission comprised 6% (0 to 57%) of the total. This and other models attempting to estimate the proportion of infections caused by undetected infections (asymptomatic, presymptomatic and paucisymptomatic) vary widely, suggesting that 50-80% of cases could be related to undetected infection (Ferreti et al, Li et al).

A preprint from Koh et al indicated the mean SI of single-location studies is estimated to be 4.87 days (95% CI: 3.98, 5.77), and there was significant heterogeneity observed in multiple location studies.

Overall, current model assumptions are based on data on the prevalence of asymptomatic infection that did not account for the possibility of prolonged postinfection shedding, and thus would be expected to overestimate transmission from asymptomatic positive persons. The chain of transmission data (see Table 2) has been consistent in suggesting shorter range serial interval data (with considerable variability, from 1.9-7.5 days) and does support spread early in infection and the possibility of presymptomatic spread being significant.

Modelling data therefore should be seen as potentially illustrating the upper limits of impact of transmission from asymptomatic persons, and newer studies using updated assumptions would be valuable.

Table 2. Summary of Serial Interval Studies

Author	**Country**	**Data type**	**n (total cases)**	**Mean or Median Incubation Period (days)**	**Mean Serial Interval (days)**	Comment
Aguilar, J.B. et al Preprint	13 countries (10 in Europe and Australia, Canada, Japan)	Case numbers				Re 15.4 (5.5-25.4)
Backer, J.A. et al Rapid Communicatio n	Imported cases from Wuhan, China; Jan 21-Feb 8	Government sources	88 case	Mean: 6.4 (95% CrI: 5.6-7.7) (sd)		

Bi, Q. et al Research Article	Shenzhen, Guangdong Province, China	Contact tracing	391 cases and 1206 close contacts	4.8 (95% CI: 4.2-5.4)	6.3 (95% CI 5.2 – 7.6)	Reproduction number 0.4 (0.3-0.5)
Cheng, H. et al Preprint	Taiwan, Republic of China	Contact tracing	32 cases and 12 paired transmission cases, from 1043 contacts; then updated with 48 pairs	4.9 (95% Credible Interval 2.7-8.4)	5.4 days (95% CrI 4.1–7.2 days) with 48 pairs	
Du, Z. et al. Research Letter	Imported cases outside of Wuhan, China; Jan 21-Feb 8	Government sources	468		Mean: 3.96 (95% CrI: 3.53-4.39); sd 4.75 (95% CrI: 4.46-5.07); 12.6% of serial intervals were neg	59 reports of negative serial interval (suggest presymptomatic transmission)
Feretti. L. et al Research Article	NR	40 infector/infectee data pairs			R0 estimated at 2.0 in early stages with 46% presymptomatic, 38% symptomatic; 10% asymptomatic and 6% environmental transmission.	
He, X. et al Brief Communication	Guangzhou, Guangdong Province, China	Hospital admissions	94 cases and a separate 77 transmission pairs	Not calculated, assumed at 5.2 from other studies	Mean 5.8 (95% CI: 4.8-6.8); median 5.2 (95% CI: 4.1-6.4)	Infectiousness from -2.3 days and peak at -0.6 days from symptoms
Lavezzo, E. et al Preprint	Vo, Italy	Government Sources			Mean: 6.9 d (95% CrI: 2.6-13.4) before lockdown and 10.1 d (95% CrI: 1.7 - 25.9) after lockdown.	Risk of household transmission OR: 84.5 (95% CI 16.8-425.4) in adults; SEIR model estimates asymptomatic infection 41-42%, transmissibility of virus decrease 89-99% with lockdown
Liao, J. et al Preprint	Chongqing, Sichuan Province, China	Pediatric hospital cases and their contacts	3.3%). On the second survey, which was conducted at the end of the lockdown, we found a	Mean: symptomatic cases 6.6 days (95% CI 4.4 - 9.6)	Median: for symptomatic cases was 1.9 days (95% CI 0.4 - 6.2)	
Li, R. et al, 2020a	Early transmission in Wuhan,	Observations of infections, mobiity data,	prevalence of 1.2% (95% CI 0.8-1.8%).	Mean: Early transmission in wuhan	Mean: Early transmission in Wuhan	Precontrol measures: undocumented

Research Article	China; before Jan 20, 2020	metapopulation network		5.2 + 2.1 (sd)	7.5 +/- 3.4 (sd)	infections were the source of 82% of infections, post control these dropped to 79%.
Mizumoto, K. et al Rapid Communication	Cruise ship, Diamond Princess	Time series data from quarantine period	634 cases/3711 passengers, 2 week quarantine; 328 asymptomatic		Estimated asymptomatic proportion of positive cases was 17.9% (95% CrI: 15.5-20.2). Most asymptomatic transmission occurred before quarantine	
Nishiura et al, 2020b Letter to the Editor	Cruise ship, Diamond Princess	Japanese evacuees from Wuhan	64/565 symptotatic; using RT-PCR 4/565 asymptomatic and 9/565 were symptomatic			
Nishiura et al, 2020a Research Article	NR	Publically available data	28 data pairs		Median: 4.0 d (95% CrI: 3.1, 4.9); mean 4.7 d (95% CrI: 3.7, 6.0) and sd 2.9 d (95% CrI: 1.9, 4.9)	
Tindale, L.C. et al Preprint	Singapore and Zianjin, China	Government sources	S: 93 cases; T: 155 caes	Mean - Singapore: 7.1 (6.13-8.25); Zianjin: 9 (7.92-10.2)	Mean - Singapore: 4.56 (2.69-6.42); Zianjin: 4.22 (3.43-5.01)	Early in outbreak transmission estimated 2-3 days before symptoms
Wong, J. et al Accepted Manuscript	Brunei	Government sources all cases and 53 pairs for Sii calculations	16/138 (12%) asymptomatic; 42/138 (30%) presymptomatic	Median calculated: 4.5	21/53 pairs had calculated SI < 3 d; 6/53 and 0 or negative SI values	High proportion presymptomatic cases
Yin, G. ad Jin, H. Preprint	Ningbo, Zhejiang Province, China	Government sources	157 Symptomatic cases -2001 close contacts, 30 asymptomatic cases -145 close contacts			Transmission rates between symptomatic (0.064,0.049) and asymptomatic (0.041,0.041) cases and contacts not statistically different
Zhang, J et al Preprint	Beijing, Hebei	Familial cluster	2 scenarios - early transmission in			Presymptomatic transmission 3.8 d prior to

	Province, China		Wuhan, imported cases outside Wuhan			Sx – based on Backer, Du and Li

4.0 The evolving role of population based serologic surveys

A number of serologic studies are in progress and some have been published to considerable controversy regarding methodology as biased sampling and poor serologic point of care tests have been problematic. However, the interim report of the Spanish Ene-Covid19 study (April 27 - May 11, 2020) is highlighted here as it is robust design: a representative national sample of 60,983 recruited patients with a participation rate of 62.3% (Instituto de Salud Carlos III, 2020). The overall seroprevalence was 5.0% (no differenced by sex) and prevalence increased by age (by decade) : from 1.1% in infants, 2.2-3.8% in children aged 1-19, 3.8-5.9% in those age 20-64, and 5.1-6.9% in those over 65. The seropositivity rate was lower in those deemed essential workers (5.3 versus 5.4%). Seropositivity was documented in 6.4% of those residing in communities of >100,000 population versus 3.8-4.3% in smaller communities. Geographic variation was considerable with antibody prevalence ranging from 1.1% to 14.2% across areas. Of those with self reported PCR positivity, 87% had SARS-CoV-2 IgG antibodies, and in people without a confirmed diagnosis the prevalence increased with number of symptoms (4.6% if 1-2 symptoms through 14.7% if > 5 symptoms, and strikingly, 43.3% in those with anosmia).

Of those who did not report ANY symptoms prior to serologic testing, 2.5% were antibody positive. This was a fingerstick test, and so far 16953 of participants have been also assessed using a central high throughput laboratory assay, with 97.3% concordance thus far by informal report (Yasinski, 2020).

With respect to the context of this serosurvey - according to Our World in Data, there were 227770 confirmed cases in Spain as of May 11, with 26744 deaths and 11.74% case fatality rate (CFR). There is likely a large number of uncaptured cases based on the high CFR and testing rate of 0.87 tests per 1000 people, and ongoing 3.1% percent positivity in RT-PCR testing. Using a population of 46 million, 0.5% pf the population has had lab confirmed infection, which is10 fold lower than the serologic prevalence detected thus far, based on IgG testing by a lateral flow assay.

Potential issues with such studies involve recall bias, collection of symptom survey data, and, importantly, test characteristics – if the test is 98% specific and the real prevalence is 5%, one would expect a false positive rate of 2.0%, making it difficult to interpret the asymptomatic positive rate in this study. In addition, it remains possible that truly asymptomatic infection may not result in as high antibody titres, leading to potential underestimation of asymptomatic infection by serosurveys. Nevertheless, the estimate of 2.5% asymptomatic infection detected by a seroprevalence survey (with recall bias expected) is not unexpected. Close contact/high risk populations in quarantine and shipboard outbreak studies would have a higher risk and suggest 15-20% rates of asymptomatic infection in these groups.

Discussion

In summary, evolving data continues to support transmission early in infection including potentially before symptom developments, and better definition of asymptomatic, paucisymptomatic, and presymptomatic states will inform better data.

There are consistent laboratory data supporting early high levels of RT-PCR detectable SARS-CoV-2 before or at the time of symptom development, and in some persistently asymptomatic or subclinical cases, with RT-PCR positivity documented for up to 6 weeks postinfection. The relative incidence of asymptomatic and presymptomatic SARS-CoV-2 infection, public health interventions to prevent asymptomatic transmission, and whether asymptomatic infection confers immunity remain important knowledge gapes (Furukawa et al, 2020). This review suggest that existing data on patients who were asymptomatic at the time of positive testing may be muddied by a lack of consistent definitions of "asymptomatic" (what symptom screening was used, and the time period discussed) as well inconsistent followup to determine if the individuals were presymptomatic.

A key practical question is whether asymptomatic or presymptomatic RT-PCR positive individuals account for significant spread of infection, compared to spread from individuals with "droplet generating" symptoms such as coughing and sneezing. Epidemiologic modelling based on mean interval estimates suggests concern for potentially significant transmission from asymptomatic or presymptomatic persons. However, the assumptions made are based on the potentially misleading extant data around asymptomatic cases, and in addition the accuracy of epidemiologic symptom onset data (determination of any symptoms versus symptoms that limited activity, for example) are weaknesses in these analysis, as potentially reflected in the serial intervals differing by significantly in different reports. Further, the nature of the contacts in the transmission chains used in modelling studies is not well described (specifically if there was prolonged household contact or food sharing).

Given the importance of real world data to clarify the transmission dynamics and allow optimally focused control efforts, this revision has focused on optimizing local data collection to inform policies and practices during the remainder of the pandemic period. It is therefore recommended that standardized definitions of presymptomatic, asymptomatic, and paucisymptomatic RT-PCR positive cases be developed to help clarify local transmission patterns as well as to allow more comparable assessment of public health data sets. In addition, public education around paying attention to seemingly unimportant symptoms to allow early testing and rapid contact tracing is highlighted, as existing data highlights a more robust role for presymptomatic spread than asymptomatic spread. Rapid contact tracing, testing and quarantine will be crucial to limit secondary cases as public health restrictions are reduced. Depending on the degree to which truly asymptomatic spread occurs and presymptomatic spread cannot be mitigated a degree of public health measures such as physical distancing, hand hygiene, appropriate masking and environmental hygiene will be required for the foreseeable future to limit community spread of infection.

It will be crucial to follow evolving evidence to resolve these discrepancies and support appropriate precautions and control measures if a significant role of asymptomatic spread is more strongly supported.

Date question received by advisory group: started by previous group (before 24 March 2020)

Date report submitted to committee: April 8, 2020

Date of reassessment: April 13, 2020.

(If applicable) Date of most recent re-assessment: June 13, 2020 – July12, 2020

The Scientific Advisory Group (SAG) supports decision making based on best available evidence, reflecting both the precautionary principle and an ethical framework (Bean et al., 2020).

Authorship & Committee Members
This report was written initially by Lynora Saxinger (co-chair), building on an initial report drafted by Ranjani Somyani, and the first review was conducted by Sylvia Checkley (and team), with primary reviewer Melissa Potestio. The third rewrite was performed by Lynora Saxinger, Sylvia Checkley, and the full Scientific Advisory Group, who were involved in discussion and revision of the document: Braden Manns (co-chair), John Conly, Alexander Doroshenko, Nelson Lee, Elizabeth MacKay, Andrew McRae, James Talbot, Shelley Duggan, Jeremy Slobodan, Brandie Walker, and Nathan Zelyas. External reviewers of the initial review included Joseph Kim, Uma Chandran, and Michael Parkins. The third rewrite was additionally reviewed by Robyn Harrison, Joseph Kim, and Uma Chandran.

COVID-19 Scientific Advisory Group Rapid Response Report

Appendix

List of Abbreviations

CDC: Centers for Disease Control and Prevention, US Department of Health and Human Services

CoV: Coronavirus

COVID-19: Coronavirus Disease 2019

CT: Computed Tomography Scan

MERS: Middle East Respiratory Syndrome

RT-PCR: Reverse Transcriptase Polymerase Chain Reaction

PHAC: Public Health Agency of Canada

PPE: Personal protective equipment

RT-PCR: Reverse Transcriptase Polymerase Chain Reaction

SAG: Scientific Advisory Group

SARS: Severe Acute Respiratory Syndrome

SARS-CoV-2: Severe Acute Respiratory Syndrome – Coronavirus – 2

WHO: World Health Organization

Literature Search Details

The literature search was conducted by Lauren Seal from Knowledge Resource Services, Knowledge Management, Alberta Health Services.

Medline/PubMed
1 exp Coronavirus/ or exp Coronavirus Infections/ or coronaviru*.mp. or "corona virus*".mp. or ncov*.mp. or n-cov*.mp. or COVID-19.mp. or COVID19.mp. or COVID-2019.mp. or COVID2019.mp. or SARS-COV-2.mp. or SARSCOV-2.mp. or SARSCOV2.mp. or SARSCOV19.mp. or Sars-Cov-19.mp. or SarsCov-19.mp. or SARSCOV2019.mp. or Sars-Cov-2019.mp. or SarsCov-2019.mp. or "severe acute respiratory syndrome cov 2".mp. or "2019 ncov".mp. or "2019ncov".mp. (19061)
2 exp Asymptomatic Diseases/ (6863)
3 asymptomatic*.mp. (151914)
4 (no adj1 symptom*).mp. (11029)
5 "not showing symptom*".mp. (6)
6 "not displaying symptom*".mp. (1)
7 subclinical.mp. (40536)
8 2 or 3 or 4 or 5 or 6 or 7 (198567)
9 exp Disease Transmission, Infectious/ (67240)
10 transmission.mp. (507091)
11 transmit*.mp. (175260)
12 infectivity.mp. (25885)
13 infectiousness.mp. (1367)
14 9 or 10 or 11 or 12 or 13 (670831)

15 1 and 8 and 14 (121)
16 limit 15 to last 2 years (40)

CINAHL

S1	(MH "Coronavirus+")	
S2	(MH "Coronavirus Infections+")	
S3	coronaviru*	
S4	"corona virus"	
S5	ncov*	
S6	n-cov*	
S7	COVID-19 OR COVID19 OR COVID-2019 OR COVID2019	
S8	SARS-COV-2 OR SARSCOV-2 OR SARSCOV2 OR SARSCOV19 OR SARS-COV-19 OR SARSCOV-19 OR SARSCOV2019 OR SARS-COV-2019 OR SARSCOV-2019	
S9	"severe acute respiratory syndrome cov 2" OR "severe acute respiratory syndrome coronavirus*"	
S10	"2019 ncov" OR 2019ncov OR Hcov*	
S11	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10	
S12	asymptomatic OR subclinical OR no n2 symptom* OR "not showing symptoms" OR "not displaying symptoms"	45,757
S13	(MH "Disease Transmission+")	15,176
S14	transmission OR transmit* OR infectivity OR infectiousness	92,851
S15	S13 OR S14	93,800
S16	S11 AND S12 AND S15	31

TRIP Pro/Google Scholar/Google/ LitCovid/CEBM/WHO/Stanford Medicine/NEJM/CochraneLibrary/CDC

(asymptomatic OR paucisymptomatic OR "no symptoms" OR "not showing symptoms" OR "not displaying symptoms" subclinical) AND (transmission OR transmit OR transmitting OR infectivity OR infectiousness) AND ("covid-19" OR coronavirus OR COVID19 OR "corona virus" OR ncov OR "n-cov" OR "covid-2019" OR covid2019 OR "SARS-COV-2" OR "sarscov-2" OR sarscov2 OR sarscov19 OR "sars-cov-19" or "sarscov-19" OR sarscov2019 OR "sars-cov-2019" OR "severe acute respiratory syndrome") from:2018

(asymptomatic OR paucisymptomatic OR "no symptoms" OR "not showing symptoms" OR "not displaying symptoms" OR subclinical) AND (transmission OR transmit OR transmitting OR infectivity OR infectiousness) AND ("covid-19" OR coronavirus OR "corona virus")

(asymptomatic OR paucisymptomatic OR "no symptoms" OR "not showing symptoms" OR "not displaying symptoms" OR subclinical) AND (transmission OR transmit OR transmitting OR infectivity OR infectiousness)

Reference List

Aguilar, J. B., Faust, J. S., Westafer, L. M., & Gutierrez, J. B. (2020). Investigating the impact of asymptomatic carriers on COVID-19 transmission. *medRxiv*. doi:10.1101/2020.03.18.20037994.

Arons, M. M., Hatfield, K. M., Reddy, M. D., Kimball, A., James, A., Jacobs, J. R., Taylor, J., Spicer, K., Bardossy, A. C., Oakley, L. P., Tanwar, S., Dyal, J. W., Harney, J., Chisty, Z., Bell, J. M., Methner, M., Paul, P., Carlson, C. M., McLaughlin, H. P., ... Jernigan, J. A. (2020). Presymptomatic SARS-CoV-2 infections and transmission in a skilled nursing facility. *The New England Journal of Medicine*. doi: 10.1056/NEJMoa2008457.

Backer, J. A., Klinkenberg D., Wallinga, J. (2020). Incubation period of 2019 novel coronavirus (2019-nCoV) infections among travellers from Wuhan, China, 20–28 January 2020. *Euro Surveillance, 25(5)*. https://doi.org/10.2807/1560-7917.ES.2020.25.5.2000062

Bai, Y., Yao, L., Wei, T., Tian, F, Jin, D.-Y., Chen, L. & Wang, M. (2020, February 21). Presumed asymptomatic carrier transmission of COVID-19. *Journal of the American Medical Association*. Retrieved from: https://jamanetwork.com/journals/jama/fullarticle/2762028.

Bean, S., Reel, K., Smith, M.S., Henry, B. & McDonald, M. (2020). Ethical framework for the allocation of personal protective equipment (during COVID-19). http://jcb.utoronto.ca/news/documents/Ethical-Framework-for-the-Allocation-of-Personal-Protective-Equipment-2020.pdf.

Bi, Q., Wu, Y., Mei, S, Ye, C., Zou, X., Zhang, Z., Liu, X., Wei, L., Truelove, S., Zhang, T., Gao, W., Cheng, C., Tang, X., Wu, X., Wu, Y., Sun, B., Huang, S., Sun, Y., Zhang, J., Ma, T., Lessier, J., & Feng, T. (2020). Epidemiology and transmission of COVID-19 in Shenzhen China: analysis of 391 cases and 1286 of their close contacts. *medRxiv*. doi: https://doi.org/10.1101/2020.03.03.20028423.

Bohmer, M. M., Buchholz, U., Corman, V. M., Hoch, M., Katz, K., Marosevic, D. V., Bohm, S., Woudenberg, T., Ackermann, N., Konrad, R., Eberle, U., Teris, B., Dangle, A., Bengs, K., Fingerle, V., Berger, A., Hormansdorfer, S., Ippisch, S., Wicklein, B.,... Zapf, A. (2020). Investigation of a COVID-19 outbreak in Germany resulting from a single travel-associated primary case: a case series. *Lancet Infectious Disease*. https://doi.org/10.1016/ S1473-3099(20)30314-5.

Bullard, J., Dust, K, Funk, D., Strong, J.E., Alexander, D., Garnett, L. Boodman, C., Bello, A., Hedley, A., Schiffman, Z., Doan, K., Bastien, N., Li, Y., Van Caeseele, P.G., Poliquin, G. Predicting infectious SARS-CoV-2 from diagnostic samples, *Clinical Infectious Diseases*, ciaa638, https://doi.org/10.1093/cid/ciaa638

Buitrago-Garcia, D. C., Egli-Gany, D., Counotte, M. J., Hossmann, S., Imeri, H., Salanti, G. & Low, N. (2020). The role of asymptomatic SARS-CoV-2 infections: rapid living systematic review and meta-analysis. medRxiv 2020.04.25.20079103; doi: https://doi.org/10.1101/2020.04.25.20079103

Byamburasan, O., Cardona, M., Bell, K., Clark, J., McLaws, M-L., Glasziou, P. Estimating the extent of asymptomatic COVID-19 and its potential for community transmission: Systematic review and meta-analysis. MedRxiv. https://doi.org/10.1101/2020.05.10.20097543

Cevik, M., Bogoch, I.I., Carson, G., D'Ortenzio, E., Kuppali, K., Low, N ... on behalf of the CORRE Network (International COVID-19 Rapid Evidence Reviews Group). (2020, June 10). An open letter to Oran and Topol, and the Annals of Internal Medicine (Version version 1). Zenodo. http://doi.org/10.5281/zenodo.3888361

Chan, J. F., Yuan, S., Kok, K. H., To, K. K., Chu, H., Yang, J., Xing, F., Liu, J., Yip, C. C., Poon, R. W., Tsoi, H. W., Lo, S. K., Chan, K. H., Poon, V. K., Chan, W. M., Daniel, J., Cai, J. P., Cheng, V. C., Chen, P. H., Hui, C. K. H. & Yuen, P. K. Y. (2020). A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: A study of a family cluster. *The Lancet: Infectious Disease, 395*(10223), 514-523. doi:S0140-6736(20)30154-9.

Chau, N.V.V, Lam, V.T., Dung, N.T., Yen, L.M., Minh, N.N.Q., Hung, L.M., Ngoc, N.M., Dung, N.T., Man, D.N.H., Nguyet, L.A., Nhat, L.T.H., Nhu, L.N.T., Ny, N.T.H., Hong, N.T.T., Kestelyn, E., Dung, N.T.P., Xuan, T.C., Hien, T.T., Phong, N.T., Tu, T.N.H., Geskus, R.B., Thanh, T.T., Truong, N.T., Binh, N.T., Thuong, T.C., Thwaites, G., Tan, L.V. OUCRU COVID-19 research group, The natural

history and transmission potential of asymptomatic SARS-CoV-2 infection, *Clinical Infectious Diseases*, ciaa711, https://doi.org/10.1093/cid/ciaa711

Chaw, L., Koh, W.C., Jamaludin, S.A., Naing, L., Alikhan, M.F., Wong, J. SARS-CoV-2 transmission in different settings: Analysis of cases and close contacts from the Tablighi cluster in Brunei Darassalm. MedRxiv. https://doi.org/10.1101/2020.05.04.20090043

Cheng, H. Y., Jian, S. W., Liu, D. P., Ng, T. C., Huang, W. T. & Lin, H. H. (2020). High transmissibility of COVID-19 near symptom onset. *MedRxiv*. https://doi.org/10.1101/2020.03.18.20034561.

Corman VM, Landt O, Kaiser M, Molenkamp R, Meijer A, Chu DKW, et al. Detection of 2019 novel coronavirus (2019-nCoV) by real-time RT-PCR. Euro Surveill. 2020;25:25; Epub ahead of print. DOIExternal LinkPubMedExternal Link

Council of State and Territorial Epidemiologists (2020). Standardized surveillance case definition and national notification for 2019 novel coronavirus disease (COVID-19). Accessed at https://cdn.ymaws.com/www.cste.org/resource/resmgr/2020ps/interim-20-id-01_covid-19.pdf.

Docherty, A.B., Harrison, E.M., Green, C.A., Hardwick, H.E., Pius, R., Norman, L., Holden, K.A., Read, J.M., Dondelinger, F., Carson, G., Merson, L., Lee, J., Plotkin, D., Sigfrid, L., Halpin, S., Jackson, C., Gamble, C., Horby, P.W., Nguyen-Van-Tam, J.S., Dunning, J., Openshaw, P.J.M., Ballie, J.K., Semple, M.G. Features of 17,749 hospitalized UK patients with COVID-19 using the ISARIC WHO Clinical Characterisation Procotol. medRxiv 2020.04.23.20076042; doi: https://doi.org/10.1101/2020.04.23.20076042

Day, M. (2020). Covid-19: China figures indicate four fifths of cases are asymptomatic *British Medical Journal 2020*, 369(1375). https://doi.org/10.1136/bmj.m1375.

Dong Y, Mo X, Hu Y, et al. Epidemiological characteristics of 2143 pediatric patients with 2019 coronavirus disease in China. Pediatrics. 2020; doi: 10.1542/peds.2020-0702

Du. Z., Xu, X., Wu, Y., Wang, L., Cowling, B. J. & Meyers L. A. (2020). Serial interval of COVID-19 among publicly reported confirmed cases. *Emerging Infectious Diseases 26*(6). https://wwwnc.cdc.gov/eid/article/26/6/20-0357_article.

Ferretti, L., Wymant, C., Kendall, M., Zhao, L., Nurtay, A., Abeler-Dorner, L., Parker, M., Bonsall, D. & Fraser, C. (2020). Quantifying SARS-CoV-2 transmission suggest epidemic control with digital contact tracing. Science 368(6491). doi: 10.1126/science.abb6936.

Flaxman,S., Mishra, S., Gandy, A., Unwin, J. T., Coupland, H., Mellan, T. A., Zhu, H., Berah, T., Eaton, J. W., Guzman, P. N. P., Schmit, N., Cilloni, L., Ainslie, K. E. C., Baguelin, M., Blake, I., Boonyasiri, A., Boyd, O., Cattarino, L., Ciavarella, C., ... Bhatt, S. (2020). Estimating the number of infections and the impact of non-pharmaceutical interventions on COVID-19 in 11 European countries. Imperial College London. https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College-COVID19-Europe-estimates-and-NPI-impact-30-03-2020.pdf.

Furukawa, N. W., Brooks, J. T.& Sobel, J. (2020). Evidence supporting transmission of severe acute respiratory syndrome coronavirus 2 while presymptomatic or asymptomatic. *Emergency Infectious Disease.* https://doi.org/10.3201/eid2607.201595.

Gao, M., Yang, L., Chen, X., Deng, Y., Yang, S., Xu, H., Chen, Z., Gao, X. (2020). A study on infectivity of asymptomatic SARS-CoV-2 carriers. Respiratory Medicine. doi: https://doi.org/10.1016/j.rmed.2020.106026

Gao, Y., Shi, C., Chen, Y., Shi, P., Liu, J., Xiao, Y., Shen, Y. & Chen, E. (2020). A cluster of the Corona Virus Disease 2019 caused by incubation period transmission in Wuxi, China. *Journal of Infection.* doi: https://doi.org/10.1016/j.jinf.2020.03.042

Guan, W. J., Ni, Z., Hu, Y. & Liang, W. H .(2020). Clinical Characteristics of Coronavirus Disease 2019 in China. *The New England Journal of Medicine.382*(1708-1720). doi: 10.1056/NEJMoa2002032

He, X., Lau, E. H., Wu, P., Deng, X., Wang, J., Hao, X., Lau, Y. C., Wong, J. Y., Guan, Y., Tan, X., Mo, X., Chen, Y., Liao, B., Chen, W., Hu, F., Zhang, Q., Zhong, M., Wu, Y., Zhao, L., Zhang, F., Cowling, B. J., Li, F. & Leung, G. M. (2020). Temporal dynamics in viral shedding and transmissibility of COVID-19. *medRxiv*. doi: 10.1038/s41591-020-0869-5.

Hodcroft, E. B. (2020, February 27). Preliminary case report on the SARS-CoV-2 cluster in the UK, France, and Spain. *Swiss Medicine Weekly, 150*(9-10). doi:10.4414/smw.2020.20212.

Hoehl, S. (2020). Evidence of SARS-CoV-2 Infection in returning travelers from Wuhan, China. *The New England Journal of Medicine*. https://www.nejm.org/doi/full/10.1056/NEJMc2003100.

Hong, Q.N., Pluye, P., Fabregues, S., Bartlett, G., Boardman, F., Cargo, M., Dagenais, P., Gagnon, M-P, Griffiths, F., Niciolau, B., O'Cathain, A., Rousseau, M-C, & Vedel, I. (2018). The Mixed Methods Appraisal Tool (MMAT) Version 2018 for Information Professionals and Researchers'. 1 Jan. 2018 : 285 – 291. http://mixedmethodsappraisaltoolpublic.pbworks.com/w/file/fetch/127916259/MMAT_2018_criteria-manual_2018-08-01_ENG.pdf.

Hu, Z., Song, C., Xu, C., Jin, G., Chen, Y., Xu, X., ... & Shen, H. (2020) Clinical characteristics of 24 asymptomatic infections with COVID-19 screened among close contacts in Nanjing, China. *Sci. China Life Sci.* https://doi.org/10.1007/s11427-020-1661-4.

Huang R, Xia J, Chen Y, Shan C, Wu C. (2020). A family cluster of SARS-CoV-2 infection involving 11 patients in Nanjing, China. *Lancet Infectious Disease*. doi: 10.1016/ S1473-3099(20)30147-X.

Huang L, Zhang X, Zhang X, et al. Rapid asymptomatic transmission of COVID-19 during the incubation period demonstrating strong infectivity in a cluster of youngsters aged 16-23 years outside Wuhan and characteristics of young patients with COVID-19: A prospective contact-tracing study. *J Infect*. 2020;80(6):e1-e13. doi:10.1016/j.jinf.2020.03.006

Ing, A.J., Cocks, C., Green, J.P. COVID-19: In the footsteps of Ernest Shackleton. *Thorax*. doi:10.1136/ thoraxjnl-2020-215091

Instituto de Salud Carlos III (2020). Estudio Ene-Covid19: Primera Ronda Estudio Nacional De Sero-Epidemiología De La Infección Por Sars-Cov-2 En España Informe Preliminar 13 De Mayo De 2020. Accessed June 1, 2020 from https://www.mscbs.gob.es/gabinetePrensa/notaPrensa/pdf/13.05130520204528614.pdf

Jing, Q-L., Liu, M-J., Yuan, J., Zhang, Z-B., Zhang, A-R., Dean, N.E., Luo, L., Ma, M-M., Longini, I., Kenah, E., Lu, Y., Ma, Y. Jalali, N., Fang, L-Q., Yang, Z-C., Yang, Y. Household secondary attack rate of COVID-19 and associated determinants. medRxiv 2020.04.11.20056010; doi: https://doi.org/10.1101/2020.04.11.20056010

Kimball, A., Hatfield, K.M., Arons, M., James, A., Taylor, J., Spicer, K., Bardossy, A. C., Oakley, L. P., Tanwar, S., Chisty, Z., Bell, J. M., Methner, M., Harney, J., Jacobs, J. R., Carlson, C. M., McLaughlin, H. P., Stone, N., Clark, S., Brostrom-Smith, C., ... Jernigan, J. A. (2020). Asymptomatic and presymptomatic SARS-CoV-2 infections in residents of a long-term care skilled nursing facility — King County, Washington. *Morbidity and Mortality Weekly Report, 69(*13) 377-381. https://www.cdc.gov/mmwr/volumes/69/wr/mm6913e1.htm?s_cid=mm6913e1_w.

Koh, W.C., Naing, L., Rosledzana, M.A., Alikhan, M.F., Chaw, L., Griffith, M., Pastore, R., Wong, J. What do we know about SARS-CoV-2 transmission? A systematic review and meta-analysis of the secondary attack rate, serial interval, and asymptomatic infection. MedRxiv. https://www.medrxiv.org/content/10.1101/2020.05.21.20108746v1.full.pdf

Lauer, S. A., Grantz, K. H., Bi, Q., Jones, F. K., Zheng, Q., Meredith, H. R., Azman, A. S., Reich, N. G., & Lessler, J. (2020). The Incubation Period of Coronavirus Disease 2019 (COVID-19) From Publicly Reported Confirmed Cases: Estimation and Application. Annals of internal medicine, 172(9), 577–582. https://doi.org/10.7326/M20-0504

Li, R., Pei, S., Chen, B., Song, Y., Zhang, T., Yang, W. & Shaman, J. (2020a) Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (SARS-CoV2). *Science 368*(6490), 489-493. doi:10.1126/science.abb3221.

Li, C., Fang, J., Wang, L., Wang, L., Hao, J., Dai, M., Liu, Y., Pan, X., Fu, J., Li, L., Yang, G., Yang, J., Yan, X. & Gu, B. (2020b) Asymptomatic and Human-to-Human Transmission of SARS-CoV-2 in a 2-Family Cluster, Xuzhou, China. *Emerging Infectious Diseases, 26(7)*. https://doi.org/10.3201/eid2607.200718.

Liao, J et al. Epidemiological and clinical characteristics of COVID-19 in adolescents and young adults.

Liu, Y., Funk, S., & Flasche, S. (2020). The contribution of pre-symptomatic infection to the transmission dynamics of COVID-2019. *Wellcome Open Research, 5(*58), 58. doi: https://doi.org/10.12688/wellcomeopenres.15788.1.

Lu, X., Zhang, L., Du, H., Zhang, J., Li, Y.Y., Qu, J., Zhang, W., & Wong, G.W.K. (2020a). SARS-CoV-2 Infection in Children. *New England Journal of Medicine*. https://www.nejm.org/doi/full/10.1056/NEJMc2005073?query=TOC.

Lu, S., Lin, J., Zhang, Z., Xiao, L., Jiang, Z., Chen, J., Hu.,& Luo, S. (2020b). Alert for non-respiratory symptoms of Coronavirus Disease 2019 (COVID-2019) patients in epidemic period: A case report of familial cluster with three asymptomatic COVID-19 patients. *Journal Medical Virol*. doi: 10.1002/jmv.25776

Luo, L., Liu, D., Liao, X. L., Wu, X. B., Jing, Q. L., Zheng, J. Z., Liu, F. H., Yang, S. G., Bi, B., Li, Z. H., Liu, J. P., Song, W. Q., Zhu, W., Wang, A. H., Zhang, X. R., Chen, P. L., Liu, H. M., Cheng, X., Cai, M. C., ...Mao, C. (2020). Modes of contact and risk of transmission in COVID-19 among close contacts. *MedRxiv*. doi: https://doi.org/10.1101/2020.03.24.20042606.

Luo, S. H., Liu, W., Liu, Z. J., Zheng, X. Y., Hong, C. X., Liu, Z. R., Liu, J. & Weng, J. P. (2020). A confirmed asymptomatic carrier of 2019 novel coronavirus. Chinese Medicine Journal 133(9)1123-1125. doi: 10.1097/CM9.0000000000000798.

Mizumoto, K., Kagaya, K., Zarebski, A., & Chowell, G. (2020). Estimating the asymptomatic proportion of coronavirus disease 2019 (COVID-19) cases on board the Diamond Princess cruise ship, Yokohama, Japan, 2020. *Euro surveillance : bulletin Europeen sur les maladies transmissibles = European communicable disease bulletin*, *25*(10), 2000180. https://doi.org/10.2807/1560-7917.ES.2020.25.10.2000180.

Nishiura, H., Kobayashi, T., Miyami, T., Suzuki, A., Jung, S.-M., Hayashi, K., Kinoshita, R., Yang, Y., Yuan, B., Akhmetzhanov, A. R. & Linton, N. M. (2020b).Estimation of the asymptomatic ratio of novel coronavirus infections (COVID-19). *International Journal of Infectious Diseases*. doi: https://doi.org/10.1016/j.ijid.2020.03.020.

Nishiura H., Linton, N.M. & Akhmetzhanov, A.R. (2020a). Serial Interval of novel coronavirus (COVID-19) infections. *International Journal of Infectious Disease*. 93. https://www.ijidonline.com/article/S1201-9712(20)30119-3/pdf.

Oran, D.P., Topol, E.J. Prevalence of asymptomatic SARS-CoV-2 infection: A narrative review. Annals of Internal Medicine. https://doi.org/10.7326/M20-3012

Pan, Y., Zhang, D., Yang, P., Poon, L.L.M. & Wang, Q. (2020a, April). Viral load of SARS-CoV-2 in clinical samples. *The Lancet 20*(4) 411-412. https://doi.org/10.1016/S1473-3099(20)30113-4.

Pan X, Chen D, Xia Y et al. (2020b) Asymptomatic cases in a family cluster with SARS-CoV-2 infection. *Lancet Infectious Disease*. doi : 10.1016/ S1473-3099(20)30114.

Park SY, Kim YM, Yi S, Lee S, Na BJ, Kim CB, et al. Coronavirus disease outbreak in call center, South Korea. Emerg Infect Dis. 2020 Aug [*date cited*]. https://doi.org/10.3201/eid2608.201274

Payne DC, Smith-Jeffcoat SE, Nowak G, et al. SARS-CoV-2 Infections and Serologic Responses from a Sample of U.S. Navy Service Members — USS Theodore Roosevelt, April 2020. MMWR Morb Mortal Wkly Rep 2020;69:714–721. DOI: http://dx.doi.org/10.15585/mmwr.mm6923e4external icon.

Qian G, Naibin Yang, Ada Hoi Yan Ma, Liping Wang, Guoxiang Li, Xueqin Chen, Xiaomin Chen, COVID-19 Transmission Within a Family Cluster by Presymptomatic Carriers in China, Clinical Infectious Diseases, ciaa316, https://doi.org/10.1093/cid/ciaa316

Ran, L., Chen, X., Wang, Y., Wu, W., Zhang L. & Tan, X. (2020). Risk Factors of Healthcare Workers with Corona Virus Disease 2019: A Retrospective Cohort Study in a Designated Hospital of Wuhan in China, *Clinical Infectious Diseases*, 287, https://doi.org/10.1093/cid/ciaa287.

Rockx, B., Kuiken, T., Herfst, S., Bestebroer, T., Lamers, M., de Meulder, D., ... & van Run, P. (2020). Comparative Pathogenesis Of COVID-19, MERS And SARS In A Non-Human Primate Model. *bioRxiv*. https://www.biorxiv.org/content/10.1101/2020.03.17.995639v1.

Rosenberg, E.S., Dufort, E.M., Blog, D.S., Hall, E.W., Hoefer, D., Backenson, B.P., Muse, A.T., Kirkwood, J.N., St George, K., Holtgrave, D.R., Hutton, B.J., Zucker, H.A. New York State Coronavirus 2019 Response Team, COVID-19 Testing, Epidemic Features, Hospital Outcomes, and Household Prevalence, New York State—March 2020, *Clinical Infectious Diseases*, , ciaa549, https://doi.org/10.1093/cid/ciaa549

Sakurai A , Sasaki T , Kato S , Hayashi M , Tsuzuki S-I , Ishihara T , et al. Natural history of asymptomatic SARS-CoV-2 infection. N Engl J Med 2020; doi:10.1056/NEJMc2013020

Samsani, M., Bagherpour, J. Z., Nematihonar, B. & Tahmasbi, H. (2020). COVID-19 pneumonia in asymptomatic trauma patients; report of 8 cases. *Archives of Academic Emergency Medicine 8(1)*46. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7158871/.

Tabata, S., Imai, K., Kawano, S., Ikeda, M., Kodama, T., Miyoshi, K., Obinata, H., Mimura, S., Kodera, T., Kitagaki, M., Sato, M., Suzuki, S., Ito, T., Uwabe, Y. & Tamura, K. (2020). The clinical characteristics of COVD-19.: a retrospective analysis of 104 patients from the outbreak on board the Diamond Princess cruise ship in Japan. *MedRxiv*. https://doi.org/10.1101/2020.03.18.20038125.

Thai, P.Q., Mai, le Q., Welkers, M.R., Hang, N., Thanh, le T., ... Fox, A. Pandemic H1N1 virus transmission and shedding dynamics in index case households of a prospective Vietnamese cohort. *J Infect*. 2014;68(6):581–590. doi:10.1016/j.jinf.2014.01.008.

Tong Z-D, Tang A, Li K-F, Li P, Wang H-L, Yi J-P, et al. Potential presymptomatic transmission of SARS-CoV-2, Zhejiang Province, China, 2020. *Emerg Infect Dis*.doi : 10.3201/eid2605.200198.

Treibel, T. A., Manisty, C., Burton, M., McKnight, A., Lambourne, J., Augusto, J. B., Couto-Parada, X., Cutino-Moguel, T., Noursadeghi, M. & Moon, J. C. (2020, May 7) COVID-19: PCR screening of asymptomatic healthcare workers at London hospital. *The Lancet*. https://doi.org/10.1016/S0140-6736(20)31100-4.

Wei, W.E. LZ, Chiew, C.J., Yong, S.E., Toh, M.P., Lee, V.J. (2020, April 1). Presymptomatic transmission of SARS-CoV-2 — Singapore, January 23–March 16, 2020. *Morbidity and Mortality Weekly Report 69*(14) 411-415.

Wolfel R., Corman, V.M, Guggemos, W. Seilmaier, M.K Zange, S., Muller, M.A., Niemeyer, D., & Wendtner, C. (2020) Virological assessment of hospitalized patients with COVID-2019. *Nature*.

Wong J, MPhil, Anita B Z Abdul Aziz, PhD, Liling Chaw, PhD, Abdirahman Mahamud, MD, Matthew M Griffith, MPH, L O Ying-Ru, MD, Lin Naing, MD, High proportion of asymptomatic and presymptomatic COVID-19 infections in travelers and returning residents to Brunei, *Journal of Travel Medicine*, , taaa066, https://doi.org/10.1093/jtm/taaa066

World Health Organization. (2020a, April 7). Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19). https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf.

World Health Organization. (2020b, April 7). Q&A: Similarities and differences – COVID-19 and Influenza, 17 March 2020. https://www.who.int/news-room/q-a-detail/q-a-similarities-and-differences-covid-19-and-influenza.

World Health Organization. (2020c, April 7). Modes of transmission of virus causing COVID-19: implications for IPC precaution recommendations, 29 March 2020. Retrieved from: https://www.who.int/publications-detail/modes-of-transmission-of-virus-causing-covid-19-implications-for-ipc-precaution-recommendations.

World Health Organization. (2020d, April 2). Coronavirus disease 2019 (COVID-19) Situation Report – 73. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports.

Xiao, A.T., Tong, Y.X., Zhang, S. Profile of RT-PCR for SARS-CoV-2: a preliminary study from 56 COVID-19 patients, *Clinical Infectious Diseases*, ciaa460, https://doi.org/10.1093/cid/ciaa460

Xu J et al (2020). Salivary glands: Potential reservoirs for COVID-19 asymptomatic infection. Journal of Dental Research. DOI: 10.1177/0022034520918518https://doi.org/10.1177/0022034520918518 journals.sagepub.com/home/jdr

Yang R, Gui X, Xiong Y. Comparison of Clinical Characteristics of Patients with Asymptomatic vs Symptomatic Coronavirus Disease 2019 in Wuhan, China. *JAMA Netw Open*. 2020;3(5):e2010182. doi:10.1001/jamanetworkopen.2020.10182

Yang, N., Shen, Y., Shi, C., Ma, A. H. Y., Zhang, X., Jian, X., Wang, L., Shi, J., Wu, C., Li, G. Fu, Y., Wang, K., Lu, M. & Qian, G. (2020). In-flight transmission cluster of COVID-19: A retrospective case series. *MedRxiv*. https://doi.org/10.1101/2020.03.28.20040097.

Yasinki, E. (2020). Researchers applaud Spanish COVID-19 serological survey. Accessed June 1, 2020 from https://www.the-scientist.com/news-opinion/researchers-applaud-spanish-covid-19-serological-survey-67590

Ye, F., Xu, S., Rong, Z., Xu, R., Liu, X., Deng, P., Liu, H. & Xu, X. (2020). Delivery of infection from asymptomatic carriers of COVID-19 in a familial cluster. *International Journal of Infectious Diseases*. https://www.ijidonline.com/article/S1201-9712(20)30174-0/fulltex.

Yu, P., Zhu, J., Zhang, Z. & Han, Y. (2020). A familial cluster of infection associated with the 2019 novel coronavirus indicating possible person-to-person transmission during the incubation period. *Journal of Infectious Disease*. doi:10.1093/jiaa077.

Zhang, J., Tian, S., Lou, J., & Chen, Y. (2020). Familial cluster of COVID-19 infection from an asymptomatic. *Critical Care*, *24*(1), 119. https://doi.org/10.1186/s13054-020-2817-7.

Zhang W. Estimating the presymptomatic transmission of COVID19 using incubation period and serial interval data. *MedRxiv*. https://doi.org/10.1101/2020.04.02.20051318.

Zhao, S., Gao, D., Chong, M., Cai, Y., Ran, J., Cao, P., Wang, K., Lou, Y., Wang, W., Yang, L., He, D., Wang., M. (2020). Estimating the serial interval of the novel coronavirus disease (COVID-19): A statistical analysis using the public data in Hong Kong from January 16 to February 15, 2020. *medRxiv*. https://www.medrxiv.org/content/10.1101/2020.02.21.20026559v1.

Zhou, C. (2020). Evaluating new evidence in the early dynamics of the novel coronavirus COVID-19 outbreak in Wuhan, China with real time domestic traffic and potential asymptomatic transmissions. *MedRxiv*, 2020.02.15.20023440. https://doi.org/10.1101/2020.02.15.2002344.

Zhu, Y., Bloxham, C.J., Hulme, K.D., Sinclair, J.E., Tong, Z.W.M., Steele, L.E., Noye, E.C., Lu, J., Chew, K.Y., Pickering, J., Gilks, C., Bowen, A.C., Short, K.R. (2020). Children are unlikely to have been the primary source of household SARS-CoV-2 infections. medRxiv 2020.03.26.20044826; doi: https://doi.org/10.1101/2020.03.26.20044826

Zou, L., Ruan, F., Huang, M., Liang, L., Huang, H., Hong, Z., & Guo, Q. (2020). SARS-CoV-2 viral load in upper respiratory specimens of infected patients. *New England Journal of Medicine*, *382*(12), 1177-1179.

REVIEW

Annals of Internal Medicine

Prevalence of Asymptomatic SARS-CoV-2 Infection

A Narrative Review

Daniel P. Oran, AM, and Eric J. Topol, MD

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has spread rapidly throughout the world since the first cases of coronavirus disease 2019 (COVID-19) were observed in December 2019 in Wuhan, China. It has been suspected that infected persons who remain asymptomatic play a significant role in the ongoing pandemic, but their relative number and effect have been uncertain. The authors sought to review and synthesize the available evidence on asymptomatic SARS-CoV-2 infection. Asymptomatic persons seem to account for approximately 40% to 45% of SARS-CoV-2 infections, and they can transmit the virus to others for an extended period, perhaps longer than 14 days. Asymptomatic infection may be associated with subclinical lung abnormalities, as detected by computed tomography. Because of the high risk for silent spread by asymptomatic persons, it is imperative that testing programs include those without symptoms. To supplement conventional diagnostic testing, which is constrained by capacity, cost, and its one-off nature, innovative tactics for public health surveillance, such as crowdsourcing digital wearable data and monitoring sewage sludge, might be helpful.

Ann Intern Med. 2020;173:362-367. doi:10.7326/M20-3012 Annals.org
For author, article, and disclosure information, see end of text.
This article was published at Annals.org on 3 June 2020.

In the early months of the coronavirus disease 2019 (COVID-19) pandemic, an iconic image has been the "proned" patient in intensive care, gasping for breath, in imminent need of artificial ventilation. This is the deadly face of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which as of 26 May 2020 had claimed more than 348 000 lives worldwide (1). But it is not the only face, because SARS-CoV-2 now seems to have a dual nature: tragically lethal in some persons and surprisingly benign in others.

Since February 2020 (2, 3), there have been reports of persons who were infected with SARS-CoV-2 but did not develop symptoms of COVID-19. In some cases (4, 5), the viral load of such asymptomatic persons has been equal to that of symptomatic persons, suggesting similar potential for viral transmission. The prevalence of asymptomatic SARS-CoV-2 infection, however, has remained uncertain. We sought to review and synthesize the available evidence on testing for SARS-CoV-2 infection, carried out by real-time reverse transcriptase polymerase chain reaction using nasopharyngeal swabs in all studies that specified the method of testing.

Most data from the 16 cohorts in this narrative review are not the output of large, carefully designed studies with randomly selected, representative samples. They do not generally purport to depict anything more than certain circumscribed cohorts at specific moments in time. We have not attempted to pool them for the purposes of statistical analysis. When viewed as a collection, though—as a kind of mosaic or patchwork—these data may offer potentially valuable insights into SARS-CoV-2 incidence and the highly variable effect of infection.

The difficulty of distinguishing asymptomatic persons from those who are merely presymptomatic is a stumbling block. To be clear, the asymptomatic individual is infected with SARS-CoV-2 but will never develop symptoms of COVID-19. In contrast, the presymptomatic individual is similarly infected but eventually will develop symptoms. The simple solution to this conundrum is longitudinal testing—that is, repeated observations of the individual over time. Unfortunately, only 5 of our cohorts include longitudinal data. We must therefore acknowledge the possibility that some of the proportions of asymptomatic persons are lower than reported.

Methods

From 19 April through 26 May 2020, using the keywords *COVID-19*, *SARS-CoV-2*, *symptoms*, and *asymptomatic*, we periodically searched the published medical literature using the PubMed service maintained by the U.S. National Library of Medicine of the National Institutes of Health. We also searched for unpublished manuscripts using the bioRxiv and medRxiv services operated by Cold Spring Harbor Laboratory. In addition, we searched for news reports using Google and monitored relevant information shared on Twitter.

Cohorts

Iceland

In the largest cohort in our set (6), researchers in Iceland used the following 2 methods to screen the general population for SARS-CoV-2 infection: an open invitation for interested parties to register online then provide biosamples at a Reykjavik location, and a text message sent to "randomly chosen Icelanders between the ages 20 and 70 years" inviting them to participate in the same manner as the first group (**Table**) (7–19). In all, 13 080 persons volunteered for the screening, 100 (0.8%) of whom tested positive for SARS-CoV-2. All who tested positive were aged 10 years or older. None of the 848 children younger than 10 years in the sample tested positive. Among those with positive results, 43 (43%) had no symptoms of COVID-19 at the time of testing. As the researchers note, though, "symptoms almost certainly developed later in some of them" (6).

Vo', Italy

At the beginning and end of a 14-day lockdown imposed by authorities in the northern Italian town of

Vo' (7), researchers collected nasopharyngeal swabs from 2812 residents during the first sampling effort and 2343 during the second; this represented 85.9% and 71.5%, respectively, of the entire population. In the first group, 30 (41.1%) of 73 persons who tested positive for SARS-CoV-2 had no symptoms. In the second, 13 (44.8%) of 29 who tested positive were asymptomatic. According to the researchers, in the roughly 2-week period between the sampling efforts, none of the asymptomatic persons developed any symptoms of COVID-19. In addition, through contact tracing, they confirmed that several new cases of SARS-CoV-2 infection that appeared during the second sampling had been caused by exposure to asymptomatic persons. In Vo' during the 14-day period studied, young children seemed to play no role in the transmission of SARS-CoV-2: "No infections were detected in either survey in 234 tested children ranging from 0 to 10 years, despite some of them living in the same household as infected people" (7).

Diamond Princess

On 3 February 2020, the *Diamond Princess* cruise ship returned to Yokohama, Japan, for quarantine (8), having transferred an ill passenger to shore in Hong Kong on 25 January who later tested positive for SARS-CoV-2. As of 16 March, 712 (19.2%) of 3711 passengers and crew had tested positive. At the time of testing, 331 (46.5%) of those with positive results were asymptomatic. Although the latter infected persons reported no symptoms, some actually had subclinical changes in their lungs. When computed tomography scans for 76 of these persons were examined, 54% showed lung opacities (20).

An independent statistical modeling analysis (21) based on data available as of 21 February claimed to estimate—with "a Bayesian framework using Hamiltonian Monte Carlo algorithm"—the proportion of asymptomatic persons on the *Diamond Princess*; it arrived at a figure of 17.9%. Considering, though, that data for asymptomatic persons were available only for 15 through 20 February and that the actual proportions of asymptomatic persons among those tested on these dates were 56.7%, 54.3%, 70.7%, 73.9%, 86.1%, and 46.2%, this estimate seems puzzling. In a separate news account (22), one of the coauthors of this analysis was reported to have estimated that "40% of the general population might be able to be infected [with SARS-CoV-2] without showing any signs."

Boston Homeless Shelter

After a cluster of 15 COVID-19 cases was identified over 5 days at a large homeless shelter in Boston, Massachusetts, the infected persons were removed from

Key Summary Points

The likelihood that approximately 40% to 45% of those infected with SARS-CoV-2 will remain asymptomatic suggests that the virus might have greater potential than previously estimated to spread silently and deeply through human populations.

Asymptomatic persons can transmit SARS-CoV-2 to others for an extended period, perhaps longer than 14 days.

The absence of COVID-19 symptoms in persons infected with SARS-CoV-2 might not necessarily imply an absence of harm. More research is needed to determine the significance of subclinical lung changes visible on computed tomography scans.

The focus of testing programs for SARS-CoV-2 should be substantially broadened to include persons who do not have symptoms of COVID-19.

Table. Summary of SARS-CoV-2 Testing Studies

Cohort	Tested, *n*	SARS-CoV-2 Positive, *n* (%)	Positive but Asymptomatic, *n* (%)	Notes*
Iceland residents (6)	13 080	100 (0.8)	43 (43.0)	R
Vo', Italy, residents (7)	5155	102 (2.0)	43 (42.2)	R, L
Diamond Princess cruise ship passengers and crew (8)	3711	712 (19.2)	331 (46.5)	–
Boston homeless shelter occupants (9)	408	147 (36.0)	129 (87.8)	–
New York City obstetric patients (11)	214	33 (15.4)	29 (87.9)	L
U.S.S. *Theodore Roosevelt* aircraft carrier crew (12)	4954	856 (17.3)	~500 (58.4)	E
Japanese citizens evacuated from Wuhan, China (2)	565	13 (2.3)	4 (30.8)	L
Greek citizens evacuated from the United Kingdom, Spain, and Turkey (14)†	783	40 (5.1)	35 (87.5)	L
Charles de Gaulle aircraft carrier crew (13)	1760	1046 (59.4)	~500 (47.8)	E
Los Angeles homeless shelter occupants (10)	178	43 (24.2)	27 (62.8)	–
King County, Washington, nursing facility residents (15)	76	48 (63.2)	3 (6.3)	L
Arkansas, North Carolina, Ohio, and Virginia inmates (16)	4693	3277 (69.8)	3146 (96.0)	–
New Jersey university and hospital employees (17)	829	41 (4.9)	27 (65.9)	–
Indiana residents (18)	4611	78 (1.7)	35 (44.8)	R
Argentine cruise ship passengers and crew (19)	217	128 (59.0)	104 (81.3)	–
San Francisco residents (29)	4160	74 (1.8)	39 (52.7)	–

E = estimated from incomplete source data; L = longitudinal data collected; R = representative sample; SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2.
* An en dash indicates that the study did not have a representative sample, collected no longitudinal data, and did not require estimation of missing data.
† Clarified via e-mail communication with coauthor.

the shelter, and all occupants were subsequently tested over a 2-day period (9). Among 408 occupants, 147 (36.0%) tested positive for SARS-CoV-2, of whom 129 (87.8%) were asymptomatic (23). The researchers concluded that "front-door symptom screening in homeless shelter settings will likely miss a substantial number of COVID-19 cases in this high-risk population" (9).

Los Angeles Homeless Shelter

On 28 March, an initial case of COVID-19 was diagnosed with a positive test result at a homeless shelter in downtown Los Angeles, California (10). After a cluster of symptomatic persons was identified early in the week of 20 April, the shelter was closed to new occupants and testing was started for current occupants. As of 22 April, 43 (24.2%) of 178 completed tests were positive for SARS-CoV-2 and 27 (63.8%) of the persons who tested positive were asymptomatic.

New York City Obstetric Patients

Between 22 March and 4 April 2020, women who delivered infants at 2 New York City hospitals were tested for SARS-CoV-2 (11). Among 214 patients, 33 (15.4%) tested positive, 29 (87.9%) of whom were asymptomatic. The researchers note that "fever developed in 3 (10%) before postpartum discharge (median length of stay, 2 days)" (11). Two of those patients, though, were presumed to have endomyometritis, for which they were treated with antibiotics.

U.S.S. *Theodore Roosevelt*

The first case of SARS-CoV-2 infection aboard the American aircraft carrier U.S.S. *Theodore Roosevelt* was diagnosed on 22 March 2020 (24). As of 24 April, 4954 crew members had been tested for the virus; 856 (17.3%) tested positive (12). According to a news report, about 60% of those with positive results were asymptomatic (25). After an extended period of isolation, many of these asymptomatic persons continued to test positive for SARS-CoV-2. An internal U.S. Navy document stated, "Results of out-testing portions of the [*Theodore Roosevelt*] crew following 14 days of quarantine leads us to reevaluate our assessment of how the virus can remain active in an asymptomatic host" (26).

Charles de Gaulle Aircraft Carrier

On 8 April 2020, crew members aboard the French naval vessel *Charles de Gaulle* first began showing symptoms of COVID-19, 24 days after last having had contact with those outside the ship while docked on 15 March (27). On 10 April, 50 crew members received positive test results for SARS-CoV-2. The entire crew of 1760 was subsequently tested. As of 18 April, 1046 (59.4%) had tested positive, and of these, nearly 50% were asymptomatic (13).

Japanese Citizens Evacuated From Wuhan, China

As of 6 February 2020, a total of 565 Japanese citizens had been repatriated from Wuhan, China, on charter flights. Thirteen (2.3%) tested positive for SARS-CoV-2, of whom 4 (30.8%) were asymptomatic. As of 6 March, none of the latter persons had developed COVID-19 symptoms (2).

Greek Citizens Evacuated From Spain, Turkey, and the United Kingdom

From 20 through 25 March 2020, a total of 783 Greek citizens were repatriated from Spain, Turkey, and the United Kingdom on 7 flights. Forty (5.1%) tested positive for SARS-CoV-2 (14). At the time of testing, 39 (97.5%) were asymptomatic. At follow-up about 2 weeks later, 35 (87.5%) had remained asymptomatic (Lytras T. Personal communication.).

Nursing Facility Residents in King County, Washington

On 1 March 2020, a staff member who had worked at a 116-bed skilled-nursing facility in King County, Washington, on 26 and 28 February tested positive for SARS-CoV-2 (15). On 13 March, 76 (92.6%) of the facility's 82 current residents were tested; 23 (30.3%) tested positive. At the time of testing, 12 (52.2%) of the latter persons were asymptomatic. On 19 and 20 March, 49 residents were retested, including those who had previously received negative results and those who had tested positive but were asymptomatic or had atypical symptoms. In this second round of testing, 24 residents (49.0%) had positive results. Of these, 15 (63.5%) were asymptomatic. After a median of 4 days of follow-up, 24 (88.9%) of the 27 asymptomatic persons developed symptoms of COVID-19.

The researchers note, "More than half of residents with positive test results were asymptomatic at the time of testing and most likely contributed to transmission. Infection-control strategies focused solely on symptomatic residents were not sufficient to prevent transmission after SARS-CoV-2 introduction into this facility" (15).

Inmates in Arkansas, North Carolina, Ohio, and Virginia

Widespread outbreaks of COVID-19 in the correctional facilities of several states have led to large-scale screening programs. According to research by Reuters journalists (16), as of 25 April 2020, SARS-CoV-2 test results that include data on symptom status were available for 4693 inmates in the state prison systems of Arkansas, North Carolina, Ohio, and Virginia. Among these inmates, 3277 (69.8%) tested positive, of whom 3146 (96%) had no symptoms at the time of testing.

Rutgers University Students and Employees

From 24 March through 7 April 2020, researchers recruited 829 students and employees at Rutgers University and 2 affiliated hospitals for SARS-CoV-2 testing (17); 546 were health care workers. In total, 41 (4.9%) tested positive. Among health care workers, 40 (7.3%) tested positive, compared with 1 (0.4%) of those in other fields. Of all who tested positive, 27 (65.9%) reported no symptoms when they were tested.

Indiana Residents

From 25 April through 1 May 2020, the Indiana State Department of Health and the Indiana University Richard M. Fairbanks School of Public Health tested 4611 residents of Indiana for SARS-CoV-2 (18, 28). "This number includes more than 3,600 people who were randomly selected and an additional 900 volunteers recruited through outreach to the African American and Hispanic communities to more accurately represent state demographics" (28). In total, 78 (1.7%) tested positive; 35 (44.8%) of these persons were asymptomatic.

Argentine Cruise Ship Passengers and Crew

In mid-March 2020, a cruise ship departed Ushuaia, Argentina, for a planned 21-day expedition (19). After the emergence of a febrile passenger on the eighth day of the cruise, the ship's itinerary was altered, and it eventually docked at Montevideo, Uruguay, on the 13th day. All 217 passengers and crew members were tested; 128 (59.0%) tested positive, of whom 104 (81.3%) were asymptomatic.

San Francisco Residents

During 4 days in late April 2020, "4,160 adults and children, including more than half of the residents in the 16 square blocks that make up San Francisco Census Tract 229.01" in the Mission District, were tested (29). Seventy-four (1.8%) tested positive, of whom 39 (52.7%) were asymptomatic.

Discussion

Despite concerns about distinguishing asymptomatic from presymptomatic persons, data from 4 of 5 of the cohorts with longitudinal reporting suggest that a small fraction of asymptomatic persons may eventually develop symptoms. In the Italian and Japanese cohorts, 0% of asymptomatic persons became symptomatic. In the Greek and New York cohorts, 10.3% of asymptomatic persons became symptomatic. In the New York cohort, the figure might be as low as 3.4% because of the presumed diagnosis of endomyometritis in 2 of the 3 women who developed fevers. The observation period in this cohort, however, was extremely brief: a median of 2 days.

The King County cohort–in a skilled-nursing facility–is an outlier. Of 27 initially asymptomatic residents, 24 (88.9%) eventually developed symptoms and were therefore recategorized as having been presymptomatic. These persons were presumably much older and had more comorbid conditions than those in the other 4 longitudinal cohorts. In addition, they resided together in a single facility, which might have allowed for repeated exposures to infected persons. More research is needed to ascertain the effect of age and environmental factors on the natural history of COVID-19.

The Vo' cohort seems to confirm that asymptomatic persons can indeed transmit SARS-CoV-2 to others, and the experience aboard the U.S.S. *Theodore Roosevelt* suggests that they might be able to transmit the virus to others for longer than 14 days. These worrisome findings could explain, in part, the rapid spread of the virus around the globe. Persons who do not feel or look ill are likely to have far more interaction with others than those who have symptoms. If asymptomatic transmission is indeed common, testing only those with symptoms would seem to be folly.

The finding that 54% of the 76 asymptomatic persons on the *Diamond Princess* who were examined by computed tomography appeared to have significant subclinical abnormalities in their lungs is disturbing. Further research will be required to confirm this potentially important finding, taking into account possible confounding factors, including the age of passengers aboard the *Diamond Princess*. If confirmed, this finding suggests that the absence of symptoms might not necessarily mean the absence of harm. The subclinical nature of the finding raises the possibility that SARS-CoV-2 infection causes subtle deficits in lung function that might not be immediately apparent.

Does the relatively high proportion (60.5%) of asymptomatic cases on the U.S.S. *Theodore Roosevelt*–whose crew members, presumably, are mostly in their 20s and 30s–suggest that asymptomatic infection is more likely in younger persons? Perhaps, but it must be noted that the proportion of asymptomatic infection (47.8%) on the *Charles de Gaulle* aircraft carrier seems to be only marginally higher than average. A case series from Wuhan, China, from 24 December 2019 to 24 February 2020 included data for "78 patients from 26 cluster cases of exposure to the Hunan seafood market or close contact with other patients with COVID-19" (30). Asymptomatic patients "were younger (median [interquartile range] age, 37 [26-45] years vs 56 [34-63] years; $P < .001$), and had a higher proportion of women (22 [66.7%] women vs 14 [31.%] [sic] women; $P = .002$)."

As noted earlier, the data and studies reviewed here are imperfect in many ways. The ideal study of asymptomatic SARS-CoV-2 infection has yet to be done. What might that study look like? Most important, it must include a large, representative sample of the general population, similar to the U.S. serosurvey for which the National Institutes of Health is currently recruiting (31). In contrast to the narrowly defined cohorts here, it will be illuminating to have data that accurately reflect the population at large. In addition, longitudinal data must be collected over a sufficiently long time to distinguish between asymptomatic and presymptomatic cases.

Closed cohorts, such as cruise ships, aircraft carriers, and correctional facilities, offer both advantages and disadvantages. Because the likelihood of viral exposure is so much greater than in other settings, the "treatment" that participants receive may be close to uniform. As a result, we may learn more about the average incidence of asymptomatic infection. But the confined environment–which ensures frequent, overlapping interaction between participants–makes it challenging to accurately trace contacts and elucidate the chain of viral transmission.

On the basis of the 3 cohorts with representative samples–Iceland and Indiana, with data gathered

through random selection of participants, and Vo', with data for nearly all residents–the asymptomatic infection rate may be as high as 40% to 45%. A conservative estimate would be 30% or higher to account for the presymptomatic admixture that has thus far not been adequately quantified. In any case, these high rates are not aligned with current testing programs that have predominantly focused on symptomatic cases. Beyond expanding testing to those without symptoms or known exposure, our inability to recognize carriers might make necessary the broad adoption of preventive strategies, such as masks.

The 96% rate of asymptomatic infection among thousands of inmates in 4 state prison systems is remarkable. Without any longitudinal data, we cannot estimate the number of presymptomatic cases. If the missing data prove to be similar to the Italian, Japanese, Greek, and New York cohorts, though, the vast majority of these persons will remain asymptomatic. Why, then, might the asymptomatic infection rate in this setting be so anomalously high?

One plausible factor could be cross-immunity imparted by the betacoronaviruses HCoV-OC43 and HCoV-HKU1, which has been proposed as a mitigating factor in the spread of SARS-CoV-2 (32). According to the U.S. Centers for Disease Control and Prevention, HCoV-HKU1 was active across the United States from late November 2019 through mid-February 2020 (33). In a locked-down congregate setting like a prison, it seems possible that contagious respiratory viruses could spread rapidly, so it would be interesting to do a serosurvey for antibodies to these betacoronaviruses. Still, 96% is very high. It would be prudent to review the source data carefully for errors.

What individual differences might account for why 2 persons of the same age, sex, and health status, for example, have idiosyncratic responses to SARS-CoV-2 infection? Why does one come through with nary a symptom, while the other lies near death in intensive care? At the moment, we simply do not know. If ever there were a need for precision medicine–for deeply and thoroughly understanding the multitudinous "-omics" that shape each of us–this is it. Perhaps there will be not just 1 therapy or vaccine for SARS-CoV-2 but versions that are individualized to maximize their efficacy.

In countries like the United States that have been hardest hit by the SARS-CoV-2 pandemic, it has been apparent for some time that the amount of testing must be significantly and rapidly increased–perhaps by an order of magnitude or more. With this new knowledge that a large proportion of those infected with SARS-CoV-2 have no symptoms, the urgency for more testing becomes even greater.

In a perfect world, perhaps using simple, accurate, inexpensive technology that is still on the drawing board (34), we would test each person every day for SARS-CoV-2. Until that is possible, innovative surveillance tactics might provide useful data for public health officials. Self-monitoring with internet-connected thermometers and smart watches that monitor heart rate, then crowdsourcing the resulting data, has been shown to accurately predict the incidence of influenza-like illness as reported by the California Department of Public Health and the Centers for Disease Control and Prevention (35-37). Similarly, monitoring sewage sludge provided "SARS-CoV-2 RNA concentrations [that] were a seven-day leading indicator ahead of compiled COVID-19 testing data and led local hospital admissions data by three days" (38).

The early data that we have assembled on the prevalence of asymptomatic SARS-CoV-2 infection suggest that this is a significant factor in the rapid progression of the COVID-19 pandemic. Medical practice and public health measures should be modified to address this challenge.

From Scripps Research Translational Institute, Scripps Research, La Jolla, California (D.P.O., E.J.T.).

Disclosures: Authors have disclosed no conflicts of interest. Forms can be viewed at www.acponline.org/authors/icmje/ConflictOfInterestForms.do?msNum=M20-3012.

Corresponding Author: Eric J. Topol, MD, Scripps Research Translational Institute, 3344 North Torrey Pines Court, 3rd Floor, La Jolla, CA 92037; e-mail, etopol@scripps.edu.

Correction: This article was corrected on 17 June 2020 to update the publication and access dates for reference 12.

Current author addresses and author contributions are available at Annals.org.

References

1. COVID-19 Case Tracker. Johns Hopkins Coronavirus Resource Center. 2020. Accessed at https://coronavirus.jhu.edu on 26 May 2020.

2. Nishiura H, Kobayashi T, Miyama T, et al. Estimation of the asymptomatic ratio of novel coronavirus infections (COVID-19) [Letter]. Int J Infect Dis. 2020;94:154-155. [PMID: 32179137] doi:10.1016/j.ijid.2020.03.020

3. Bai Y, Yao L, Wei T, et al. Presumed asymptomatic carrier transmission of COVID-19. JAMA. 2020. [PMID: 32083643] doi:10.1001/jama.2020.2565

4. Zou L, Ruan F, Huang M, et al. SARS-CoV-2 viral load in upper respiratory specimens of infected patients [Letter]. N Engl J Med. 2020;382:1177-1179. [PMID: 32074444] doi:10.1056/NEJMc2001737

5. Kimball A, Hatfield KM, Arons M, et al; Public Health - Seattle & King County. Asymptomatic and presymptomatic SARS-CoV-2 infections in residents of a long-term care skilled nursing facility – King County, Washington, March 2020. MMWR Morb Mortal Wkly Rep. 2020;69:377-381. [PMID: 32240128] doi:10.15585/mmwr.mm6913e1

6. Gudbjartsson DF, Helgason A, Jonsson H, et al. Spread of SARS-CoV-2 in the Icelandic population. N Engl J Med. 2020. [PMID: 32289214] doi:10.1056/NEJMoa2006100

7. Lavezzo E, Franchin E, Ciavarella C, et al. Suppression of COVID-19 outbreak in the municipality of Vo, Italy. medRxiv. Preprint posted online 18 April 2020. doi:10.1101/2020.04.17.20053157

8. Moriarty LF, Plucinski MM, Marston BJ, et al; CDC Cruise Ship Response Team. Public health responses to COVID-19 outbreaks on cruise ships – worldwide, February-March 2020. MMWR Morb Mortal Wkly Rep. 2020;69:347-352. [PMID: 32214086] doi:10.15585/mmwr.mm6912e3

9. Baggett TP, Keyes H, Sporn N, et al. COVID-19 outbreak at a large homeless shelter in Boston: implications for universal testing. medRxiv.

Preprint posted online 15 April 2020. doi:10.1101/2020.04.12.20059618

10. Chou E. Dozens positive for coronavirus at LA's Skid Row homeless shelter, after all residents tested. Los Angeles Daily News. 21 April 2020. Updated 22 April 2020. Accessed at www.dailynews.com/2020/04/21/dozens-positive-for-coronavirus-at-las-skid-row-homeless-shelter-after-all-residents-tested on 23 April 2020.

11. Sutton D, Fuchs K, D'Alton M, et al. Universal screening for SARS-CoV-2 in women admitted for delivery [Letter]. N Engl J Med. 2020; 382:2163-2164. [PMID: 32283004] doi:10.1056/NEJMc2009316

12. U.S. Navy COVID-19 updates. Daily Update: April 24, 2020. Navy Live. 24 April 2020. Accessed at https://navylive.dodlive.mil/2020/03/15/u-s-navy-covid-19-updates on 24 April 2020.

13. Coronavirus: bilan définitif de 1046 cas sur le Charles de Gaulle. Le Figaro. 18 April 2020. Accessed at www.lefigaro.fr/international/coronavirus-bilan-definitif-de-1046-cas-sur-le-charles-de-gaulle-20200418 on 21 April 2020.

14. Lytras T, Dellis G, Flountzi A, et al. High prevalence of SARS-CoV-2 infection in repatriation flights to Greece from three European countries. J Travel Med. 2020;27. [PMID: 32297940] doi:10.1093/jtm/taaa054

15. Arons MM, Hatfield KM, Reddy SC, et al; Public Health-Seattle and King County and CDC COVID-19 Investigation Team. Presymptomatic SARS-CoV-2 infections and transmission in a skilled nursing facility. N Engl J Med. 2020;382:2081-2090. [PMID: 32329971] doi:10.1056/NEJMoa2008457

16. So L, Smith G. In four U.S. state prisons, nearly 3,300 inmates test positive for coronavirus – 96% without symptoms. Reuters. 25 April 2020. Accessed at www.reuters.com/article/us-health-coronavirus-prisons-testing-in-idUSKCN2270RX on 26 April 2020.

17. Barrett ES, Horton DB, Roy J, et al. Prevalence of SARS-CoV-2 infection in previously undiagnosed health care workers at the onset of the U.S. COVID-19 epidemic. medRxiv. Preprint posted online 24 April 2020. doi:10.1101/2020.04.20.20072470

18. Ratliff V. About 45% of COVID-19-positive Hoosiers don't know it. News and Tribune. 14 May 2020. Accessed at www.newsandtribune.com/about-45-of-covid-19-positive-hoosiers-don-t-know-it/article_1f424a76-9570-11ea-ae01-037620a46735.html on 14 May 2020.

19. Ing AJ, Cocks C, Green JP. COVID-19: in the footsteps of Ernest Shackleton. Thorax. 2020. [PMID: 32461231] doi:10.1136/thoraxjnl-2020-215091

20. Inui S, Fujikawa A, Jitsu M, et al. Chest CT findings in cases from the cruise ship "Diamond Princess" with coronavirus disease 2019 (COVID-19). Radiol Cardiothorac Imaging. 2020;2. doi:10.1148/ryct.2020200110

21. Mizumoto K, Kagaya K, Zarebski A, et al. Estimating the asymptomatic proportion of coronavirus disease 2019 (COVID-19) cases on board the Diamond Princess cruise ship, Yokohama, Japan, 2020. Euro Surveill. 2020;25. doi:10.2807/1560-7917.ES.2020.25.10.2000180

22. USS Roosevelt's asymptomatic cases helping scientists understand virus. NBC 7 San Diego. 20 April 2020. Accessed at www.nbcsandiego.com/videos/uss-roosevelts-asymptomatic-cases-could-help-scientists-understand-virus/2309131 on 21 April 2020.

23. Baggett TP, Keyes H, Sporn N, et al. Prevalence of SARS-CoV-2 infection in residents of a large homeless shelter in Boston. JAMA. 2020. [PMID: 32338732] doi:10.1001/jama.2020.6887

24. Peniston B. The battle of USS Theodore Roosevelt: a timeline. Defense One. 7 April 2020. Updated 13 April 2020. Accessed at www.defenseone.com/threats/2020/04/timeline-battle-uss-theodore-roosevelt/164408 on 20 April 2020.

25. Stewart P, Ali I. U.S. to start antibody testing of sailors on coronavirus-hit aircraft carrier. Reuters. 17 April 2020. Accessed at www.nytimes.com/reuters/2020/04/17/us/17reuters-health-coronavirus-usa-military.html on 20 April 2020.

26. Seligman L. Sailors keep testing positive on aircraft carrier, despite 2-week isolation. Politico. 21 April 2020. Accessed at www.politico.com/news/2020/04/21/navy-extends-isolation-for-uss-theodore-roosevelt-sailors-may-delay-ship-departure-198081 on 22 April 2020.

27. Coronavirus: 50 cas de contamination à bord du "Charles-de-Gaulle", trois marins évacués. Le Parisien. 10 April 2020. Accessed at www.leparisien.fr/politique/coronavirus-50-cas-de-contamination-a-bord-du-charles-de-gaulle-trois-marins-evacues-10-04-2020-8297511.php on 21 April 2020.

28. IU, ISDH release preliminary findings about impact of COVID-19 in Indiana. Indiana University. 13 May 2020. Accessed at https://news.iu.edu/stories/2020/05/iupui/releases/13-preliminary-findings-impact-covid-19-indiana-coronavirus.html on 13 May 2020.

29. McFarling UL. When hard data are 'heartbreaking': testing blitz in San Francisco shows Covid-19 struck mostly low-wage workers. STAT. 28 May 2020. Accessed at www.statnews.com/2020/05/28/sobering-finding-covid19-struck-mostly-low-wage-essential-workers-san-francisco on 30 May 2020.

30. Yang R, Gui X, Xiong Y. Comparison of clinical characteristics of patients with asymptomatic vs symptomatic coronavirus disease 2019 in Wuhan, China. JAMA Netw Open. 2020;3:e2010182. [PMID: 32459353] doi:10.1001/jamanetworkopen.2020.10182

31. National Institutes of Health. NIH begins study to quantify undetected cases of coronavirus infection. 10 April 2020. Accessed at www.nih.gov/news-events/news-releases/nih-begins-study-quantify-undetected-cases-coronavirus-infection on 22 April 2020.

32. Kissler SM, Tedijanto C, Goldstein E, et al. Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period. Science. 2020;368:860-868. [PMID: 32291278] doi:10.1126/science.abb5793

33. Centers for Disease Control and Prevention. National trends for common human coronaviruses. The National Respiratory and Enteric Virus Surveillance System. 2020. Accessed at www.cdc.gov/surveillance/nrevss/coronavirus/natl-trends.html on 27 April 2020.

34. Zhang F, Abudayyeh OO, Gootenberg JS. A protocol for detection of COVID-19 using CRISPR diagnostics. 21 March 2020. Accessed at www.broadinstitute.org/files/publications/special/COVID-19 detection (updated).pdf on 7 May 2020.

35. Miller AC, Singh I, Koehler E, et al. A smartphone-driven thermometer application for real-time population- and individual-level influenza surveillance. Clin Infect Dis. 2018;67:388-397. [PMID: 29432526] doi:10.1093/cid/ciy073

36. Ackley SF, Pilewski S, Petrovic VS, et al. Assessing the utility of a smart thermometer and mobile application as a surveillance tool for influenza and influenza-like illness. Health Informatics J. 2020:1460458219897152. [PMID: 31969046] doi:10.1177/1460458219897152

37. Radin JM, Wineinger NE, Topol EJ, et al. Harnessing wearable device data to improve state-level real-time surveillance of influenza-like illness in the USA: a population-based study. Lancet Digit Health. 2020;2:e85-93. doi:10.1016/S2589-7500(19)30222-5

38. Peccia J, Zulli A, Brackney DE, et al. SARS-CoV-2 RNA concentrations in primary municipal sewage sludge as a leading indicator of COVID-19 outbreak dynamics. medRxiv. Preprint posted online 22 May 2020. doi:10.1101/2020.05.19.20105999

Current Author Addresses: Mr. Oran and Dr. Topol: Scripps Research Translational Institute, 3344 North Torrey Pines Court, 3rd Floor, La Jolla, CA 92037.

Author Contributions: Conception and design: D.P. Oran, E.J. Topol.
Analysis and interpretation of the data: D.P. Oran, E.J. Topol.
Drafting of the article: D.P. Oran, E.J. Topol.
Critical revision of the article for important intellectual content: E.J. Topol.
Final approval of the article: D.P. Oran, E.J. Topol.
Statistical expertise: E.J. Topol.
Administrative, technical, or logistic support: E.J. Topol.
Collection and assembly of data: D.P. Oran, E.J. Topol.

JAMA Network Open

THIS IS EXHIBIT " ✓ " referred to in the Affidavit / Declaration of Dr. Deena Hinshaw affirmed / Sworn / Declared before me this 12th day July A.D., 2021
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public.
Heather L. Veale, Barrister & Solicitor

Original Investigation | Infectious Diseases

SARS-CoV-2 Transmission From People Without COVID-19 Symptoms

Michael A. Johansson, PhD; Talia M. Quandelacy, PhD, MPH; Sarah Kada, PhD; Pragati Venkata Prasad, MPH; Molly Steele, PhD, MPH; John T. Brooks, MD; Rachel B. Slayton, PhD, MPH; Matthew Biggerstaff, ScD, MPH; Jay C. Butler, MD

Abstract

IMPORTANCE Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the etiology of coronavirus disease 2019 (COVID-19), is readily transmitted person to person. Optimal control of COVID-19 depends on directing resources and health messaging to mitigation efforts that are most likely to prevent transmission, but the relative importance of such measures has been disputed.

OBJECTIVE To assess the proportion of SARS-CoV-2 transmissions in the community that likely occur from persons without symptoms.

DESIGN, SETTING, AND PARTICIPANTS This decision analytical model assessed the relative amount of transmission from presymptomatic, never symptomatic, and symptomatic individuals across a range of scenarios in which the proportion of transmission from people who never develop symptoms (ie, remain asymptomatic) and the infectious period were varied according to published best estimates. For all estimates, data from a meta-analysis was used to set the incubation period at a median of 5 days. The infectious period duration was maintained at 10 days, and peak infectiousness was varied between 3 and 7 days (−2 and +2 days relative to the median incubation period). The overall proportion of SARS-CoV-2 was varied between 0% and 70% to assess a wide range of possible proportions.

MAIN OUTCOMES AND MEASURES Level of transmission of SARS-CoV-2 from presymptomatic, never symptomatic, and symptomatic individuals.

RESULTS The baseline assumptions for the model were that peak infectiousness occurred at the median of symptom onset and that 30% of individuals with infection never develop symptoms and are 75% as infectious as those who do develop symptoms. Combined, these baseline assumptions imply that persons with infection who never develop symptoms may account for approximately 24% of all transmission. In this base case, 59% of all transmission came from asymptomatic transmission, comprising 35% from presymptomatic individuals and 24% from individuals who never develop symptoms. Under a broad range of values for each of these assumptions, at least 50% of new SARS-CoV-2 infections was estimated to have originated from exposure to individuals with infection but without symptoms.

CONCLUSIONS AND RELEVANCE In this decision analytical model of multiple scenarios of proportions of asymptomatic individuals with COVID-19 and infectious periods, transmission from asymptomatic individuals was estimated to account for more than half of all transmissions. In addition to identification and isolation of persons with symptomatic COVID-19, effective control of spread will require reducing the risk of transmission from people with infection who do not have symptoms. These findings suggest that measures such as wearing masks, hand hygiene, social distancing, and strategic testing of people who are not ill will be foundational to slowing the spread

Key Points

Question What proportion of coronavirus disease 2019 (COVID-19) spread is associated with transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) from persons with no symptoms?

Findings In this decision analytical model assessing multiple scenarios for the infectious period and the proportion of transmission from individuals who never have COVID-19 symptoms, transmission from asymptomatic individuals was estimated to account for more than half of all transmission.

Meaning The findings of this study suggest that the identification and isolation of persons with symptomatic COVID-19 alone will not control the ongoing spread of SARS-CoV-2.

+ Multimedia

+ Supplemental content

Author affiliations and article information are listed at the end of this article

Abstract (continued)

of COVID-19 until safe and effective vaccines are available and widely used.

JAMA Network Open. 2021;4(1):e2035057.
Corrected on February 12, 2021. doi:10.1001/jamanetworkopen.2020.35057

Introduction

As severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the novel coronavirus that causes coronavirus disease 2019 (COVID-19), began to spread globally, it became apparent that the virus, unlike the closely related SARS-CoV in the 2003 outbreak, could not be contained by symptom-based screening alone. Asymptomatic and clinically mild infections were uncommon during the 2003 SARS-CoV outbreak, and there were no reported instances of transmission from persons before the onset of symptoms.[1] SARS-CoV-2 spread faster than SARS-CoV, and accumulating evidence showed that SARS-CoV-2, unlike SARS-CoV, is transmitted from persons without symptoms. However, measures to reduce transmission from individuals who do not have COVID-19 symptoms have become controversial and politicized and have likely had negative effects on the economy and many societal activities. Optimal control of COVID-19 depends on directing resources and health messaging to mitigation efforts that are most likely to prevent transmission. The relative importance of mitigation measures that prevent transmission from persons without symptoms has been disputed. Determining the proportion of SARS-CoV-2 transmission that occurs from persons without symptoms is foundational to prioritizing control practices and policies.

Transmission by persons who are infected but do not have any symptoms can arise from 2 different infection states: presymptomatic individuals (who are infectious before developing symptoms) and individuals who never experience symptoms (asymptomatic infections, which we will refer to as never symptomatic). Early modeling studies of COVID-19 case data found that the generation interval of SARS-CoV-2 was shorter than the serial interval, indicating that the average time between 1 person being infected and that person infecting someone else was shorter than the average time between 1 person developing symptoms and the person they infected developing symptoms.[2-5] This finding meant that the epidemic was growing faster than would be expected if transmission were limited to the period of illness during which individuals were symptomatic. By the time a second generation of individuals was developing symptoms, a third generation was already being infected. Epidemiological data from early in the pandemic also suggested the possibility of presymptomatic transmission,[6,7] and laboratory studies confirmed that levels of viral RNA in respiratory secretions were already high at the time of symptom onset.[8-10]

Asymptomatic SARS-CoV-2 transmission also occurs because of individuals with infection who are never symptomatic (or who experience very mild or almost unrecognizable symptoms). The proportion of individuals with infection who never have apparent symptoms is difficult to quantify because it requires intensive prospective clinical sampling and symptom screening from a representative sample of individuals with and without infection. Nonetheless, evidence from household contact studies indicates that asymptomatic or very mild symptomatic infections occur,[11-14] and laboratory and epidemiological evidence suggests that individuals who never develop symptoms may be as likely as individuals with symptoms to transmit SARS-CoV-2 to others.[9,15,16]

Methods

The Centers for Disease Control and Prevention determined that this decision analytical study, which involved no enrollment of human subjects, did not require institutional review board approval. We used a simple model to assess the proportion of transmission from presymptomatic (ie, infectious before symptom onset), never symptomatic, and symptomatic individuals across a range of

scenarios in which we varied the timing of the infectious period to assess different contributions of presymptomatic transmission and the proportion of transmission from individuals who never develop symptoms (ie, remain asymptomatic).

For all estimates we used data from a meta-analysis of 8 studies from China to set the incubation period at a median of 5 days with 95% of symptomatic individuals developing symptoms by day 12.[17] Therefore the daily (t) probability of symptom onset (p_{so}) for individuals who develop symptoms was:

$$p_{so}(t) = F_{Log\text{-}Normal}(t,\text{logmean} = 1.63,\text{logsd} = 0.5).$$

To approximate a distribution of the infectious period, we made a baseline assumption that peak infectiousness occurs on average at the same time as the median incubation period, such that infectiousness begins prior to symptom onset (**Table**).[9,12,14-16,18,20] We then assumed that infectiousness (I) over time can be approximated by a γ density function and that the average person is infectious for as long as approximately 10 days (ie, 98% of transmission happens within a 10-day period)[11]:

$$I(t) = f_{\gamma}(t,\text{mode} = 5,\text{interval} = 10).$$

For all estimates, we maintained the infectious period duration as 10 days, but varied the mode between 3 and 7 days (−2 and +2 days relative to the median incubation period).

Uncertainty also remains about the proportion of individuals with infection who are never symptomatic (p_{ns}) and the relative contribution of these infections to transmission (r_{ns}). Estimates of p_{ns} range from single digits to more than 50%, many with potential biases related to the study population (eg, age, prevalence of comorbidities) and the extent of long-term follow-up[12,14,19,20] (Table). We made a baseline assumption that 30% of individuals with infection are never symptomatic and then assessed higher or lower assumptions. We also made a baseline assumption that individuals with asymptomatic infections are on average 75% as infectious as those with symptomatic infections.[9,15,16] Combined, these baseline assumptions imply that persons with infection who never develop symptoms may account for approximately 24% of all transmission (T):

$$T_{ns} = p_{ns} \times r_{ns} / (p_{ns} \times r_{ns} + [1 - p_{ns}]).$$

Table. Key Assumptions and Evidence Informing Those Assumptions

Source	Evidence base	Estimate or assumption
Assumptions for presymptomatic transmission		
Peak infectiousness relative to onset, d		
Casey et al, 2020[18]	Range, 17 studies	−3 to 1.2 d
Assumed baseline	NA	0 d
Assumed range	NA	−2 to 2 d
Assumptions for never symptomatic transmission		
Proportion never symptomatic		
Oran et al, 2020[12]	Inferred range, 16 studies	30% to 45%
Buitrago-Garcia et al, 2020[14]	Meta-estimate, 7 studies	26% to 37%
Davies et al, 2020[20]	Age-dependent estimate, 6 studies	20% to 70%
Assumed baseline	NA	30%
Relative infectiousness of individuals who never have symptoms		
Lee et al, 2020[9]	303 patients, assessment of viral shedding	Approximately 100%
Chaw et al, 2020[15]	1701 secondary contacts	40% to 140%
Mc Evoy et al, 2020[16]	Inferred range, 6 studies	40% to 70%
Assumed baseline		75%
Overall proportion of individuals who never have symptoms transmission		
Assumed range	NA	0% to 70%

Abbreviation: NA, not applicable.

We varied this overall proportion, T_{ns}, between 0% and 70% to assess a wide range of possible proportions. The daily proportion of transmission from individuals after symptom onset (T_s) was therefore:

$$T_s(t) = (1 - T_{ns}) \times p_{so}(t) \times I(t),$$

and the daily proportion of transmission from presymptomatic (T_{ps}) individuals, ie, those who develop symptoms but become infectious prior to symptom onset, is:

$$T_{ps}(t) = 1 - T_s(t) - T_{ns}.$$

We modified baseline assumptions to consider the relative importance of different levels of never symptomatic and presymptomatic transmission. Code is available in the eAppendix in the Supplement.

Statistical Analysis

All analyses were conducted in R version 4.0.1 (R Project for Statistical Computing). No statistical testing was conducted, so no prespecified level of significance was set.

Results

Under baseline assumptions, approximately 59% of all transmission came from asymptomatic transmission: 35% from presymptomatic individuals and 24% from individuals who are never symptomatic (**Figure 1**). Because each component is uncertain, we assessed different timings of peak infectiousness relative to illness onset and different proportions of transmission from individuals who never have symptoms. Maintaining the 24% of transmission from individuals who never have symptoms, but shifting peak infectiousness 1 day earlier (to day 4) increased presymptomatic transmission to 43% and all asymptomatic transmission to 67% (Figure 1A). A later peak (ie, day 6) decreased presymptomatic to 27% and all asymptomatic transmission to 51% (Figure 1C).

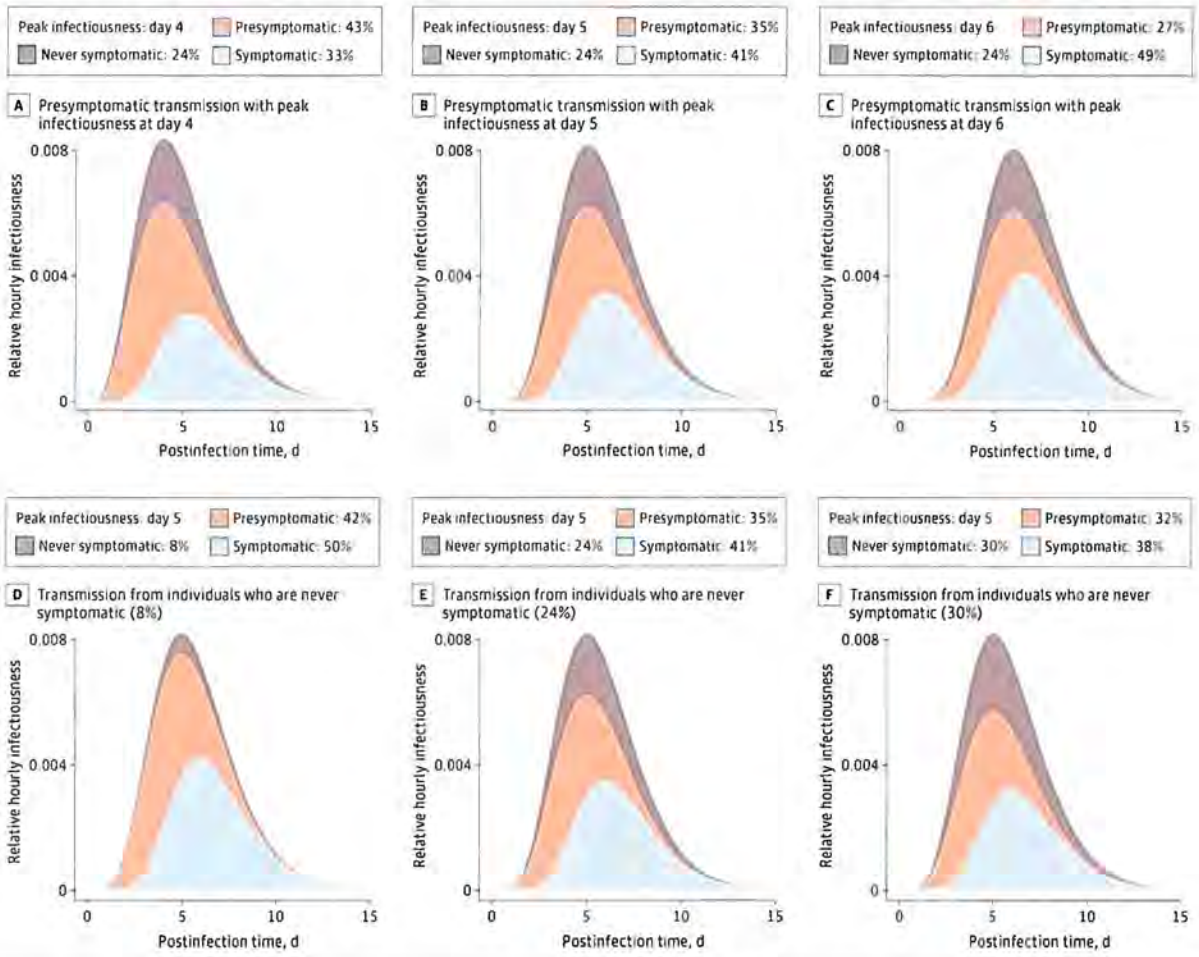
Holding the day of peak infectiousness constant at day 5 and decreasing the proportion of transmission from individuals who are never symptomatic to 10% with a relative infectiousness of 75% (baseline assumption), the proportion of all transmission from those who are never symptomatic decreased to 8%, presymptomatic transmission increased to 42%, and combined asymptomatic transmission was 50% of all transmission (Figure 1D). In contrast, if the proportion of those who ever develop symptoms was 30% and their relative infectiousness increased to 100%, they contributed 30% of all transmission, presymptomatic transmission was 32%, and combined asymptomatic transmission was 62% of all transmission (Figure 1F).

Uncertainty remains regarding the magnitude of both presymptomatic and never symptomatic transmission. Therefore, we analyzed a wider range of each of these components, with peak infectiousness varying between 2 days before (more presymptomatic transmission) to 2 days after (less presymptomatic transmission) median symptom onset and with never symptomatic transmission ranging from 0% to 70% (**Figure 2**). Under this broader range of scenarios, most combined assumptions of peak infectiousness timing and transmission from individuals who never have symptoms indicated that at least 50% of new SARS-CoV-2 infections likely originated from individuals without symptoms at the time of transmission. If more than 30% of transmission was from individuals who never have symptoms, total asymptomatic transmission was higher than 50% with any value of peak infectiousness, up to 2 days after the median time of symptom onset. If peak infectiousness was at any point approximately 6 hours before median symptom onset time, more than 50% of transmission was from individuals without symptoms, regardless of the proportion from those who never have symptoms. Even a very conservative assumption of peak infectiousness 2 days post-median onset and 0% never symptomatic transmission still resulted in more than 25% of transmission from asymptomatic individuals.

Discussion

The findings presented here complement an earlier assessment[21] and reinforce the importance of asymptomatic transmission: across a range of plausible scenarios, at least 50% of transmission was estimated to have occurred from persons without symptoms. This overall proportion of transmission from presymptomatic and never symptomatic individuals is key to identifying mitigation measures that may be able to control SARS-CoV-2. For example, if the reproduction number (*R*) in a given setting is 2.0, then at least a 50% reduction in transmission is needed to drive the reproductive number below 1.0. Given that in some settings *R* is likely much greater than 2 and more than half of transmissions may come from individuals who are asymptomatic at the time of transmission, effective control must mitigate transmission risk from people without symptoms.

Figure 1. The Contribution of Asymptomatic Transmission Under Different Infection Profiles



The top curve in each panel represents the average relative hourly infectiousness, such that while the lower curves change under different assumptions, the total hourly infectiousness equals 1 in all cases. Within each curve, the colored area indicates the proportion of transmission from each class of individuals. The portion attributed to individuals with symptoms (light blue) can also be interpreted as the maximum proportion of transmission that can be controlled by immediate isolation of all symptomatic cases. Panels A, B, and C show different levels of presymptomatic transmission. We calibrated infectiousness to peak at day 4 (A), 5 (B; median incubation period), or 6 (C) days. Panels D, E, and F show different proportions of transmission from individuals who are never symptomatic: 8% (C; eg, 10% never symptomatic and 75% relative infectivity), 24% (D; baseline, 30% never symptomatic and 75% relative infectivity), and 30% (E; eg, 30% never symptomatic and 100% relative infectivity).

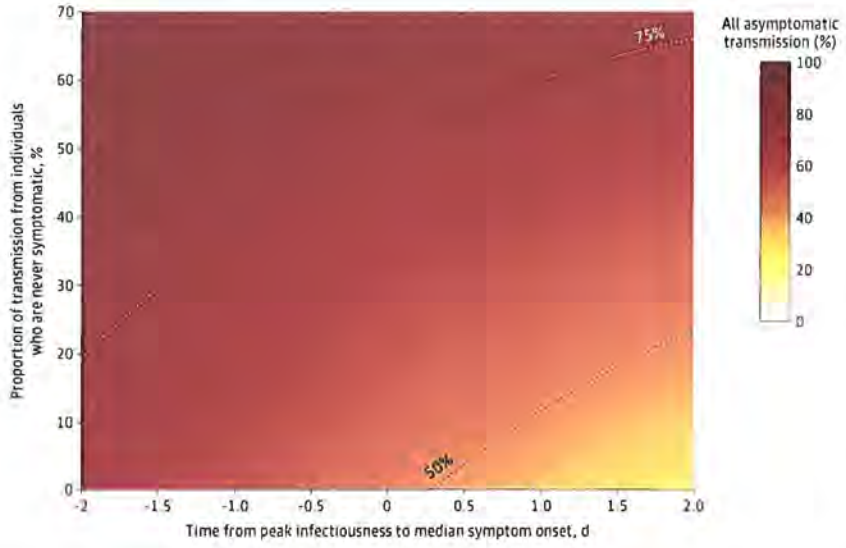
Limitations

This study has limitations. First, we used a simplistic model to represent a complex phenomenon, ie, the average infectiousness of SARS-CoV-2 infections over time. We used this model deliberately to test assumptions about the timing of peak infectiousness and transmission among asymptomatic individuals so that we could vary only these 2 critical parameters and assess their relative effects. Therefore, these results lack quantitative precision, but they demonstrate the qualitative roles of these 2 components and show that across broad ranges of possible assumptions, the finding that asymptomatic transmission is a critical component of SARS-CoV-2 transmission dynamics remains constant.

As discussed here, the exact proportions of presymptomatic and never symptomatic transmission are not known. This also applies to the incubation period estimates, which are based on individual exposure and onset windows that are difficult to observe with precision and therefore include substantial uncertainty even when leveraging estimates across multiple studies. Moreover, they likely vary substantially in different populations. For example, older individuals are more likely than younger persons to experience symptoms,[20] so in populations of older individuals, never asymptomatic transmission may be less important. However, specific age groups are rarely exclusively isolated from other age groups, so asymptomatic transmission risk is still important in those groups and even more so in younger age groups, in which transmission may be even more dominated by asymptomatic transmission.[20]

Real-world transmission dynamics are also not entirely dependent on the individual-level dynamics of infectiousness over time. Now that COVID-19 is widely recognized, individuals with COVID-19 symptoms are more likely to isolate themselves and further reduce the proportion of transmission from symptomatic individuals, shifting a greater proportion of transmission to those who do not have symptoms. In this sense, the estimates here represent the lower end of the proportion of asymptomatic transmission in the presence of interventions to reduce symptomatic transmission.

Figure 2. Combined Transmission From Individuals Who Are Presymptomatic and Those Who Never Have Symptoms



Colors indicate the proportion of transmission due to all individuals without symptoms at the time of transmission, including presymptomatic transmission (x-axis, the timing of peak infectiousness relative to symptom onset) and transmission from individuals who are never symptomatic (y-axis). For example, peak infectiousness at the same time as median symptom onset (0 days difference) with 10% of transmission from individuals who never have symptoms would mean that approximately 51% of transmission is from asymptomatic individuals.

Conclusions

Under a range of assumptions of presymptomatic transmission and transmission from individuals with infection who never develop symptoms, the model presented here estimated that more than half of transmission comes from asymptomatic individuals. In the absence of effective and widespread use of therapeutics or vaccines that can shorten or eliminate infectivity, successful control of SARS-CoV-2 cannot rely solely on identifying and isolating symptomatic cases; even if implemented effectively, this strategy would be insufficient. These findings suggest that effective control also requires reducing the risk of transmission from people with infection who do not have symptoms. Measures such as mask wearing and social distancing empower individuals to protect themselves and, if infected, to reduce risk to their communities.[21] These measures can also be supplemented by strategic testing of people who are not ill, such as those who have exposures to known cases (eg, contact tracing) or are at high risk of exposing others (eg, congregate facility staff, those with frequent contact with the public). Multiple measures that effectively address transmission risk in the absence of symptoms are imperative to control SARS-CoV-2.

ARTICLE INFORMATION

Accepted for Publication: December 7, 2020.

Published: January 7, 2021. doi:10.1001/jamanetworkopen.2020.35057

Correction: This article was corrected on February 12, 2021, to fix an error in the Supplement.

Corresponding Author: Jay C. Butler, MD, Office of the Deputy Director for Infectious Diseases, US Centers for Disease Control and Prevention, 1600 Clifton Rd, Mailstop H24-12, Atlanta, GA 30329 (jcb3@cdc.gov).

Author Affiliations: COVID-19 Response, US Centers for Disease Control and Prevention, Atlanta, Georgia (Johansson, Quandelacy, Kada, Prasad, Steele, Brooks, Slayton, Biggerstaff); Office of the Deputy Directory for Infectious Diseases, US Centers for Disease Control and Prevention, Atlanta, Georgia (Johansson, Slayton, Biggerstaff, Butler).

Author Contributions: Dr Johansson had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Johansson, Quandelacy, Kada, Brooks, Slayton, Butler.

Acquisition, analysis, or interpretation of data: All authors.

Drafting of the manuscript: Johansson, Quandelacy, Brooks, Biggerstaff, Butler.

Critical revision of the manuscript for important intellectual content: Johansson, Kada, Prasad, Steele, Brooks, Slayton, Biggerstaff, Butler.

Statistical analysis: Johansson, Quandelacy, Kada.

Administrative, technical, or material support: Prasad, Steele, Brooks, Biggerstaff, Butler.

Supervision: Johansson, Butler.

Conflict of Interest Disclosures: None reported.

Funding/Support: This work was performed as part of the US Centers for Disease Control and Prevention's coronavirus disease 2019 response and was supported solely by federal base and response funding.

Role of the Funder/Sponsor: The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.

REFERENCES

1. Peiris JS, Yuen KY, Osterhaus AD, Stöhr K. The severe acute respiratory syndrome. *N Engl J Med*. 2003;349(25):2431-2441. doi:10.1056/NEJMra032498

2. Tindale LC, Stockdale JE, Coombe M, et al. Evidence for transmission of COVID-19 prior to symptom onset. *Elife*. 2020;9:e57149. doi:10.7554/eLife.57149

3. Nishiura H, Linton NM, Akhmetzhanov AR. Serial interval of novel coronavirus (COVID-19) infections. *Int J Infect Dis*. 2020;93:284-286. doi:10.1016/j.ijid.2020.02.060

4. Zhao S, Gao D, Zhuang Z, et al. Estimating the serial interval of the novel coronavirus disease (COVID-19): a statistical analysis using the public data in Hong Kong from January 16 to February 15, 2020. *Front Phys*. Published online September 17, 2020. doi:10.3389/fphy.2020.00347

5. Du Z, Xu X, Wu Y, Wang L, Cowling BJ, Meyers LA. Serial interval of COVID-19 among publicly reported confirmed cases. *Emerg Infect Dis*. 2020;26(6):1341-1343. doi:10.3201/eid2606.200357

6. Wei WE, Li Z, Chiew CJ, Yong SE, Toh MP, Lee VJ. Presymptomatic transmission of SARS-CoV-2—Singapore, January 23-March 16, 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69(14):411-415. doi:10.15585/mmwr.mm6914e1

7. Tong Z-D, Tang A, Li K-F, et al. Potential presymptomatic transmission of SARS-CoV-2, Zhejiang Province, China, 2020. *Emerg Infect Dis*. 2020;26(5):1052-1054. doi:10.3201/eid2605.200198

8. He X, Lau EHY, Wu P, et al. Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nat Med*. 2020;26(5):672-675. doi:10.1038/s41591-020-0869-5

9. Lee S, Kim T, Lee E, et al. Clinical course and molecular viral shedding among asymptomatic and symptomatic patients with SARS-CoV-2 infection in a community treatment center in the Republic of Korea. *JAMA Intern Med*. 2020. doi:10.1001/jamainternmed.2020.3862

10. Benefield AE, Skrip LA, Clement A, Althouse RA, Chang S, Althouse BM. SARS-CoV-2 viral load peaks prior to symptom onset: a systematic review and individual-pooled analysis of coronavirus viral load from 66 studies. *medRxiv*. Preprinted published online September 30, 2020. doi:10.1101/2020.09.28.20202028

11. Byrne AW, McEvoy D, Collins AB, et al. Inferred duration of infectious period of SARS-CoV-2: rapid scoping review and analysis of available evidence for asymptomatic and symptomatic COVID-19 cases. *BMJ Open*. 2020;10(8):e039856. doi:10.1136/bmjopen-2020-039856

12. Oran DP, Topol EJ. Prevalence of asymptomatic SARS-CoV-2 infection : a narrative review. *Ann Intern Med*. 2020;173(5):362-367. doi:10.7326/M20-3012

13. Poletti P, Tirani M, Cereda D, et al. Probability of symptoms and critical disease after SARS-CoV-2 infection. arXiv. Preprint published online June 22, 2020. Accessed December 10, 2020. https://arxiv.org/abs/2006.08471

14. Buitrago-Garcia D, Egli-Gany D, Counotte MJ, et al. Occurrence and transmission potential of asymptomatic and presymptomatic SARS-CoV-2 infections: a living systematic review and meta-analysis. *PLoS Med*. 2020;17(9):e1003346. doi:10.1371/journal.pmed.1003346

15. Chaw L, Koh WC, Jamaludin SA, Naing L, Alikhan MF, Wong J. Analysis of SARS-CoV-2 transmission in different settings, Brunei. *Emerg Infect Dis*. 2020;26(11):2598-2606. doi:10.3201/eid2611.202263

16. Mc Evoy D, McAloon CG, Collins AB, et al. The relative infectiousness of asymptomatic SARS-CoV-2 infected persons compared with symptomatic individuals: a rapid scoping review. *medRxiv*. Preprint published online August 1, 2020. doi:10.1101/2020.07.30.20165084

17. McAloon C, Collins Á, Hunt K, et al. Incubation period of COVID-19: a rapid systematic review and meta-analysis of observational research. *BMJ Open*. 2020;10(8):e039652. doi:10.1136/bmjopen-2020-039652

18. Casey M, Griffin J, McAloon CG, et al. Pre-symptomatic transmission of SARS-CoV-2 infection: a secondary analysis using published data. *medRxiv*. Preprint published online June 11, 2020. doi:10.1101/2020.05.08.20094870

19. Byambasuren O, Dobler CC, Bell K, et al. Comparison of seroprevalence of SARS-CoV-2 infections with cumulative and imputed COVID-19 cases: systematic review. *medRxiv*. Preprint published online October 22, 2020. doi:10.1101/2020.07.13.20153163

20. Davies NG, Klepac P, Liu Y, Prem K, Jit M, Eggo RM; CMMID COVID-19 working group. Age-dependent effects in the transmission and control of COVID-19 epidemics. *Nat Med*. 2020;26(8):1205-1211. doi:10.1038/s41591-020-0962-9

21. US Centers for Disease Control and Prevention. Things to know about the COVID-19 pandemic. Updated December 4, 2020. Accessed December 10, 2020. https://www.cdc.gov/coronavirus/2019-ncov/your-health/need-to-know.html

SUPPLEMENT.

eAppendix. Code for Analysis

THIS IS EXHIBIT "W" referred to in the Affidavit / Declaration of Dr. Deena Hinshaw affirmed Sworn / Declared before me this 12th day of July A.D., 2021
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public.
Heather L. Veale
Barrister & Solicitor

Alberta

Public Health Disease Management Guidelines

Coronavirus – COVID-19

Alberta

Ministry of Health, Government of Alberta
June 2021
Coronavirus, Novel Public Health Disease Management Guideline
https://www.alberta.ca/notifiable-disease-guidelines.aspx

For further information on the use of this protocol contact:
Health.CD@gov.ab.ca
Health and Wellness Promotion Branch
Public Health and Compliance Branch
Alberta Health

Table of Contents

Case Definition

NOTE: Alberta Health will update this guideline as new information becomes available on the situation

Confirmed Case

A person with confirmation of infection with the virus (SARS-CoV-2) that causes COVID-19 by:

- Detection of at least one specific gene target by a validated nucleic acid amplification tests (NAAT) (e.g. real-time PCR or nucleic acid sequencing) performed at a community, hospital or reference laboratory (NML or a provincial public health laboratory)

OR

- A positive result on a validated rapid/point-of-care (POC) NAAT-based assay or antigen test[A] that has been deemed acceptable to provide a final result (i.e. does not require confirmatory testing)

[A] The performance characteristics of commercial testing kits such as the Simplexa®, GeneXpert®, Aptima or BD Max™ NAT are similar to the COVID-19 lab-developed test being used at Alberta Precision Laboratories (APL) therefore additional confirmatory testing is not necessary. For more information refer to Rapid COVID-19 Tests. Positive results by the Abbott ID NOW COVID-19 molecular test or the Rapid Antigen tests such as the Abbott PanBio are considered valid and additional confirmatory testing is not required if completed under the conditions outlined by Health Canada and in accordance with the manufacturer's instructions. (See Section 2: Testing Modality, Recommendations, Interpretation and Management and the Guidance For Employer-Initiated Covid-19 Testing)

Probable Case[B]

A person with clinical illness[C] **who in the last 14 days[D]:**

- Had close contact with a confirmed COVID-19 case **OR** was exposed to a known outbreak of COVID-19 **OR** had laboratory exposure to biological material (e.g., primary clinical specimens, virus culture isolates) known to contain COVID-19

AND

- Has not had a laboratory-based NAAT assay for SARS-CoV-2 completed **or** the result is inconclusive[E]

[B] All symptomatic contacts should be tested where feasible to confirm diagnosis. The probable case definition should only be used in the rare circumstances when the laboratory testing cannot be done or is inconclusive but clinical suspicion is high

[C] Clinical illness: Any one or more of the following: fever (over 38 degrees Celsius), new onset/exacerbation of following symptoms: cough, shortness of breath (SOB)/difficulty breathing, sore throat, loss of sense of taste and/or smell or runny nose . **NOTE:** Individuals may present with other symptoms that qualify them to be tested. Refer to Section 2: Testing Modality, Recommendations, Interpretation and Management and Table 2a: Symptom List for COVID-19 Testing for more information.

[D] The incubation period is up to 14 days between infection and the onset of clinical symptoms of the disease; therefore exposure history based on the previous 14 days is recommended.

[E] An **inconclusive** result on a real-time PCR assay is defined as:

- an indeterminate result on a single or multiple real-time PCR target(s) without sequencing confirmation or
- a positive result from an assay that has limited performance data available or
- performed by a laboratory that lacks/has not demonstrated accredited status by the College of Physicians and Surgeons of Alberta.

Reporting Requirements

1. Physicians

Physicians shall notify the Medical Officer of Health (MOH) (or designate) of the zone, of all probable and confirmed cases by the Fastest Means Possible (FMP).

2. Laboratories

All laboratories shall provide all reportable positive laboratory results, including results from rapid diagnostic tests, by FMP (e.g., secure electronic notification) to

- the MOH (or designate) of the zone and
- the Chief Medical Officer of Health (CMOH) (or designate)

The minimum client information required for reporting on the positive laboratory report must include:

- name,
- date of birth,
- health care number,
- address and
- phone number
- symptomatic, or asymptomatic and
- Exposure Investigation (EI) number if linked to an outbreak site

- NOTE: Employer initiated COVID-19 testing results must be reported using the minimum data set outlined in Appendix B: Positive Result Reporting of the Guidance For Employer-Initiated COVID-19 Testing document.

3. Alberta Health Services (AHS) and First Nations Inuit Health Branch (FNIHB)

- The MOH (or designate) of the zone where the case currently resides shall forward the Public Health Agency of Canada's *Coronavirus Disease (COVID-19) Case Report Form* or use another mutually agreed upon reporting system, to report all probable and confirmed cases to the CMOH (or designate) within 24 hours of initial laboratory FMP notification.
- All out-of-province and out-of-country case and contact reports shall be forwarded to the CMOH (or designate) within 24 hours, using existing protocols i.e., AHS enters information into CDOM if investigation initiated in AB; FNIHB emails information to CD.Data@gov.ab.ca:
  - name,
  - date of birth,
  - out-of-province health care number,
  - out-of-province address and phone number,
  - positive laboratory report, and
  - other relevant clinical / epidemiological information.
- Any new **confirmed COVID-19 outbreaks** shall be reported to Alberta Health via email as soon as possible using HEALTH-AHSCOVIDReporting@gov.ab.ca. In addition, the Alberta Outbreak Report Form (AORF) is still required and should be submitted as soon as possible using existing processes (e.g., CDOM or fax) for reporting and surveillance purposes.

4. Rapid/Point Of Care Testing (POCT) Reporting

- All **positive** rapid/POCT test results (antigen or molecular) used for diagnosis of COVID-19 in symptomatic individuals must be reported to Alberta Health as outlined in the Guidance For Employer-Initiated COVID-19 Testing document.

Epidemiology

Etiology

Human coronaviruses are enveloped, ribonucleic acid (RNA) viruses that are part of the *Coronaviridae* Family.[1] There are 7 known human coronaviruses at present:

- Four types that cause generally mild illness- 229E, OC43, NL63 and HKU; and
- Two types that can cause severe illness: Middle East respiratory syndrome coronavirus (MERS-CoV) and severe acute respiratory syndrome coronavirus (SARS-CoV).[1] Refer to the *Public Health Disease Management Guideline for Coronavirus – MERS/SARS* for more information.
- COVID-19 is an illness caused by a coronavirus (SARS-CoV-2) first identified in December 2019, in Wuhan, China as having caused an outbreak of respiratory infections, including pneumonia.[2,3]

Viruses constantly change through mutation, and new variants of a virus are expected to occur. A variant of concern (VOC) is a variant that has one or more of the following characteristics:

- increased transmissibility,
- evades natural or vaccine-related immunity,
- increased virulence,
- evades detection by available diagnostic tests, or
- is less responsive to treatment [4,5]

For more information including designated VOCs in Canada, refer to the SARS-CoV-2 variants: National definitions, classifications and public health actions.

SARS-CoV-2 VOCs have been reported globally since December 2020. The B.1.1.7 (Alpha) variant was first identified in the United Kingdom, B.1.351 (Beta) in South Africa, P.1 (Gamma) in Brazil and B.1.617.2 (Delta) in India. These VOCs have also been identified in Alberta and Alberta Health is continuously monitoring and assessing their impact on viral transmission, disease severity, diagnostic testing, therapeutics, and vaccine effectiveness in the province. For more information refer to the Alberta Health website on COVID-19 variants of concern.

Clinical Presentation

Individuals infected with the virus that causes COVID-19 may have few or no symptoms and symptoms may range from mild to severe. COVID-19 symptoms include cough, fever, headache, sore throat, shortness of breath, nasal congestion and new loss of sense of taste or smell, fatigue, muscle aches, vomiting or diarrhea. For some of the other symptoms that can be associated with COVID-19 infection, refer to Table 2a: Symptom List for COVID-19 Testing. Current evidence suggests that vaccinated individuals infected with COVID-19 may present with milder symptoms.[6] Complications of COVID-19 include severe pneumonia, acute respiratory distress syndrome, sepsis, septic shock, multi-organ failure or death.[7]

Generally, the duration of illness is about two weeks for cases with mild infection but can be up to six weeks for critical cases and in immunocompromised individuals.[8,9] Post COVID-19 condition is a term used for a wide range of new, returning, or ongoing health problems people can experience more than four weeks after their COVID-19 infection.[10,11] Research is ongoing to better understand all the health impacts associated with COVID-19. For more information refer to Post-COVID Conditions.

Children and adolescents infected with SARS-CoV-2 typically have mild or no symptoms and in Canada, account for approximately 19% of reported cases.[12] Although rare, severe illness and death have been reported. Since April 2020, there have been reports of children and adolescents presenting with acute illness with a hyper inflammatory syndrome, leading to shock and multi-organ failure. This has been termed Multi-System Inflammatory Syndrome in children and adolescents (MIS-C). Some cases have been associated with COVID-19 (often several weeks following a SARS-CoV-2 infection), but a causal link with COVID-19 has not

been definitively established. The risk factors associated with developing MIS-C are currently unknown.[13] Research to further understand MIS-C is ongoing.[14–16] For more information refer to the WHO Multisystem inflammatory syndrome in children and adolescents temporally related to COVID-19 and the Alberta Health MIS-C Public Health Disease Management Guideline.

Analyses so far indicate that B.1.1.7, B.1.351, P.1 and B.1.617.2 variants are possibly associated with increased risk of severe disease and hospitalization, but this has not been confirmed yet.[17]Research is ongoing regarding the spectrum of COVID-19 illness and severity of outcomes associated with all the circulating VOCs.

Reservoir

SARS-CoV-2 is thought to have emerged from an animal source although this has not yet been confirmed.

Transmission

SARS-CoV-2 virus (non-VOC and VOCs) is transmitted person-to-person primarily via respiratory droplets that are generated when a person coughs, sneezes, talks, shouts or sings. The droplets range in size from large droplets (defined as >5-10 µm in diameter) that spread at close range (i.e., less than two metres) to smaller droplets (or aerosols) that in certain circumstances, have the potential to be infectious over longer distances and may be suspended for longer periods of time and can play a role in COVID-19 transmission. These circumstances include aerosol-generating medical procedures (AGMP) or specific settings such as indoor locations that may be poorly ventilated, crowded, where gatherings are taking place for prolonged periods or where heavy breathing or exertion is occurring. For more information refer to the Transmission of SARS CoV-2 and Considerations for aerosol transmission. Current evidence shows there is an increase in transmissibility with currently known VOCs.[18]

COVID-19 can also spread via direct physical contact with another person (e.g., hand shake) or by touching contaminated objects or surfaces and then touching one's own mouth, nose, or possibly eyes.[7] However, fomites do not appear to be a major source of transmission.[19] Infected individuals can transmit the virus 48 hours before symptom onset (i.e., pre-symptomatic) or even if they have an asymptomatic infection (i.e., never developed symptoms) or when their symptoms went unnoticed.[20,21]

Incubation Period

The incubation period ranges from 1-14 days with median estimates of 5-6 days between infection and the onset of clinical symptoms of the disease.[2]

Period of Communicability

The period of communicability may begin up to 48 hours before symptom onset and throughout the symptomatic period, even if symptoms are mild or very non-specific. Studies have shown that after day **eight** of illness/symptoms no live virus was recovered from patients with upper respiratory tract disease or limited lower respiratory tract disease. People with more severe disease are likely to be infectious for a few days longer.[22,23] NAAT positivity from respiratory samples can be prolonged to 3-4 weeks after symptom onset even when no viable virus was detected.[24] There have been case reports of persistent RT-PCR results for up to 82 days after symptom onset.[25,26] Experience from other respiratory viral infections suggests that immunocompromised patients with COVID-19 may shed detectable SARS-CoV-2 viral material and potentially infectious virus longer.[27] Research is ongoing to determine if there is a difference in the period of communicability of VOC compared to non-VOC.

Host Susceptibility

Susceptibility is assumed to be universal. Knowledge about COVID-19 disease continues to evolve and this includes evidence on individuals who are most susceptible to infection and severe outcomes.[13] To date, studies[9,13,21] have found the following:

- Older adults (>60 years) and people with existing chronic medical conditions (e.g., cardiovascular and liver disorders, lung disease, diabetes, high blood pressure, kidney disease, sickle cell disease, dementia or stroke) or immune compromising conditions are more vulnerable to severe COVID-19 illness. The list of chronic conditions above only includes those for which there is sufficient evidence available to conclude a higher level of risk.[13]
- Even though obesity is not well defined in the literature, individuals with a body mass index (BMI) ≥35 have a higher risk of ICU admission/intubation.
- There is no clear evidence on the role that race/ethnicity plays in outcomes of COVID-19 i.e., it is unclear whether any differences in outcomes are due to social determinants of health or biological factors.
- Male biological sex shows low-moderate association for severe outcomes of COVID-19.
- Pregnant women have a higher risk of severe illness compared to non-pregnant women and may also be at an increased for adverse pregnancy outcomes (e.g. preterm birth).
- Generally, children (under 18 years of age) are less susceptible to severe clinical disease than older people.[28] However, some children do have severe outcomes and those with underlying medical conditions are at increased risk for severe illness compared to children with no underlying medical conditions.[13]

Understanding of the immune response in COVID-19 disease is evolving. There are increasing reports of individuals who were infected a second time with a VOC or non-VOC after having recovered from a first infection.[29] Ongoing COVID-19 studies are working to help establish the frequency and severity of reinfection with VOC and non-VOC and who might be at higher risk.

Incidence

For cases reported in Alberta refer to the following link:
https://www.alberta.ca/covid-19-alberta-data.aspx

For cases reported in Canada refer to the following link:
https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection.html

World Health Organization provides daily updates on global case counts and situation reports:
www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports

Johns Hopkins COVID-19 Case Map
gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6

Public Health Management

NOTE: *This guidance is based on current available scientific evidence and expert opinion and is subject to change as new information on transmissibility and epidemiology becomes available.*[30]

Public Health Management of VOC and non-VOC

VOCs now make up a significant proportion of COVID-19 cases in Alberta. The following public health guidance applies for both VOC and non-VOC cases and their close contacts.

Since the COVID-19 pandemic began, Alberta Precision Labs (APL) has been performing surveillance for variants using whole-genome sequencing (WGS) on select samples. High-throughput nucleic acid screening tests that are faster than WGS were subsequently developed to detect VOCs in samples soon after they test positive for COVID-19. Variant screening may not be possible in samples with low viral loads.[31] Screening and sequencing strategy is constantly reviewed and adjusted to meet surveillance needs and maintain laboratory capacity and turnaround times. For more information, refer to the lab bulletins on the APL website

Section 1: Diagnosis

A diagnosis of SARS-CoV-2 infection is based on testing. Acceptable specimen types for COVID-19 testing include nasopharyngeal (NP) swab, throat swab, NP aspirate, endotracheal tube (ETT) suction/sputum, or bronchoalveolar lavage/bronchial wash (BAL/BW). NP and throat swabs are recommended over nasal swabs for COVID-19 testing. If unable to collect a NP swab or throat swab, a deep nasal swab can be collected instead, though sensitivity may be reduced. It is recommended that hospitalized patients with COVID-19 symptoms be tested with an NP swab. For patients who have a lower respiratory tract infection and are intubated, also submit an ETT suction or BAL/BW.[32]

Section 2: Testing Modality, Recommendations, Interpretation and Management

Molecular, antigen and serology tests have been developed and continue to be developed and approved to test for COVID-19. Molecular tests detect the unique genetic sequence of the SARS-CoV-2 virus and antigen tests detect proteins of the virus. Both can be used to diagnose acute infection. For more information on molecular and rapid antigen test performance, refer to Annex A: Testing Performance.

Serology tests do not directly detect the virus but measure antibodies the body produces after infection with the virus. These antibodies can provide evidence of previous or current infection. Since it can take more than a week for antibodies to be produced following infection, serology tests are generally not recommended for use as a diagnostic tool to confirm acute infection.[33] Currently in Alberta, serology tests are mainly used for population serosurveys. Serology testing is available for clinical use for certain situations (e.g., to assist in the diagnosis of children with MIS-C) in consultation with APL microbiologists/virologists. Serology testing is not needed before receiving a COVID-19 vaccine to assess susceptibility to SARS-CoV-2 or after receiving the vaccination to assess immune response to the vaccine.

Testing Recommendations

Testing is recommended for the diagnosis of individuals with COVID-19 compatible symptoms as listed in Table 2a: Symptom List for COVID-19 Testing. Individuals with these symptoms who are working in high risk settings, including HCWs as well as residents/clients in congregate settings, should always be offered testing to confirm the diagnosis. An individual with symptoms not listed in **Table 2a** such as "COVID toes" or altered mental status may also be considered for testing at the discretion of the individual's clinician.

Table 2a: Symptom List for COVID-19 Testing

Symptoms
- Fever - Cough (new cough or worsening chronic cough) - Shortness of breath/difficulty breathing (new or worsening) - Runny nose - Sore throat - Stuffy nose - Painful swallowing - Headache - Chills - Muscle/joint ache - Feeling unwell/fatigue/severe exhaustion - Nausea/Vomiting/Diarrhea/Unexplained loss of appetite - Loss of sense of smell or taste - Conjunctivitis

Testing in Alberta:

- The following individuals are eligible for testing:
  - any person exhibiting symptoms listed in Table 2a: Symptom List for COVID-19 Testing.
  - close contacts of confirmed and probable COVID-19 cases.
    - **NOTE:** Testing is not recommended for close contacts who are fully immunized and are asymptomatic. For more information refer to Section 7: Management of Close Contacts Immunized Against COVID-19
  - Workers and/or residents at specific outbreak sites including:
    - staff/residents in supportive living (including group homes and lodges), long-term care facilities (nursing homes and auxiliary hospital), hospices, shelters and correctional facilities when a NEW COVID-19 outbreak has been declared,
    - residents/staff in an existing COVID-19 outbreak if transmission appears to still be occurring.
  - New admissions to a congregate living facility e.g. supportive living (including lodges and group homes), long-term care (nursing homes and auxiliary hospital), hospices and correctional facilities. For more information refer to Testing Recommendations for Residents Admitted to a Facility.
  - **NOTE:** Albertans can access private testing for COVID-19 if they are asymptomatic and do not meet the eligibility criteria for testing in the public testing system.
- For more information on management refer to Table 2b: Management of Tested Individuals.

Table 2b: Management of Tested Individuals who are NOT Previous Cases[€]

Symptoms**	COVID-19 Test	Management
Symptomatic	Positive	- Manage as a lab-confirmed symptomatic case.
	Negative	- **Who is a close contact:** Quarantine for 14 days since the last exposure or isolate until symptoms resolve, whichever is longer - NOTE: for quarantine requirements for fully and partially immunized close contact refer to Table 7a. Management of Immunized Close Contacts
		- **Who is NOT a close contact**: Strongly recommended to stay at home and limit contact with others until symptoms resolve. Retesting may be considered.
Asymptomatic	Positive	- Manage as a lab confirmed asymptomatic case.
	Negative	- **Who is a close contact**: Quarantine for 14 days since the last exposure and monitor for symptoms. - NOTE: for quarantine requirements for fully and partially immunized close contacts refer to Table 7a. Management of Immunized Close Contacts
		- **Who is NOT a close contact:** NO quarantine required. Continue with normal activities.

**See symptoms listed in Table 2a: Symptom List for COVID-19 Testing

€This also applies to resolved cases after 90 days of the initial positive test

Rapid Screening Program

In an effort to reduce spread of COVID-19 from pre-symptomatic and asymptomatic cases, rapid testing can be used to screen for infection in individuals who are not exhibiting COVID-19 symptoms. A number of screening programs have been initiated in Alberta in a variety of settings such as continuing care facilities, workplaces, schools etc. Individuals screening positive must isolate and their positive screen results must be confirmed by follow-up PCR test. For more information on the rapid screening program refer to the Alberta Health Rapid testing program website.

Testing and Management of Resolved Cases [F]

- Studies have demonstrated prolonged detection of SARS-CoV-2 RNA in COVID-19 cases even after symptoms have resolved; however in most cases, prolonged RNA detection does not reflect infectious virus. The median range of viral shedding has been reported to be 3-4 weeks after symptom onset, with case reports of persistent RT-PCR results for up to 82 days after symptom onset.[25,26]
- Due to uncertainty regarding immunity after infection and the possible risk of re-infection,[34,35] resolved cases should be advised to take the same precautions to avoid exposure as an individual who has never had COVID-19, including wearing a mask, physical distancing, practicing proper hand hygiene and respiratory etiquette and if they are a HCW to follow IPC recommendations regarding PPE.[36]
- Generally, asymptomatic resolved cases should NOT be re-tested for COVID-19 within 90 days of the initial positive test result. However if the resolved case develops NEW COVID-19 symptoms within the 90 days, screening for VOC and testing for other pathogens should be considered depending on symptoms and the setting, and management of these individuals is based on symptoms and diagnosis.
- It may be possible for a few individuals to shed detectable SARS-CoV-2 viral material longer than 90 days. If suspected to be the case, consultation with the local MOH and other specialists including microbiologists/virologists and infectious disease physicians can help with the management decision. For more information refer to Table 2c: Testing and Management of Resolved Cases.

[F] Resolved cases refers to previously lab-confirmed COVID-19 cases that have completed isolation – see Section 4: Management of Cases for more detail.

Table 2c: Testing and Management of Resolved Cases

Timing of test from previous positive result**	New onset of COVID-19 Symptoms¥	Testing Recommendations	Management Recommendations
Less than 90 days	Not applicable (Asymptomatic)	No testing recommended	If inadvertently tested for COVID-19 less than 90 days & result positive: - No repeat isolation - No contact follow-up **Note:** positive test result generally indicates residual non-viable virus and this person is considered not infectious and NOT a new case
90 days or more	Not applicable (Asymptomatic)	Testing indications are the same as for people who have never had COVID-19	- If tested for COVID-19 refer to Table 2b: Management of Tested Individuals and manage according to lab results and exposure. - If concerned about the risk of re-infection, the individual should isolate while waiting for test results. - Exceptions may be made to this management requirement in consultation with the local MOH and other specialists including microbiologists/virologists and infectious disease physicians.
Less than 90 days	Symptomatic	- Generally do not re-test - If re-testing is considered refer to the section on Indications to Re-Test Resolved Cases within 90 days	- Depending on symptoms & setting, consider testing for other pathogens (e.g. RPP). - If re-tested for COVID-19 and result is positive, request screening for VOC if not done automatically by the lab - Manage according to symptoms and diagnosis. - If concerned about the risk of re-infection, the individual should isolate while waiting for test results. - Further management is based on lab results and assessment.
90 days or more	Symptomatic	- COVID-19 - With or without Respiratory Pathogen Panel (RPP	- Isolate while laboratory and epidemiological investigation is being conducted. - If only COVID-19 testing is done, refer to Table 2b: Management of Tested Individuals and manage according to lab results and exposure. - Exceptions may be made to this management requirement in consultation with the local MOH and other specialists including microbiologists/virologists and infectious disease physicians.

***This is 90 days from test date which yielded the initial positive result. ¥ Refer to Table 2a: Symptom List for COVID-19 testing*

Indications to Re-Test Resolved Cases within 90 days

- Re-testing for COVID-19 within 90 days from a previous positive test can be considered if a clinician has concerns about the risk of re-infection (i.e., NEW COVID-19 symptoms develop after the person's isolation period) in the following situations:
  - new symptoms develop within 14 days after **they are identified as a close contact** [G]
  - severe COVID-19-like illness or hospitalized
  - anyone with a high degree of interaction with populations who are at high risk of more severe disease or outbreaks (e.g., HCWs, staff and residents in LTC facilities, prisons, shelters, work camps)
  - immunocompromised person.

Management of Resolved Cases with New Exposure

- There is growing evidence to support that resolved cases do not need to undergo repeat quarantine if they **are identified as a close contact**[G] within 90 days of their initial diagnosis.
- Despite millions of COVID-19 cases worldwide, surveillance and investigations have only identified few confirmed cases of re-infection with non-VOC or VOC within 90 days of the initial diagnosis. Available evidence suggests that most individuals would have a certain degree of immunity for at least 90 days after initial diagnosis of COVID-19. However the risk for reinfection is likely to increase due to waning immunity after initial infection and exposure to variants that cause immune escape.[37]
- Therefore, if a resolved case is **identified as a close contact**[G] (unrelated to their previous infection), no repeat quarantine is required if the exposure is within 90 days of their previous positive test result AND they are asymptomatic.[34] *Risks of potential transmission from asymptomatic resolved cases who have a new exposure are likely outweighed by the personal and societal benefits of avoiding repeat quarantine.* (CDC, 2021)
  - They should closely monitor for COVID-19 symptoms for 14 days after the last exposure
  - If any COVID-19 symptoms develop, they should isolate immediately and be re-tested for COVID-19. Refer to the section above for other testing and management recommendations.
- If a resolved case **is identified as a close contact**[G] 90 days or more from their previous positive test result, manage as any other close contact and quarantine for 14 days from last exposure. Refer to Section 5: Management of Close Contacts.

[G] The individual is identified as a close contact after exposure to a COVID-19 case unrelated to their previous infection

Testing Recommendations for Residents Admitted to a Facility

- Testing is recommended for all new residents admitted to a congregate living facility e.g., licensed supportive living (including lodges and group homes), long-term care (nursing homes and auxiliary hospital) and hospices, regardless of symptoms upon admission.
- Residents who return to these settings post-hospitalization for non-COVID-19 illnesses are also recommended to be tested whether they have symptoms or not.
- Refer to **Table 2d** below for more information.

Table 2d: Testing Recommendations for Residents Admitted to a Facility

Previous COVID-19 Test Result	Timing of Previous Test	Testing Recommendations on Admission to Facility
Positive	Less than 90 days	No
	90 days or more	Yes
Negative	Less than 90 days	Yes
	90 days or more	Yes

Section 3: Key Investigation

- Confirm the diagnosis and that individual meets case definition.
- Ensure appropriate clinical specimen(s) have been collected (see Diagnosis Section).
- Obtain history of illness including date of onset of signs and symptoms. See Table 2a: Symptom List for COVID-19 Testing.
- Determine immunization status.
- Determine previous COVID-19 infection. Refer to Testing and Management of Resolved Cases
- Determine spectrum of illness and if case requires hospitalization or if they can be managed at home.
- Determine any underlying chronic or immunocompromising condition. Determine possible source of infection:
  - Identify recent travel/residence history inside and outside Canada, or contact with a recent traveler outside Canada, including dates of travel, itineraries and mode of transportation (e.g., airplane, train, etc.);
  - Identify type of contact within health care settings with known COVID-19 cases (e.g., work, visiting patient, etc.), if applicable;
  - Recent contact with a known COVID-19 case or a person with COVID-19-like illness
  - Assess if other members in the household have similar symptoms or have had any contact with a known COVID-19 case/person with COVID-19 symptoms.
- Determine occupation (e.g., healthcare worker[H] or works with vulnerable individuals i.e., long-term care facilities/continuing care/group homes/shelters)
- Determine possible transmission settings (e.g., household, healthcare setting, community setting, workplace, school, flight etc.).
- Identify close contacts that may have had exposure to the **confirmed/probable case** 48 hours prior to onset of symptoms in the confirmed/probable case and/or while the confirmed/probable case was symptomatic and not isolating. Refer to Table 3a: Definition of Close Contacts.
- Determine if a **laboratory confirmed case asymptomatic at testing** had two or more of the symptoms listed in clinical illness[B] for at least 24 hours in the **seven** days prior to specimen collection date. (For more information refer to the Management of a Laboratory Confirmed Case Asymptomatic at Testing).
- For public health management of a **laboratory confirmed case asymptomatic at testing** not meeting the criteria of having two or more of the symptoms listed in clinical illness[B] for at least 24 hours in the **seven** days prior to specimen collection, the period of communicability that may be used is 48 hours before laboratory specimen was collected to 10 days after the date of specimen collection. (**NOTE:** The period of communicability may be longer if they develop symptoms during the 10 days after lab specimen collection date).
- Identify close contacts that may have had exposure to a **laboratory confirmed case asymptomatic at testing**[I] between 48 hours before the laboratory specimen collection date and isolation date of that case. Refer to Table 3a: Definition of Close Contacts.

[H] Health Care Workers (HCW) are individuals who provide service in a clinical care setting, including hospitals, clinics, continuing care facilities, licensed supportive living sites (including group homes), public health centers, community assessment centers, and any other settings where face-to-face patient care is provided (including fire fighters and EMS)
[I] Where feasible, contact tracing for asymptomatic cases should include close contacts that were exposed to the case 48 hours before the specimen collection date. If not feasible, the specimen collection date can be used as the starting point for contact tracing.

Table 3a: Definition of Close Contacts[38–41]

DEFINITION OF CLOSE CONTACTS
Individuals that: • provided direct care for the case, (including HCW[H], family members or other caregivers), or who had other similar close physical contact (e.g., intimate partner, hug, kiss, handshake) without consistent and appropriate use of personal protective equipment (PPE), OR • lived with or otherwise had close prolonged[J] contact which may be cumulative, i.e., multiple interactions for a total of 15 min or more over a 24-hour period and within two metres with a case without consistent and appropriate use of PPE and not isolating OR • had direct contact with infectious body fluids of a case (e.g., shared cigarettes, glasses/bottles, eating utensils) or was coughed or sneezed on while not wearing recommended PPE.

- For definition of close contacts in sports teams and schools, refer to the AHS website on Information for Close Contacts of a COVID-19 Case.

[J] As part of the individual risk assessment, consider the duration of the contact's exposure (e.g., a longer exposure time likely increases the risk), the case's symptoms (coughing or severe illness likely increases exposure risk) and whether exposure occurred in a health care setting.

Section 4: Management of Cases

Management of Hospitalized Cases

- Isolation precautions apply for hospitalized cases. Consult with hospital Infection Prevention and Control (IPC) for recommendations for lifting isolation.
- Provide information about disease transmission and measures to minimize transmission, including wearing a mask, practicing proper hand hygiene, physical distancing and respiratory etiquette.
- Provide information on immunization as applicable.
- For information on infection prevention and control precautions refer to the following:
  - *AHS IPC Resources*
  - *Infection prevention and control for COVID-19: Second interim guidance for acute healthcare settings*

Discharge/Transfer of a Hospitalized Case[K]

- Hospitalized cases that are discharged to their own home before hospital isolation is complete should remain on home isolation for 10 days from onset of symptoms or until symptoms have improved AND they are afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer, after arrival at home.
- **NOTE:** The attending physician may have ordered a different isolation period for a patient based on their specific circumstances when they are discharged to the community (home or continuing care facility).
  - If a patient has been advised by their physician to isolate for longer than the minimum 10 days, they should follow the instructions of their physician.
- Hospitalized cases being discharged/transferred to long-term care facilities/continuing care/group homes/shelters etc. before their isolation period is complete should remain on isolation for **14 days** from onset of symptoms or until symptoms have improved AND they are afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer.
  - This additional length of time (four more days from the 10 days) is recommended as the case had severe disease (i.e., hospitalized) and will be re-entering a facility with other vulnerable persons (i.e., long-term care facilities/continuing care/group homes/shelters).

[K] This refers to cases hospitalized due to COVID-19.

Management of Non-Hospitalized Case

- It is highly recommended that ALL cases of COVID-19 (VOC or non-VOC) isolate completely away from their household members to prevent ongoing exposure. If this cannot be accomplished at home, use of an isolation hotel or a different dwelling should be considered.
- Provide information about disease transmission and measures to minimize transmission, including wearing a mask, physical distancing, practicing proper hand hygiene and respiratory etiquette.
- A non-test based approach to clearance for COVID-19 is recommended for cases with mild and moderate illness. Since NAAT positivity from respiratory samples can be prolonged and generally does not reflect infectious virus, a "test of cure" is often misleading.
- Symptomatic confirmed and probable cases are required to isolate for 10 days from onset of symptoms or until symptoms have improved AND they are afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer.
  - Absence of cough is not required for those known to have chronic cough or who are experiencing reactive airways post-infection.
  - Symptoms such as loss of sense of taste/smell or fatigue may last longer than 10 days, but do not require a longer isolation period.
- Residents of licensed supportive living (including group homes and lodges), long-term care (nursing homes and auxiliary hospitals) and hospices should be isolated with contact and droplet precautions for a minimum 10 days or until symptoms improve AND they are afebrile for 24 hours without the use of fever reducing medications, whichever is longer. Isolation may be extended to 14 days at the discretion of the MOH/Site IPC.
- Active daily surveillance by Public Health is not required.
- **NOTE:** If a person is determined to be at high risk of clinical decompensation and without necessary supports (e.g., elderly with comorbidities who lives alone), their primary care physician should provide active daily surveillance if feasible, or the case should be encouraged to arrange for family/friends/community organizations to provide wellness checks.
- If the case requires non-urgent medical attention, advise to contact 811 for further direction on where to go for care, the appropriate mode of transportation to use, and IPC precautions to be followed. If they require urgent attention, advise them to call 911 and to let 911 know they have COVID-19 so that appropriate precautions can be taken to care for the case safely.
- Non-hospitalized cases who were isolated (for example, in an isolation center) and are returning to congregate settings (e.g., long-term care facilities/continuing care/group homes/shelters etc.) shall be in isolation for at least 10 days from onset of symptoms or until symptoms have improved AND they are afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer.
- Due to the theoretical possibility that animals in the home could be affected by COVID-19, it is recommended that cases also refrain from contact with pets.
- COVID-19 virus RNA has been detected in the stool of some infected patients[42], so there may be a risk of spread through stool. For these reasons, the case should be instructed of the following:
  - effective infection prevention control such as hand hygiene.
  - safe food handling practices.
  - refrain from preparing foods for others in the household until isolation is lifted.

Management of an Immunocompromised Case

- There is currently little information on viral shedding in confirmed COVID-19 cases who are immunocompromised.
- However based on experience from other respiratory viruses, especially influenza virus, immunocompromised confirmed cases may shed SARS-CoV2 for a longer period of time.[27]
  - These cases should be isolated for 14 days from onset of symptoms or until symptoms have improved AND they are afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer.
    - Absence of cough is not required for those known to have chronic cough or who are experiencing reactive airways post-infection.
    - Symptoms such as loss of sense of taste/smell or fatigue may last longer than 14 days, but do not require a longer isolation period.
  - Duration of isolation for those hospitalized should be decided in consultation with hospital IPC.

Management of a Laboratory Confirmed Case Asymptomatic at Testing

- Provide information about disease transmission and measures to minimize transmission, including wearing a mask, physical distancing, practicing proper hand hygiene and respiratory etiquette.
- Determine if the case had two or more of the following symptoms that lasted at least 24 hours in the **seven** days before laboratory specimen collection date:
  - fever (over 38 degrees Celsius),
  - new onset/exacerbation of following symptoms: cough, shortness of breath (SOB)/difficulty breathing, loss of sense of taste or smell, sore throat or runny nose.
    - If the case had two or more symptoms as outlined above, the positive result may indicate that the symptoms were due to COVID-19 and that date of symptom onset should be used for public health investigation and management purposes.
    - However, it is possible that the previous symptoms were due to another respiratory pathogen, so the case should be instructed to monitor for COVID-19 symptoms for the 10 days following lab specimen collection date.
    - For a case that had two or more of the symptoms listed above, for at least 24 hours in the **seven** days prior to specimen collection date, the period of communicability is 48 hours prior to onset of symptoms to 10 days after symptom onset.
- A hospitalized asymptomatic case should be isolated and placed on contact and droplet precautions. Consult with hospital IPC for recommendations for lifting isolation/discharge.
- A non-hospitalized asymptomatic case should be isolated for at least 10 days from the laboratory specimen collection date.
  - Instruct the case to monitor for symptoms in Table 2a: Symptoms for COVID-19 Testing and if symptoms develop during the isolation period, the (hospitalized/non-hospitalized) case must remain in isolation for 10 days after onset of symptoms, or until symptoms have improved AND they are afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer.

Return to Work for Cases

- Proof of a negative COVID-19 test and/or a medical note is not required for cases to return to school/work/activities once the isolation period is complete.

Treatment of Cases

- For information on treatment of COVID-19 Cases refer to the following sources:
  - PHAC guidance on Clinical Management of Patients with COVID-19.
  - The World Health Organization's Clinical Management of COVID-19 Patients

Section 5: Management of Close Contacts

Management of Close Contact of Confirmed or Probable Case

- Determine the type of exposure, the setting, and the time since last exposure.[L]
- Provide information about COVID-19 disease including signs and symptoms.
- Determine immunization status. If immunized, refer to Section 7: Management of Close Contacts Immunized Against COVID-19 for information on quarantine and testing.
- If not immunized the following apply:
  - Close contacts of **confirmed cases require mandatory** quarantine for 14 days from last day of exposure and should be offered testing. Refer to Section 2: Testing Modality, Recommendations, Interpretation and Management. Quarantine must be maintained even if test is negative.
  - Close contacts of **probable** cases should also be quarantined for 14 days.
  - Close contacts of **laboratory confirmed cases asymptomatic at testing, require mandatory** quarantine for 14 days from last day of exposure and should be offered testing. Quarantine must be maintained even if test is negative.
  - Refer to Section 2: Testing Modality, Recommendations, Interpretation and Management.
  - For more information refer to Annex B: Isolation and Quarantine
  - **NOTE:** Where feasible, contact tracing for any tested individual (symptomatic or asymptomatic) should be initiated once lab results have been received and the person has been determined to be a confirmed/probable case.
    - For more information on contact tracing notification process refer to the AHS website.

Guidance on the Use of Masks

- Non-medical masks and face coverings used in the community may reduce the risk of transmission of COVID-19 on the individual and population level.
- However, non-medical masks and face coverings are not considered to be sufficient PPE in an exposure to a confirmed COVID-19 case when assessing whether an individual is a close contact (i.e., wearing a non-medical mask or face covering does not preclude the individual who was exposed from being considered a close contact. See rationale below).
  - This includes self-reporting of use of medical masks by non-HCW in situations where the case is asymptomatic/pre-symptomatic, and where both persons involved in the exposure event are masked.
- Continuous masking (medical/surgical masks) and proper hand hygiene is considered to offer sufficient protection for HCWs[I] who have cared for patients with pre-symptomatic/asymptomatic COVID-19 infection. This is NOT considered sufficient PPE for HCWs who work with symptomatic patients or confirmed/probable cases. For more information on appropriate PPE for HCW refer to the AHS COVID-19 Personal Protective Equipment website.

[L] For close contacts with on-going exposure, the last date of exposure is the date the case is determined to be non-infectious i.e., 10 days after onset of symptoms or until symptoms have improved AND afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer.

Rationale:

- HCWs have direct access to professional IPC/WHS support to ensure/evaluate appropriate practice standards. They are also trained in donning/doffing/using appropriate hand hygiene, are able to implement risk assessment practices, and are more aware of the types of interactions they are having with patients. For more information refer to Section 6: Management of Health Care Workers (HCW)
- In addition, mask quality specifications, fit and appropriate use are difficult to assess for members of the general public, and self-reports may not be accurate.

Assessment of PPE in Workplaces

- In general, employers will be contacted by Public Health if there is a case of COVID-19 who is identified as having been at the worksite while infectious.
  - Public Health will work with the case, employer and their occupational health and safety (OH&S) practitioner (if available) to identify persons who may have been exposed at work (close contacts).
  - Public Health will ask employers to identify and notify workplace close contacts.
- Workplaces that meet specific criteria listed below may consider PPE use in their assessment of close contacts if all of the following applies:
  - There needs to be a formal OH&S or an IPC professional/practitioner[M] that has knowledge of what constitutes adequate PPE for that particular work setting in the context of COVID-19.
  - The professional/practitioner must provide oversight of PPE use and provide PPE training to workers in that work setting.
  - In the event of an exposure to COVID-19 in the work setting, the OH&S or IPC professional/practitioner should be able to conduct an assessment to determine if the exposed worker was wearing the appropriate PPE as per work site guidance and training.
  - This assessment should be documented and made available, if requested by AHS.
- If the assessment determines the worker was following all PPE guidance and there were no breaches, the worker would be considered protected and would NOT be considered a close contact and quarantine would not be required.
- If workplaces do not meet the criteria outlined above, workers exposed to COVID-19 will follow the same direction that applies to members of public (i.e. mask use is not considered in the close contacts assessment).

[M] OH&S or IPC team/program includes any one of the following:
- A certified Occupational Health and Safety (OH&S) professional/practitioner (as defined by the Canadian Society of Safety Engineering),
- A health professional certified in Infection Prevention and Control (by CHICA-Canada)
- An individual who holds a certificate or other credential in Occupational Health and Safety from a recognized post-secondary institution in Canada

Section 6: Management of Health Care Workers (HCW) (H)

Recommendations on Return to Work

- Refer to COVID-19 Return to Work Guide for AHS Healthcare Workers
- HCW who may have been exposed to COVID-19 should refer to the COVID-19 Self-Assessment Tool for Healthcare Workers and the COVID-19 Testing / Online Booking for more information.
- The following applies for HCW who tested positive for COVID-19:
  - They require mandatory isolation for 10 days from onset of symptoms or until symptoms have improved AND afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer.
  - If symptoms such as a lingering cough, loss of sense of taste/smell or fatigue persist beyond 10 days, the HCW may return to work as long as other symptoms have improved and they are well enough to go back to work.
  - If they are asymptomatic and remain asymptomatic, the HCW may return to work 10 days after the lab specimen date.
  - If the HCW is immunocompromised or has other health conditions (e.g. cardiovascular and liver disorders, lung disease, diabetes, high blood pressure, kidney disease, sickle cell disease, dementia or stroke (see Host Susceptibility section for more information), they should consult with WHS/OHS/MOH/designate for further direction about returning to work.

Recommendations on Mask Use for HCWs

- A surgical/procedure mask and good hand hygiene is considered sufficient PPE for asymptomatic HCW working with asymptomatic patients, including within the 48 hours prior to developing symptoms.
  - If HCW becomes symptomatic, all the patients who they cared for (or co-workers) in the ***48 hours prior to symptom onset*** in that HCW will **NOT** be considered close contacts if the HCW wore a surgical/procedure mask and practiced routine, frequent hand hygiene.
  - If a patient becomes symptomatic, all HCW that cared for the patient in the ***48 hours prior to symptom onset*** in that patient, would **NOT** be considered close contacts if they were wearing a surgical/procedure mask and practiced good hand hygiene i.e., sufficient PPE.
    - If the time of symptom onset for the patient cannot be reliably ascertained (e.g., patient with cognitive impairment), WHS/OHS/MOH/designate should be consulted regarding period of communicability and its relationship to appropriate PPE use.
- A surgical/procedure mask and good hand hygiene is **NOT** appropriate PPE for HCW caring for **symptomatic** patients or when identified as a close contact of a symptomatic co-worker.
- Appropriate PPE for HCW caring for symptomatic patients or confirmed/probable cases of COVID-19 includes: medical masks (or N95 respirators when AGMP is performed), eye protection (e.g., goggles, visor, and face shield), gloves and gown, which means full contact and droplet precautions. For more information, refer to the AHS COVID-19 Personal Protective Equipment website.
- At this time, immunized HCW should continue to use recommended PPE when caring for patients.
  - Immunized HCW who are determined to be a close contacts should follow recommendations outlined in Section 7: Management of Close Contacts Immunized Against COVID-19.

Additional PPE Recommendations for HCWs

- **NOTE**: Eye protection is recommended as an additional layer of protection for all patient interactions within two metres in areas where there are ongoing high levels of community transmission.
  - If a HCW was wearing a surgical/procedure mask, eye protection and was practicing good hand hygiene and had brief/transient contact with a patient who had symptoms that were not recognized to be COVID-19 at the time (e.g. confusion), it's possible that HCW may not be considered a close contact but this assessment would have to be done on a case by case basis by WHS/OHS/MOH/designate.

Regulated Health Professionals[N] in Community Healthcare Settings

- In private community healthcare settings, some health professionals are accountable to their regulatory body/colleges and some may have received professional guidance and training on PPE. These professionals are accountable to their college/regulatory body to follow guidance on the appropriate PPE products to use in their practice settings.
- **NOTE:** All regulated health professionals will be assessed by the MOH/designate regarding their IPC practices to determine if those offered sufficient protection while caring for COVID-19 patients. Quarantine recommendations based on this assessment are at the discretion of the MOH.

[N] This includes professionals regulated under the *Health Professions Act* and the *Veterinary Profession Act*.

Section 7: Management of Close Contacts Immunized Against COVID-19

- Vaccines against COVID-19 have been developed and approved for use in Alberta. For more information refer to COVID-19 Vaccines and the Alberta Health website on Vaccine Distribution.
- Current evidence suggests one dose of COVID-19 vaccines can offer very good protection against symptomatic COVID-19 infection and severe outcomes including hospitalization and death. A complete vaccine series offers even greater protection.[43]
- Due to the lower risk of infection in immunized persons and reduced transmission from them, the following quarantine requirements outlined in CMOH Order 26-2021 apply for Albertans who have received COVID-19 vaccine. Refer to Table **7a** below for more information:

Table 7a: Management of Immunized Close Contacts

Immunization Status on First Day of Exposure	Symptoms*	COVID-19 Testing Recommendations	COVID-19 Test Results	Management
Fully Immunized -more than 14 days after receiving the second dose of a two-dose vaccine series OR one dose in a one-dose vaccine series	No	No	If NO test done OR if tested & result is negative	NO quarantine required
			If tested & result is positive	Manage as a confirmed case of COVID-19
	Yes Begin to isolate*	Yes Test immediately after symptom onset	If NO test done	Manage as a probable case, Continue to isolate**
			Result is negative	Strongly recommended to stay at home and limit contact with others until symptoms resolve. NO quarantine required
			Result is positive	Manage as a confirmed case of COVID-19
Partially Immunized -more than 14 days after receiving one dose in a two-dose vaccine series	No Begin to quarantine	Yes Test on day 7 or later after exposure	If NO test done	Complete quarantine for 10 days from last day of exposure
			If tested BEFORE day 7 & result is negative	
			If tested on day 7 or later & result is negative	Quarantine lifted after negative test result received
			If tested at any time and result is positive	Manage as a confirmed case of COVID-19
	Yes Begin to isolate*	Yes Test immediately after symptom onset	NO test done	Manage as a probable case, Continue to isolate**
			If tested BEFORE day 7 & result is negative	Complete quarantine for 10 days from last day of exposure***
			If tested on day 7 or later & result is negative	Quarantine lifted after negative test result received AND Strongly recommended to stay at home and limit contact with others until symptoms resolve.
			If tested at any time & result is positive	Manage as a confirmed case of COVID-19

This includes symptoms outlined in Table 2a: Symptom List for COVID-19 Testing
"Isolate for 10 days from onset of symptoms or until symptoms have improved AND afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer
"" If tested again on day 7 or later, quarantine can be lifted after receipt of negative result.

Other Considerations:

- There may be circumstances where it is operationally or medically necessary to exceed the above recommendations.
  - The Medical Officer of Health, their designate or IPC team responsible for a public health investigation, having conducted a clinical assessment, may require individuals to quarantine for periods longer than the timeframes included above.
  - Organizations (including Alberta Health Services) may require more stringent/longer exclusions for higher risk clinical settings or for vulnerable populations.
- Quarantine outlined in **Table 7a** does not apply to international travelers returning to Canada. International travelers must comply with federal quarantine required by the federal *Quarantine Act*.
- **NOTE:** Individuals who are immunocompromised and immunized should discuss testing recommendations with their primary care physician. Profoundly immunocompromised individuals who are fully or partially immunized may have a reduced immune response to immunization. Although there are no different legal quarantine requirements if they are exposed to a COVID-19 case, it is recommended that those in this category exercise extra caution knowing that they may be at higher risk of becoming infected and exposing others.

Additional Recommendations

- During the 14 days post-exposure, the following apply for fully or partially immunized individuals when not required to quarantine:
  - may return to work, school, childcare, and other activities,
  - they must adhere to all public health measures to minimize transmission, including wearing a mask, physical distancing, practicing proper hand hygiene and respiratory etiquette
  - reduce their number of contacts when possible (especially avoiding non-essential visits to continuing care or acute care settings),
  - self-monitor for symptoms and isolate immediately and get tested if develop symptoms.
  - Immunized HCWs are still required to adhere to existing PPE guidance. Refer to AHS Personal Protective Equipment (PPE) website.

Annex A: Testing Performance

Testing Performance:

Real-time Reverse Transcriptase-PCR Tests

The overall performance of COVID-19 molecular tests to determine or rule out lab-confirmed COVID-19 cases depends on sensitivity/specificity of the test, stage of illness and the epidemiology of COVID-19 in the population.[44,45]

False negative rates of molecular tests used to test for SARS Co-V-2 ranges from 1 to 30%. The following may lead to false negative results:

- Low viral load,
- insufficient virus at the time of specimen collection (i.e., early in the incubation period or later in the course of illness),
- low analytic sensitivity,
- variability in viral shedding or
- inappropriate specimen type.[46]

False negative results pose a challenge in public health management of COVID-19 cases as an individual may still be infected and be infectious to others. If the clinical index of suspicion is high, a negative result should not rule out disease and the test should be repeated.[O]

Although considered extremely rare, false positive results can happen because of non-specific PCR reactions, contamination, or specimen mislabeling or mix-up .The proportion of false positive results increases as the prevalence of COVID-19 in the population decreases.[45] If a test is thought to be a false positive, the test should be repeated. For more information refer to the COVID-19 Scientific Advisory Group Rapid Response Report.

COVID-19 rapid nucleic acid tests (NAT) such as Simplexa®, GeneXpert®, or BD Max™ are now available in Alberta and provide test results within six hours of receipt at the hospital laboratory. These kits are considered Rapid COVID-19 Tests and are referred to as such in the current reporting scheme used by APL and Dynalife. The performance characteristics of these rapid tests are similar to the COVID-19 lab-developed test being used at the APL and additional confirmatory testing is not necessary.[47]

CT Values

There is considerable interest in using cycle threshold (CT) values produced by real-time PCR assays to help guide interpretation of tests and patient management. While CT values provide a general sense of the level of viral nucleic acid in a given sample, they are raw values generated by the testing instruments and are not meant to be interpreted in a quantitative manner. CT values are not routinely reported by the laboratory and caution must be exercised in their interpretation if they are disclosed. APL discourages the use of CT values to guide patient management. Any interpretation of CT values must take the following into account:

- CT values are not viral loads – all tests used in Alberta are qualitative tests and therefore do not provide viral loads.
- No COVID-19 PCR assays are FDA or Health Canada authorized as quantitative tests.
- CT values are imprecise measurements due to the heterogeneous nature of respiratory specimens.
- CT values are also dependent on collection quality, sample type, transport medium, transport conditions, and shipping time.

[O] While waiting for results of the repeat test, the suspect case should continue to isolate or if hospitalized, continue to be on droplet and contact precautions.

- CT values are not suitable predictors of transmissibility, which is dependent on numerous clinical factors as well. CT values for the same samples will vary widely depending on the instrument and assay used – they are not comparable from assay-to-assay.[48]

Serology Testing

Limitations of serology tests include the following:

- They are not useful in the diagnosis of acute COVID-19 infection (see above for more information).
- The relationship of various antibody types, amounts and timing of appearance to immunity is currently unknown.
- The sensitivity of serology testing in immunocompromised individuals or the elderly is currently not known.

Serological assays may be useful in targeted sampling studies in the population to model the spread of the virus and the immune response dynamics to inform the risk of further epidemic waves. They may also be used for retrospective case identification, diagnosing post-infectious complications, and to more accurately determine the prevalence of COVID-19 infection.[45]

Rapid COVID-19 Tests

Health Canada has approved a number of rapid tests for diagnostic use in symptomatic individuals, including the ID NOW™, PanBio™ manufactured by Abbott which are available in certain sites in Alberta. The ID NOW™ is a molecular test which detects SARS-CoV-2 from throat swab specimens and approaches the sensitivity and specificity of lab-based molecular testing done by APL. The PanBio™ is an antigen test which has high specificity but reduced sensitivity (higher rate of false negative results) that detects SARS-Co-V2 from nasopharyngeal or nasal specimens. The BD Veritor™ is another point-of-care antigen test recently introduced in Alberta. In situations where pre-test probability for COVID-19 infection is high, referral for RT-PCR testing at APL is necessary to confirm negative results from antigen tests.[33,47,49]

The ID NOW™, PanBio™ and BD Veritor™ provide results in approximately 15 minutes. For best performance, it is recommended these tests be used in individuals who have been symptomatic for less than seven days and are not recommended for use in those who are asymptomatic or who have been symptomatic for more than seven days.[49,50] However, the ID NOW may be used in asymptomatic close contacts of a confirmed case of COVID-19.[51]

Annex B: Isolation and Quarantine

Isolation is required for the following:

- It is highly recommended that ALL cases of COVID-19 (VOC or non-VOC) isolate completely away from their household members to prevent ongoing exposure. If this cannot be accomplished at home, use of an isolation hotel or a different dwelling should be considered.
  - If the case isolates at home, the following would apply:
    - the case must remain completely away from others, in a separate room with access to their own bathroom.
    - if the case must use a shared space, even temporarily when others are not present (such as a hallway to the bathroom), the case must wear a mask.
    - if there are multiple individuals in the household, these individuals should also remain separate from each other as much as possible.
    - If any household contacts become a COVID-19 case, the remainder of the household contacts will have to restart their quarantine period based on their last date of exposure to the most recent case.
- Individuals with new onset of any of the following symptoms: fever (over 38 degrees Celsius) and/or new onset of (or exacerbation of chronic) cough, SOB/difficulty breathing, sore throat or runny nose, loss of sense of taste or smell must isolate for 10 days from onset of symptoms or until symptoms have improved AND afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer.
- **NOTE**: Exemption applies for children with runny nose or sore throat. See Exemptions to Mandatory Isolation/Quarantine.
- Individuals with any of these symptoms and others listed in **Table 2a: Symptom List for COVID-19 Testing** should complete the online COVID-19 self-assessment or call 811 to arrange for testing, and remain isolated until test results are available:
  - If COVID-19 test result is positive, manage as a confirmed case and continue isolation for 10 days from onset of symptoms or until symptoms have improved AND afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer.
  - If person was NOT a close contact and if COVID-19 test result is **negative,** they are strongly recommended to stay at home and limit contact with others until symptoms resolve.
  - If person was a close contact to COVID-19 and if COVID-19 test result is negative, they still MUST complete the 14-day **quarantine** since their last exposure.
- For more information on isolation requirements refer to the COVID-19 Alberta website.

Quarantine is required for the following:

- Returning international travelers must follow federal quarantine requirements after arrival in Canada (unless exempted by Federal/Provincial Government) and should monitor for symptoms. Refer to **Table 2a: Symptom List for COVID-19 Testing.**
  - If at any time during the quarantine period they develop symptoms, they should follow instructions provided by Government of Canada upon arrival in Canada. This may include accessing provincial COVID-19 testing by completing the online COVID-19 self-assessment or call 811 to arrange testing for COVID-19:
    - If COVID-19 test result is negative, continue quarantine for full 14 days.
    - If COVID-19 test result is positive, isolation is required for 14 days from onset of symptoms or until symptoms have improved AND afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer.
- The following quarantine requirements apply for unimmunized close contacts. For close contacts who are immunized, refer to Section 7: Management of Close Contacts Immunized Against COVID-19
  - Close contacts of **confirmed** cases **must** quarantine for 14 days since last exposure and should monitor for symptoms. Refer to **Table 2a: Symptom List for COVID-19 Testing.**
  - Close contacts of **probable** cases **should** also be quarantined for 14 days since last exposure and monitor for symptoms.
  - Quarantine requirements for household contacts: The last day of exposure for household contacts depends on whether the case is able to isolate adequately away from the household or not:
    - A case is considered to be adequately isolated from their household members at home if they are able to remain completely away from others (i.e. in a separate room with access to their own bathroom and no interaction with the rest of their household or if they are isolating in an isolation hotel).
    - The last day of exposure for household contacts of cases who CAN adequately isolate away from their household members would be the day the case went into an adequate isolation location e.g. went to an isolation hotel.
    - All household contacts of cases who CANNOT adequately isolate away from their household members are required to quarantine every day they are exposed to the case during the case's isolation period, and continue their quarantine for 14 days after the last day of exposure (i.e., the last day of isolation for the case).
  - Close contacts of confirmed/probable cases should be offered testing and instructed to complete the online COVID-19 self-assessment or call 811 to arrange testing for COVID-19. For more information refer to **Table 2b: Management of Tested Individuals**. As of April 28, 2021, one test is recommended for all close contacts during their quarantine period:
    - Arrangements for the test should occur when they are first notified they are a close contact.
    - If at any time during the quarantine period, the close contact becomes symptomatic they should be re-tested.
    - NOTE: Under certain circumstances, and in certain settings such as acute care facilities and long-term care facilities, additional testing recommendations are at the discretion of the MOH.
- For more information on quarantine refer to difference between quarantine and isolation

Exemptions to Mandatory Isolation/Quarantine

Children Under the Age of 18

- Runny nose and sore throat were removed from the core symptom list on the Alberta Health daily checklist for children and youth under the age of 18 years, as well as all students who attend kindergarten to grade 12, including high school students over 18 years, in October 2020.
- Any child with a single symptom of runny nose or sore throat but no fever, cough, SOB/difficulty breathing and who has **NO KNOWN EXPOSURE** is exempt from the 10 day isolation requirement as outlined in the exemption for individuals under 18 years of age.
- For more information refer to the COVID-19 Alberta Health Daily Checklist and the Alberta Health website on changes to the daily symptoms checklist for children under 18.

Immunized Individuals [P]

- Following the administration of any vaccine, an immunized person should be counseled about the risk of short-term self-limited side effects, including local reactions and systemic reactions.
- Because some side effects following immunization such as fever, fatigue, headache, muscle/joint ache, vomiting/diarrhea are similar to symptoms for COVID-19, if a vaccine recipient develops these symptoms after vaccination in the expected timeframe for that vaccine (for most vaccines: within 24 hours; for MMR, Varicella and MMRV, usually within **five** to 12 days; COVID-19 vaccines, usually within a few hours to a few days), they should stay home and away from others.
- If the symptoms resolve within **two** days (48 hours), they can resume normal activities, unless they have been instructed to quarantine or isolate for other reasons.
- If the symptoms do not resolve within **two** days (48 hours) of symptom onset, they should continue to stay home and complete the online COVID-19 self-assessment or call 811 to arrange testing.
- If testing is not done, anyone 18 years of age and older should remain at home for 10 days after onset of symptoms if they exhibit any of the following symptoms - fever, cough, runny nose, sore throat, shortness of breath, loss of sense of taste or smell until symptoms have improved AND afebrile for 24 hours, without the use of fever-reducing medications, whichever is longer. For information about children under 18 years old or about students who attend kindergarten to Grade 12, including high school students over 18, refer to the COVID-19 Alberta Health Daily Checklist
- Anyone (adult/child) with other COVID-19 symptom list outlined in Table 2a: Symptom List for COVID-19 Testing but not included in CMOH Order 26-2021 or exempted as outlined in the COVID-19 Alberta Health Daily Checklist should stay at home until symptoms resolve.

[P] Exemptions are outlined in Clarification of CMOH Order 05-2020 posted on the Alberta Health website August 27, 2020.

Annex C: Management of COVID-19 Outbreaks

Outbreak-related Definitions

- **Outbreak:** *"The occurrence of cases of disease in excess of what would normally be expected in a defined community, geographical area or season"* (World Health Organization, 2018). **NOTE**: A common source of infection or the identification of transmission between cases are not requirements for an outbreak. The epidemiologic features of an outbreak and subsequent public health actions are assessed through the outbreak investigation process.
- **Alert:** A warning sign that the situation may evolve into an outbreak. The threshold for triggering an alert is dependent on the specific setting. For more information, refer to Table C1: Outbreak Definitions of COVID-19.
- **Public Reporting:** The minimum number of cases marking the threshold for public reporting of COVID-19 outbreaks.

Management of Community Outbreaks

- A COVID-19 outbreak may be declared for community settings based on outbreak definitions listed in Table C1: Outbreak Definition of COVID-19. The *Alberta Outbreak Reporting Form (AORF)* ***must*** be completed and sent to Alberta Health when an outbreak is declared as described in Table C1.
- An outbreak in the community or workplace/work camp may be declared over 28 days (i.e., two incubation periods) from date of onset of symptoms in the last case.

Table C1: Outbreak Definitions of COVID-19

- **NOTE:** Different alert and outbreak definitions are developed for different settings according to the risk level of that specific setting.
- The risk level is based on the combination of vulnerability of the population to severe illness and ease of transmission within the setting. It is critical to take early action to investigate and institute control measures.

Type of Setting	Risk	Example	Alert	Outbreak**	Public Reporting
Congregate Settings	Very High Risk	Continuing Care, Long-term Care, DSL	1 symptomatic person (see Table A3)	1 confirmed case	2 confirmed cases
		Acute care	See AHS Acute Care Outbreak document	See AHS Acute Care Outbreak document	
	High Risk	Prisons/Correctional Facilities	1 symptomatic person (see Table A3)	1 confirmed case	5 confirmed cases
		Homeless Shelters or Temporary Housing	1 symptomatic person (see Table A3)	1 confirmed case	5 confirmed cases
	High Risk Workplaces	Standalone work camps OR work sites with ≥ 1 work camp	2 confirmed case¥	5 confirmed cases€	10 confirmed cases
		Workplaces where individuals work in close proximity indoors for extended periods of time e.g. Food Processing Facilities, Warehouses, Distribution, or Manufacturing Facilities etc.	1 confirmed case¥	2 confirmed cases€	10 confirmed cases
	Medium Risk	Schools	See Table C5: Management of Outbreaks in Schools (K-12)		
		Child care setting: includes daycares, after school care, day homes and preschools	2 symptomatic individuals within 48 hours ***OR*** 1 confirmed case (see Table A4)	2 confirmed cases€	5 confirmed cases
Events	Medium Risk	*Including but not limited to weddings, funerals, religious gatherings, community events and small gatherings with more than one household*	N/A	5 confirmed cases*	10 confirmed cases associated with at least 3 households
Public Settings	Medium-Low Risk	*Including but not limited to hair salons, restaurants, retail spaces, indoor or outdoor recreation facilities, etc.*	N/A	5 confirmed cases*	10 confirmed cases
		Post-Secondary Institutions (i.e., classes, cafeteria/restaurant, residences)	See Table C6: Management of Outbreaks in PSI		
Other work places	Medium-Low Risk	*Workplaces that do not fit into the categories above (e.g. office buildings, group homesΩ, work sites with no association with a work camp ***)*	N/A	5 confirmed cases*	

"Confirmed case(s) needs to have been in the setting during their incubation period or infectious period
¥ Work camps and other facilities: Consider involvement of Environmental Public Health to ensure knowledge of the worksite and workforce. For schools refer to the Resource Guide for COVID-19 Outbreaks in Schools.
€Case numbers within a 14 day period, OR cases with an epi link (i.e. an exposure at a common setting, presence at a gathering, or time spent in a common location or venue, where there is reasonable evidence that transmission could have occurred)
**Case numbers within a 14 day period, OR cases with an epi link (see above) AND at least two or more households are involved.*
ΩThese are group homes not covered by CMOH Order 23-2021.
**** Work sites where all workers leave site using own transportation or charter/shuttle bus and go to nearest municipality (e.g., Fort McMurray) to their own private accommodations at the end of each shift.*

Management of COVID-19 Outbreaks in Facility/Other Congregate Settings[Q]

Testing of Staff/Residents/Children

- Testing should be done for the following symptomatic individuals:
  - Residents/staff in facilities as per CMOH Order 23-2021 (i.e., licensed supportive living (including group homes and lodges), long-term care (nursing homes and auxiliary hospitals), and hospice services,
  - Residents/staff in other congregate settings* not covered by CMOH Order 23-2021 (e.g., corrections, shelters)
- Refer to **Table C2: Symptoms to Initiate Testing**.
- For more information on testing refer to Section 2: Testing Modality, Recommendations, Interpretation and Management.

Table C2: Symptoms to Initiate Testing

• Staff in Facility • Staff/Resident in Other Congregate Setting[U] • Staff/Children in Childcare Setting/School	Residents in Facility
- Fever - Cough (new cough or worsening chronic cough) - Shortness of breath/difficulty breathing (new or worsening) - Runny nose - Sore throat New/unusual onset of any of the following: - Stuffy nose - Painful swallowing - Headache - Chills - Muscle/joint ache - Feeling unwell/fatigue/severe exhaustion - Nausea/Vomiting/Diarrhea/Unexplained loss of appetite - Loss of sense of smell or taste - Conjunctivitis	- Fever (37.8°C or higher) - Cough (new cough or worsening chronic cough) - Shortness of breath/difficulty breathing (new or worsening) - Runny nose - Sore throat NEW ONSET of any of the following: - Stuffy nose/Sneezing - Hoarse Voice/Difficulty or Painful swallowing - Headache - Chills - Muscle/joint ache - Feeling unwell/fatigue/severe exhaustion - Nausea/Vomiting/Diarrhea/Unexplained loss of appetite - Loss of sense of smell or taste - Conjunctivitis - Altered/change in mental status

- For recommendations on management of outbreaks in facilities and other congregate settings refer to **Table C3: Management of COVID-19 Outbreaks in Facility/Other Congregate Settings**

[Q] Congregate settings are defined as locations where individuals live, work or are cared for within close quarters in a communal environment.

Table C3: Management of COVID-19 Outbreaks in Facility/Other Congregate Settings[U]

Setting	Management of a Single Symptomatic Person	Definition of COVID-19 Outbreak	Management of Confirmed COVID-19 Outbreak
Facility (e.g., long term care facility) Other Congregate Setting[U] (e.g., corrections, shelters)	• For any staff/resident with symptoms listed in Table C2 above, the following actions apply: - Resident must be isolated, placed on contact and droplet precautions and tested for COVID-19. - Any symptomatic staff MUST NOT work. They must self-isolate at home and arrange for COVID-19 testing on site or via the HCW screening online tool. • Determine any urgent issues for the site/facility e.g., access to testing, personal protective equipment (PPE) etc. • No reporting to Alberta Health (AH) required. • If test results are negative for COVID-19, usual influenza like-illness (ILI) or gastrointestinal illness (GI) outbreak protocols (e.g., daily line lists, enhanced IPC and other control measures) should be followed, as appropriate to the identified organism causing the outbreak and report to AH as per usual processes.	A COVID-19 Outbreak is defined as: - Any resident who is confirmed to have COVID-19 and/or - Any staff member who is confirmed to have COVID-19[R] AND worked at the site during the period of communicability OR likely acquired infection at work	- All confirmed COVID-19 outbreaks should be investigated and reported

[R] This refers to staff in facilities as per CMOH Order 23-2021 and in other congregate settings who **worked** at the site/s during the incubation period or during the communicable period **WITHOUT** appropriate PPE. (See section on Management of HCW). This also includes any staff who may have been symptomatic even while using continuous masking, eye protection and practicing good hand hygiene.

- The communicable period is defined as 48 hours before symptom onset to isolation date in symptomatic cases, OR 48 hours before lab specimen collection date to isolation date in asymptomatic cases.
- **NOTE:** If staff worked at multiple sites in the 48 hours prior to symptom onset/lab test **WITHOUT** appropriate PPE, outbreak should be declared at those sites.

Other COVID-19 Outbreak Management Recommendations for Facilities

- For more information refer to the AHS Guidelines for COVID-19 Outbreak Prevention, Control and Management in Congregate Living Sites and the CMOH Order 23-2021.
- An outbreak in licensed supportive living (including group homes and lodges), long-term care (nursing home and auxiliary hospitals) and hospice services may be declared over after 28 days (two incubation periods) from date of onset of symptoms in the last case, with the following exception
  - If a staff member is the only confirmed case at the outbreak site, the outbreak can be declared over after 14 days from their last day of work.
    - **NOTE:** Asymptomatic staff and residents should NOT be retested during a site outbreak if they were a lab confirmed COVID-19 case within the past 90 days. For more information, refer to the Testing and Management of Resolved Cases section.

PPE Recommendations for Staff during a Confirmed Facility COVID-19 Outbreak

- Where there is evidence of transmission (defined as two or more lab-confirmed COVID-19 cases), continuous use of surgical/procedure mask and eye protection (e.g., goggles, visor, or face shield) is recommended for all staff providing direct face-to-face care of residents/patients.
- Full contact and droplet precautions should be applied when providing care to any symptomatic person (including any lab-confirmed case of COVID-19) until that person is determined by IPC (where available) or the MOH/designate to be non-infectious.
- **NOTE:** For PPE recommendations for all other patient care areas in AHS and community settings with NO COVID-19 outbreak, refer to the AHS website on Personal Protective Equipment (PPE)

Management of COVID-19 Outbreaks in Child Care Settings

- Child care settings includes daycares, after school care, preschools, and day homes.
- Parents/students should be instructed to complete the COVID-19 Alberta Daily Checklist (for Children under 18) before going to childcare and follow instructions as outlined in the checklist.
- Childcare staff should complete the COVID-19 Alberta Daily Checklist for adults before going to a childcare setting.
- For staff with COVID-19 symptoms listed in Table C2: Symptoms to Initiate Testing the following actions apply:
  - Any symptomatic staff MUST NOT work. They must isolate at home and arrange testing via the online COVID-19 self assessment or call 811.
  - Refer to Table C4: Management of COVID-19 Outbreaks in Child Care Setting for more information.
  - An outbreak in a child care setting can be declared over 28 days (two incubation periods) after date of onset of symptoms in the last case.
- Asymptomatic staff and children should NOT be retested during a childcare setting outbreak if they were a lab confirmed COVID-19 case within the past 90 days. For more information, refer to the Testing and Management of Resolved Cases section.
- **NOTE:** For any child with a rash illness, follow usual notification/management process as outlined by AHS.

Table C4: Management of COVID-19 Outbreaks in a Child Care Setting

Setting	COVID-19 Alert		COVID-19 Outbreak	Management of Confirmed COVID-19 Outbreak
	Two Symptomatic Individuals	One Confirmed Case		
Child Care Setting	• Two symptomatic individuals (child/staff) within 48 hours • The child care setting must call the Coordinated Early Identification and Response (CEIR) Team at 1-844-343-0971 to connect with public health who will: - advise on additional IPC measures, - recommend testing for symptomatic persons via the online COVID-19 self assessment tool or call 811 - refer to EPH or CDC if investigation determines symptoms may be due to another pathogen • No reporting to Alberta Health (AH) required. • If test results are negative for COVID-19, usual influenza like-illness (ILI) or gastrointestinal illness (GI) outbreak protocols (e.g., daily line lists, enhanced IPC and other control measures) should be followed, as appropriate to the identified organism causing the outbreak and report to AH as per usual processes.	When there is one confirmed case (staff/child) in a child care setting, actions include but not limited to the following: - Case investigation and contact follow-up - Engagement with the child care setting as appropriate to ensure measures are in place to prevent spread, identify additional cases early and communicate with parents in a timely manner - Report to AH	A COVID-19 Outbreak is defined as: - Two confirmed cases (staff/child) within 14 days (one incubation period) OR - Two confirmed cases (staff/child) that are epidemiologically linked AND who were at the child care setting during the period of communicability OR likely acquired infection at that setting	All confirmed COVID-19 outbreaks should be investigated and reported

Management of COVID-19 Outbreaks in Schools (K-12)

- Parents/students should be instructed to complete the COVID-19 Alberta Daily Checklist (for Children under 18) before going to school and follow instructions as outlined in the checklist.
- School staff/teachers should complete the COVID-19 Alberta Daily Checklist for adults before going to school.
- For one staff with COVID-19 symptoms listed in Table C2: Symptoms to Initiate Testing, the following actions apply:
  - Any symptomatic staff MUST NOT work. They must isolate at home and arrange testing via the online COVID-19 self assessment or call 811.
- Refer to Table C5: Management of COVID-19 Outbreaks in Schools for more information. For full guidance, please refer to the COVID-19 guidance and health measures for K-12 schools website
- An outbreak in a school can be declared over 28 days (two incubation periods) after date of onset of symptoms in the last case.
- **NOTE:** Asymptomatic staff and children should NOT be retested or quarantined during a school outbreak if they were a lab confirmed COVID-19 case within the past 90 days. For more information, refer to the Testing and Management of Resolved Cases section.

Table C5: Management of COVID-19 Outbreaks in Schools (K-12)

Setting	COVID-19 Alert	COVID-19 Outbreak	Management of Confirmed COVID-19 Outbreak
School	• One confirmed case (i.e., staff, student and/or visitor) in the school setting who was present at the school while infectious and/or most likely became infected at the school. • Actions during an alert include but not limited to the following: - Engagement with the school as appropriate to ensure measures are in place to prevent further spread - Communication with parents/ school board - Report to AH	A COVID-19 Outbreak investigation will begin when: - Two confirmed cases (i.e., staff, student and/or visitor) within 14 days (one incubation period) who were present at the school while infectious and/or most likely became infected at the school OR - Two confirmed cases (staff, student and or visitor) that are epidemiologically linked who were present at the school while infectious and/or most likely became infected at the school. Outbreak investigations in schools will be publicly reported on the Alberta Health website as follows: - A school with 2-4 confirmed cases will be publicly reported as an "Alert (2-4 cases)" - A school with 5-9 confirmed cases will be publicly reported as an "Outbreak (5-9 cases)" - A school with 10+ confirmed cases will be publicly reported as an "Outbreak (10+ cases)"	- All confirmed COVID-19 outbreak investigations should be investigated and reported

Management of COVID-19 Outbreaks in Post-Secondary Institutions (PSI)

- PSI should follow recommendations as outlined in the Post-Secondary Institution Guidance document posted on the BizConnect website.
- Refer to Table C6: Management of COVID-19 Outbreaks in PSI for more information.
- An outbreak in PSI can be declared over 28 days (two incubation periods) after date of onset of symptoms in the last case.

Table C6: Management of COVID-19 Outbreaks in PSI

Setting	COVID-19 Alert	COVID-19 Outbreak	Management of Confirmed COVID-19 Outbreak
Class Setting or Other Program in which students/faculty are attending in person	N/A	A COVID-19 Outbreak is defined as: - Five confirmed cases (staff/student) within 14 days (one incubation period)	All confirmed COVID-19 outbreaks should be investigated and reported
Residence (operated/contracted by PSI to cater for PSI students in which students share dormitory rooms, bathrooms, food preparation/in residence food services)	Two confirmed COVID-19 cases (staff/student) in a PSI (staff/student) within 14 days (one incubation period)		
Restaurant/Cafeteria located on PSI	N/A		

Management of COVID-19 Outbreaks in a Workplace

- Any staff/client with COVID-19 symptoms listed in Table C2: Symptoms to Initiate Testing MUST NOT work and testing should be arranged by completing the online COVID-19 self assessment or by calling 811.
- Refer to Table C1: Outbreak Definitions of COVID-19 for information on COVID-19 alerts and confirmed outbreaks.

Notifications of Public Exposures of COVID-19

- In instances where it is determined that a known COVID-19 positive case attended a public space/event while infectious, every effort should be made by public health to identify close contacts and notify them individually of their exposure.
- However, in the following circumstances, notification of public exposures using communication tools such as distribution of letters or a media announcement may be considered to notify potentially exposed individuals of their risk and actions they should take:
  - If there is a significant exposure risk (e.g., case attended the public space/event two days before and/or within 5 days of their symptom onset with respiratory symptoms, multiple exposures or prolonged close contact, i.e., cumulative for a total of 15 minutes or more over a 24-hour period and within two metres with a case, crowded setting, confined and enclosed spaces with poor ventilation) AND there is no ability to identify close contacts AND it has been a short time since exposure occurred,
  - Site/event organizer not willing or able to provide contact lists,
  - Vulnerability of individuals in that setting e.g., seniors' coffee space
  - Other situations as determined by the MOH.
- These tools should be utilized on the recommendation of the Zone MOH and in collaboration with public health teams, impacted stakeholders, and Alberta Health.

Annex D: Management of Travelers

- An official global travel advisory is in effect and non-essential travel is NOT recommended.
- Any returning travelers to Canada, must follow mandatory requirements as laid out in the *Federal Emergency Order* under the *Quarantine Act* and CMOH Order 26-2021.
- Some individuals may be exempt from travel restrictions (e.g., if they provide critical services and have no symptoms, or meet other exemption criteria). For more information refer to the PHAC website on Exemptions to travel restrictions.

Flight Notification to PHAC for Posting on Their Website: Known COVID-19 + (VOC or non-VOC) Passenger on Board While Infectious

- Information for domestic/international flights with infectious cases are sent to PHAC to be posted on the Government of Canada Coronavirus disease (COVID-19): Locations where you may have been exposed.
- Local public health (AHS/FNIHB) will notify PHAC directly (and cc airline) of flights with known COVID-19 case that flew while infectious. Reporting criteria includes:
  - Cases who were symptomatic during travel, or
  - Cases with symptom onset/lab specimen collection date no more than 10 days BEFORE the date of travel, or
  - Cases with symptom onset no more than 48 hours AFTER the date of travel.
  - Flight has occurred within past 14 days.
- **NOTE:** since pre-symptomatic/asymptomatic transmission of COVID-19 can occur, individuals do not have to have been symptomatic while on the flight in order to post flight information on the website.
- Minimum information needed to post flight information:
  - Includes travel within Canada OR travel into Canada as a final destination (this may involve more than 1 flight for 1 person);
  - Flight date;
  - Airline and Flight Number;
  - Departure location and Arrival destination;
  - Seat/row information (if known);
  - Case Onset date (as per notifiable disease guideline for symptomatic/asymptomatic cases); and
  - DI (or NDR#) number & DI Initials (First Name Initial, Last Name Initial).

Flight Notification to Airline to Request Flight Manifest for Domestic Flights: Known VOC[(S)] Case on Board while Infectious

At this time flight manifests are only being requested for domestic flights (flights within Canada).

- Local public health (AHS/FNIHB) will request flight manifest from airline (and cc PHAC IJN) for flights with a confirmed/presumptive VOC case that flew while infectious within the last 21 days.
  - The same fields required here as for flight notification with addition of VOC identified or presumptive status
- Once manifest is received, local public health team reviews the list as outlined in the table.

[(S)] Public Health will request flight manifests for flights that had B.1.351 (Beta), P.1 (Gamma) and B.1.617.2 (Delta) variant case on board.

Table D1: Flight Notification Domestic Flights

	Alberta Health Services	Alberta Health
Domestic VOC Flights that have landed in Alberta	• **<u>All</u> flight contacts in affected rows will be followed-up by local PH.** - Flight contacts that are currently in AB (i.e., both residents and non-residents) will be managed by local PH. - Flight contacts that are not currently in AB, are to be transferred to Alberta Health via established processes (e.g., CDOM). - If unable to reach a flight contact the file should be closed as "Unable to Contact" or "Lost to Follow up"; do not transfer to AH.	• Alberta Health will obtain OOP/OOC flight contacts from local PH and transfer to appropriate P/T if in Canada and to PHAC if out-of-country (OOC). • If OOP/OOC notification has already occurred, AH will send updated VOC information to appropriate OOP/OOC jurisdiction
International VOC Flights that have landed in Canada or Alberta	• Do NOT request flight manifests due to the new federal quarantine requirements.[T]	• Not applicable.
AB VOC cases identified by another P/T and transferred to AB for reporting and management	• AB public health to follow-up and manage these cases for reporting and surveillance purposes. • Flight notifications and manifests should be made/requested as outlined above.	• OOP/OOC notifications as outlined above.

[T] Source: https://travel.gc.ca/travel-covid/travel-restrictions/flying/covid-19-testing-travellers-coming-into-canada#getting-tested

Provincial Chartered Flights

- Flight manifests, especially those relating to work camps, should be requested from the airline by the company's Occupation Health and Safety team as part of the case/contact investigation, and follow up as per guidance below. AHS should ensure that this has been completed and assist in the notification of out-of-province cases and contacts as per below.
- AHS/FNIHB will notify AH via established processes (e.g., CDOM) of any **cases that reside outside Alberta**, and that travelled **while infectious**. The following information should be included:
  - ULI or CDOM DI#,
  - Contact information (address, phone #)
  - Onset date of source case,
  - Dates of travel,
  - Airline(s), and
  - Seat number(s) (if known).
- AHS/FNIHB will notify Alberta Health via established processes (e.g., CDOM) of any **close contacts that reside outside of Alberta** and that travelled on the same flight as a confirmed case that require notification.
  - ULI or CDOM DI# (if available)
  - Contact information (address, phone #)
  - Dates of travel,
  - Airline(s), and
  - Seat number(s) (if known).
- Contact tracing of travelers on a chartered airplane who may have been exposed to case of COVID-19 during a flight should be made on a case-by-case basis based on the following:
  - case's classification (e.g., confirmed),
  - the type and severity of symptoms of the case during the flight,
  - movement of case around the plane cabin, and
  - distancing and preventive measures during flight.
- There is currently no evidence of transmission risk related to flight duration. The following recommendations apply regardless of length of flight.
- When a case(passenger) was symptomatic on the flight contact tracing should focus on the following:
  - passengers seated within two meters of the index case, AND
  - crew members serving the section of the aircraft where the index case was seated, AND
  - persons who had close contact with the index case, e.g., travel companions or persons providing care.
- Expanding the scope of contact tracing may be considered based on the severity of symptoms of the case (passenger) during the flight e.g., persistent coughing, sneezing, diarrhea or vomiting.
- If the case on the flight was a symptomatic crew member, contact tracing may also be considered for all passengers seated in the area where the crew member provided service and all other crew members.
- Refer to Management of Close Contacts of Confirmed/Probable Cases section for further management of these contacts.

Annex E: Preventative Measures

- For more information on prevention of COVID-19 refer to the following websites:
  - COVID-19 info for Albertans
  - Help prevent the spread
  - Information for Albertans
  - Measures to reduce COVID-19

Resources on COVID-19

- Alberta Health www.alberta.ca/coronavirus-info-for-albertans.aspx
- Alberta Health Services www.albertahealthservices.ca/topics/Page16944.aspx
- PHAC www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection.html
- WHO www.who.int/emergencies/diseases/novel-coronavirus-2019
- CDC www.cdc.gov/coronavirus/2019-ncov/index.html
- ECDC www.ecdc.europa.eu/en/novel-coronavirus-china

Annex F: Revision History

- **NOTE:** Revision history from 2020-01-29 to 2020-05-20 available in the Public Health Disease Management Guidelines: Coronavirus – COVID-19 posted August 28, 2020.

Revision Date	Document Section	• Description of Revision
2020-08-25	Case definition	• Under footnote A added information on the performance characteristics of the Simplexa®, GeneXpert®, or BD Max™ NAT
	Clinical presentation	• Added information on Multi-system inflammatory Syndrome in Children (MIS-C)
	Diagnosis	• Added information on Simplexa®, GeneXpert®, and BD Max™ NAT test results are considered confirmatory
	Section 2: Testing Modality, Recommendations, Interpretation and Management	• Added information on COVID-19 testing performance for molecular tests and serology • Added new section on management of resolved cases
	Section 3: Key Investigation	• Expanded close contact definition
	Section 5: Management of Close Contacts	• Added information on Guidance on the use of masks
	Section 6: Mandatory Quarantine & Isolation	• Added new information regarding immunized individuals with COVID-19 symptoms post immunization
	Annex A- Management of Outbreaks	• Expanded section to include outbreak definitions, management of COVID-19 outbreaks in childcare settings, schools and workplaces • Added section on notification of COVID-19 in public exposures
	Annex B: Management of Travelers	• Updated section on national and international flights
2020-01-03	Case Definition	• Added rapid/POC NAAT and antigen tests to the confirmed case definition • Footnote A updated to include info on the ID NOW and PanBio tests from Abbott
	General	• Order 23-2020 has been updated to Order 32-2020
	Clinical presentation	• Updated information to include symptoms most frequently observed in Canada
	Transmission	• Updated to include information on aerosol/airborne transmission
	Host Susceptibility	• Updated with conditions/individuals most susceptible to COVID-19
	Section 1: Diagnosis	• Information on rapid nucleic acid tests moved to Section 2: Testing Modality, Recommendations, Interpretation and Management

	Section 2: Testing Modality, Recommendations, Interpretation and Management	• Updated information on individuals eligible for testing in AB • Added section on Rapid COVID-19 Tests • Reworded section on Testing and Management of Resolved Cases
	Section 5: Management of Close Contacts	• Updated section on Guidance on the use of Masks • Added new section on Assessment of PPE in Workplaces
	Section 6: Mandatory Isolation and Quarantine	• Added section on Exemptions to Isolation/Quarantine
	Section 7: Management of HCW	• Added information on when HCW who are cases can return to work • Added that eye protection is recommended during patient interactions in places where community transmission is high • Added section on recommendations for regulated HCW
	Section 9: Management of Individuals Immunized Against COVID-19	• New section added
	Section 9: Preventative Measures	• Updated to include links to AH, AHS, PHAC websites
	Annex A: Management of COVID-19 Outbreaks	• Updated Outbreaks in Schools section to align with the School Outbreak Resource Guide • Added section on Outbreaks in Post-Secondary Institutions • Updated section on Notifications of Public Exposures of COVID-19
	Annex C:	• Older revisions removed. Table only includes revisions from August 2020.
2021-03-16	Annex A: Management of COVID-19 Outbreaks	• Updated some of the reporting thresholds in Table A1: Outbreak Definitions for COVID-19
	Annex C: Management of COVID-19 Variants of Concern	• New Annex added
	Annex D: Revision History	• This used to be the old Annex C
2021-05-27	Case Definition	• Probable Case definition updated to align with PHAC case definition • Suspect Case definition and Exposure criteria removed.
	Reporting Requirements	• Added reporting requirements for POCT (antigen & molecular) tests
	Epidemiology	• Sections updated to include information on variants of concern

	Public Health Management	• Added information that following sections on public health management apply to VOC and non-VOC cases and their close contacts
	Section 2: Testing Modality, Recommendations, Interpretation and Management	• Added information on rapid screening program
	Treatment of Cases	• Section updated
	Section 7: Management of Close Contacts Immunized Against COVID-19	• Updated to include new quarantine recommendations for fully and partially immunized individuals
	Annex A: Testing Performance	• This is a new annex and includes information from Section 2: Testing Modality, Recommendations, Interpretation and Management
	Annex B: Isolation and Quarantine	• New annex that includes information on isolation and quarantine from the previous Annex C: Management of VOC
	Annex C: Management of COVID-19 Outbreaks	• This was the previous Annex A
	Annex E: Preventative Measures	• New Annex. Information was in the epidemiology section

References

1. Heymann DL. Control of Communicable Diseases Manual. Washington, DC: American Public Health Association; 2015.
2. Government of Canada. 2019 Novel Coronavirus infection (Wuhan, China): For health professionals [Internet]. 2020. Available from: www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/health-professionals.html
3. Centers for Disease Control and Prevention (CDC). Symptoms of Novel Coronavirus (2019-nCoV) [Internet]. 2020. Available from: www.cdc.gov/coronavirus/2019-ncov/about/symptoms.html
4. NCCEH. The Basics of SARS-CoV-2 Transmission | National Collaborating Centre for Environmental Health | NCCEH - CCSNE [Internet]. 2021 [cited 2021 Apr 7]. Available from: https://ncceh.ca/documents/evidence-review/basics-sars-cov-2-transmission
5. Public Health Ontario. COVID-19 Variants of Concern (VOCs) | Public Health Ontario [Internet]. [cited 2021 Mar 29]. Available from: https://www.publichealthontario.ca/en/diseases-and-conditions/infectious-diseases/respiratory-diseases/novel-coronavirus/variants
6. Alberta Health Services SAG. COVID-19 Scientific Advisory Group Rapid Evidence Report COVID-19 Symptoms: Symptoms Predictive of a Positive COVID-19 Test, Duration of Symptoms, and Duration of RT-PCR and Viral Culture Positivity. 2021.
7. Hui DS, Azhar EI, Madani TA, Ntoumi F, Kock R, Dar O, et al. The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health The latest 2019 novel coronavirus outbreak in Wuhan, China. 2020; Available from: doi.org/10.1016/j.ijid.2020.01.009
8. ECDC. SARS-CoV-2 variants of concern pose a higher risk for hospitalisation and intensive care admission [Internet]. [cited 2021 May 8]. Available from: https://www.ecdc.europa.eu/en/news-events/sars-cov-2-variants-concern-pose-higher-risk-hospitalisation-and-intensive-care
9. AHS-Scientific Advisory Group. What risk factors (such as age, medical conditions, or lifestyle factors) are associated with the development of severe outcomes in COVID-19? 2020 Aug.
10. WHO. Expanding our understanding of post COVID-19 condition: report of a WHO webinar - 9 February 2021 [Internet]. 2021 [cited 2021 Jun 11]. Available from: https://www.who.int/publications/i/item/9789240025035
11. CDC. Post-COVID Conditions | CDC [Internet]. 2021 [cited 2021 Jun 11]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/long-term-effects.html
12. CPS. COVID-19 vaccine for children | Canadian Paediatric Society [Internet]. 2021 [cited 2021 Jun 11]. Available from: https://www.cps.ca/en/documents/position/covid-19-vaccine-for-children
13. Certain Medical Conditions and Risk for Severe COVID-19 Illness | CDC [Internet]. [cited 2020 Dec 4]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/people-with-medical-conditions.html
14. Health Ontario P. COVID-19 – What We Know So Far About...Kawasaki Disease-Like Illness.
15. CDC Health Alert Network. Multisystem Inflammatory Syndrome in Children (MIS-C) Associated with Coronavirus Disease 2019. 2020. p. 2019–21.
16. World Health Orgranization (WHO). Multisystem inflammatory syndrome in children and adolescents with COVID-19 [Internet]. 2020 [cited 2020 May 28]. Available from: https://www.who.int/publications-detail/multisystem-inflammatory-syndrome-in-children-and-adolescents-with-covid-19

17. WHO. Weekly epidemiological update on COVID-19 - 8 June 2021. 2021.

18. CDC. About Variants of the Virus that Causes COVID-19 | CDC [Internet]. 2021 [cited 2021 Apr 3]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/transmission/variant.html

19. CDC. Science Brief: SARS-CoV-2 and Surface (Fomite) Transmission for Indoor Community Environments | CDC [Internet]. 2021 [cited 2021 May 15]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/more/science-and-research/surface-transmission.html

20. Ending Isolation for Immunocompromised Persons | CDC [Internet]. [cited 2020 May 19]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/hcp/ending-isolation.html

21. AHS COVID-19 Scientific Advisory Group. COVID-19 Scientific Advisory Group Rapid Evidence Report Topic: Is being immunosuppressed (in its various forms) associated with increased likelihood of recognized COVID-19 and/or increased disease severity? . 2020.

22. European Centre for Disease Control and Prevention. Q & A on the novel coronavirus [Internet]. 2020. Available from: www.ecdc.europa.eu/en/q-novel-coronavirus

23. Woelfel R, Corman VM, Guggemos W, Seilmaier M, Zange S, Mueller MA, et al. Clinical presentation and virological assessment of hospitalized cases of coronavirus disease 2019 in a travel-associated transmission cluster. medRxiv. Cold Spring Harbor Laboratory Press; 2020 Mar 8;2020.03.05.20030502.

24. Public Health Ontario. COVID-19 – What We Know So Far About... Viral Detection. 2020 May.

25. KCDC. Findings from Investigation and Analysis of Re-positive Cases | [Internet]. 2020. [cited 2020 Jul 10]. Available from: https://www.cdc.go.kr/board/board.es?mid=a30402000000&bid=0030

26. Ontario PH. COVID-19 : Ongoing Viral Detection and Repeat Positives. 2020;1–9.

27. Centers for Disease Control and Prevention (CDC). Ending Home Isolation for Immuncompromised Persons with COVID-19. 2020.

28. COVID-19 in children and the role of school settings in COVID-19 transmission [Internet]. [cited 2020 Dec 3]. Available from: https://www.ecdc.europa.eu/en/publications-data/children-and-school-settings-covid-19-transmission

29. Health Ontario P. Public Health Management of COVID-19 Exposure Post Infection. 2021.

30. Governmernt of Canada. Interim guidance: Public health management of cases and contacts associated with novel coronavirus (2019-nCoV) [Internet]. 2020. Available from: www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/health-professionals/interim-guidance-cases-contacts.html

31. Precision Laboratories A. SARS-CoV-2 Variants of Concern [Internet]. 2021 [cited 2021 May 8]. Available from: https://www.albertahealthservices.ca/assets/wf/lab/if-lab-hp-bulletin-sars-cov-2-variants-of-concern.pdf

32. Laboratory Bulletins | Alberta Health Services [Internet]. [cited 2020 Apr 19]. Available from: https://www.albertahealthservices.ca/lab/Page3290.aspx

33. Ulrich A, Bartkus J, Moore KA, Hansen G, Mathieson MJ. COVID-19: The CIDRAP Viewpoint Part 3: Smart Testing for COVID-19 Virus and Antibodies [Internet]. 2020 [cited 2020 Jul 6]. Available from: www.cidrap.umn.edu.

34. Duration of Isolation and Precautions for Adults with COVID-19 | CDC [Internet]. [cited 2020 Nov 30]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/hcp/duration-isolation.html

35. Government of Canada. COVID-19 signs, symptoms and severity of disease: A clinician guide -

Canada.ca [Internet]. 2020 [cited 2020 Oct 5]. Available from: https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/guidance-documents/signs-symptoms-severity.html#tb1

36. PHAC. Re-testing guidance for COVID-19 - Nov 26 post SGBA clean EN. 2020;

37. CDC. Interim Guidance on Duration of Isolation and Precautions for Adults with COVID-19 [Internet]. 2021 [cited 2021 May 23]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/hcp/duration-isolation.html

38. Health A. Public Health Disease Management Guidelines | Meningococcal Disease [Internet]. 2019 [cited 2020 Jul 6]. Available from: https://open.alberta.ca/publications/meningococcal-disease-invasive-imd

39. BCCDC. Interim Guidance: Public Health Management of cases and contacts associated with novel coronavirus (COVID-19) in the community. 2020.

40. Ministry of Health NZ. Contact tracing for COVID-19 [Internet]. 2020 [cited 2020 Jul 6]. Available from: https://www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus/covid-19-health-advice-general-public/contact-tracing-covid-19

41. Wisconsin Dept of Health Services. Next Steps: Close Contacts of Someone with COVID-19. 2020 Jun.

42. Zhang W, Du R-H, Li B, Zheng X-S, Yang X-L, Hu B, et al. Molecular and serological investigation of 2019-nCoV infected patients: implication of multiple shedding routes. Emerg Microbes Infect [Internet]. 2020;9(1):386–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/32065057

43. NACI. National Advisory Committee on Immunization (NACI) Recommendations on the use of COVID-19 Vaccines [Internet]. 2021 [cited 2021 Jun 5]. Available from: https://www.canada.ca/content/dam/phac-aspc/documents/services/immunization/national-advisory-committee-on-immunization-naci/recommendations-use-covid-19-vaccines/recommendations-use-covid-19-vaccines-en.pdf

44. Woloshin S, Patel N, Kesselheim AS. False Negative Tests for SARS-CoV-2 Infection - Challenges and Implications. N Engl J Med [Internet]. 2020 Jun 5 [cited 2020 Jun 8];NEJMp2015897. Available from: http://www.ncbi.nlm.nih.gov/pubmed/32502334

45. National laboratory testing indication guidance for COVID-19 - Canada.ca [Internet]. [cited 2020 Jun 9]. Available from: https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/guidance-documents/national-laboratory-testing-indication.html

46. Kanji JN, Zelyas N, MacDonald C, Pabbaraju K, Khan MN, Prasad A, et al. False negative rate of COVID-19 PCR testing: a discordant testing analysis. Virol J [Internet]. BioMed Central Ltd; 2021 Dec 1 [cited 2021 May 8];18(1):13. Available from: https://doi.org/10.1186/s12985-021-01489-0

47. Alberta Precision Laboratories (APL). Rapid COVID-19 Testing Pilot for PLC and FMC Inpatients [Internet]. 2020 May [cited 2020 Jun 16]. Available from: www.albertaprecisionlabs.ca

48. Virus R, Working I. PCR and Ct values in COVID-19 testing – Frequently Asked Questions and Important Considerations.

49. AHS-Scientific Advisory Group. COVID-19 Scientific Advisory Group Rapid Evidence Report Do the rapid COVID-19 tests on the market represent a feasible opportunity for Alberta? 2020;

50. Stokes W, Labs AP. Rapid Tests for SARS-CoV2 : Abbott ID NOW COVID-19 (molecular test) and Abbott PanBio COVID-19 Antigen Rapid Test (antigen test) ID NOW COVID-19 PanBio COVID-19 Antigen Rapid Test. 19:0–3.

51. Alberta Precision Laboratories (APL). COVID-19 POCT with ID NOW or Panbio Availability in Assessment Centres Across Alberta [Internet]. 2021 [cited 2021 Jun 6]. Available from:

https://www.albertahealthservices.ca/assets/wf/lab/if-lab-hp-bulletin-new-test-criteria-and-locations-for-acute-care-on-site-id-now-covid-19-testing.pdf

Notifications

COVID-19 Updates

- Alberta entered Stage 3 on July 1: Limited restrictions remain.
- Get vaccinated: Everyone 12+ can book first and second doses now.

THIS IS EXHIBIT " X " referred to in the Affidavit / Declaration of Dr. Deena Hinshaw.
affirmed
~~Sworn / Declared~~ before me this 12th day of July A.D., 2021
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public.
Heather L. Veale
Barrister & Solicitor

Alberta.ca

Home → Government → About government → Government organizational structure → Alberta Cabinet → Government of Alberta articles

Herd immunity and the Great Barrington Declaration

Alberta's Chief Medical Officer of Health on the right approach for Alberta.

Posted by

Dr. Deena Hinshaw

Date

October 28, 2020

Topic

COVID-19

There has been a significant amount of discussion recently about the Great Barrington Declaration[1]. Its authors promote an approach to COVID-19 that they call "Focused Protection". They describe this approach as follows: "...to allow those who are at minimal risk of death to live their lives normally to build up immunity to the virus through natural infection, while better protecting those who are at highest risk."

This is a very appealing statement to those who are tired of restrictions and in a context where the economic and social impacts of the restrictions are being felt keenly by those under 60, ("retirement age" is the cut off proposed in the Barrington document) who are at lower risk of severe outcomes. Unfortunately, the claim that this approach is achievable with minimal impact is not correct for several reasons.

Evidence around long-lasting immunity is still unclear

First, the stated goal of this approach is to build up herd immunity through infection, which assumes that infection by SARS-CoV2, the virus that causes COVID-19, will automatically confer long-lasting protection against future infections.

This is not currently known to be the case. Other common coronaviruses that cause respiratory infections in humans have been shown to cause repeat infections[2]. With COVID-19 specifically, there have been rare individual documented cases of re-infection with SARS-CoV2.[3, 4, 5, 6] At a population level, the Brazilian city of Manaus was widely cited as having reached herd immunity with approximately 66% of the population testing positive for antibodies[7, 8, 9], yet there are recent reports of a resurgence of cases with up to 50 new deaths per day.[10, 11]

Therefore making the assumption that widespread infection will confer lasting immunity is not certain to be true.

Increased deaths

However, if we assumed for the sake of argument that infection does confer immunity, there are still issues with the herd immunity plan. The second problem with the premise of the Great Barrington Declaration is the inaccurate assertion that if we segregate the old and the young, and let the young live 'normally', potentially getting infected along the way but not passing the virus to older people, herd immunity could be achieved with few costs in health related to COVID.

Returning to the city of Manaus in Brazil, it is important to know that although just 6% of its population is over the age of 60[9], the high antibody level in the city still came at a high price – a death toll estimated between 2,500 and 3,400[8, 11], in a city of about 1.8 million. If we had the same overall per-capita death rate, to reach 66% antibody positivity would cost us between 6,100 and 8,300 deaths in Alberta. It is not clear what proportion of the deaths in Manaus were in those over age 60, but even if we assume that we could somehow completely protect those over 60 from infection, and that the risk of death from infection would just be in those living 'normally' (under age 60), there would still be a cost in deaths.

If we use our own Alberta data on the age-specific risk of death in those diagnosed with COVID[12], and if we assumed that reaching a 50% infection rate was sufficient for herd immunity (though many estimates are that a higher percentage would be required), infecting 50% of those in the Alberta population under 60 would cost approximately 1,000 lives in that same younger population.

Increased hospitalizations

Assuming we were willing to pay that cost in lives for the benefit of 'normal' life in younger age groups, the other thing to remember is that death is not the only severe outcome. Hospitalization and ICU admissions are also severe outcomes that are more common than death in all age groups. Again, assuming we could somehow successfully segregate those over 60 from those under 60, and using our own Alberta data for age-specific risk of hospitalization in diagnosed cases, we would expect over 39,000 hospitalizations to achieve an infection rate of 50% in the population under the age of 60.

Using diagnosed case fatality and hospitalization rates could over-state the risks, as not all cases are diagnosed, and those cases that are more severe are more likely to be diagnosed.

However, all serology studies in Alberta have consistently shown antibody prevalence in our population at present to be less than 1%. Assuming a maximum 1% infection rate as of early August (our last serosurvey timeframe for when we have results) and calculating a non-age-adjusted ratio of diagnosed cases as of mid-July (2 weeks prior to the time of serology testing – 9673 cases) to serologically positive Albertans (1% of the Alberta population is 44,219), we could estimate that actual infections may be about 4.6 times higher than what was diagnosed.

If we reduce the estimated deaths and hospitalizations in the under 60 population by 4.6, we would still have about 240 deaths and 8,600 hospitalizations as a consequence of a 50% infection rate in Albertans under 60. If these infections were allowed to spread unchecked over a short period of time (the Barrington document does not state for how long those over "retirement age" should be restrained in their movement, but commentary on the document suggests 3 months), the hospitalization volume alone would be sufficient to impair the ability of our acute care system to manage all the other health care needs of our population.

In order to manage the demand for hospital beds and ICU care, other services would have to be paused or stopped in order to care for the acutely ill. This would worsen, not improve, the outcomes of concern in the Barrington document such as cardiac care, cancer screening and childhood immunizations.

Long-term health impacts

In addition, while hospitalizations, ICU admissions and deaths are the most obvious severe outcomes of COVID-19 illness, there is a growing body of evidence on the long term impacts that some people experience after an infection with SARS-CoV2. These include prolonged illness[13, 14], sometimes called "Long COVID Syndrome", which in some cases resembles Chronic Fatigue Syndrome, and emerging case reports of other possible long-term health impacts[15, 16] that could irrevocably alter the course of people's lives.

Limits to any "Focused Protection"

Finally, the premise that we could successfully shield continuing care facilities and hospitals from COVID-19, and that we would be able to support all those over 60 (and presumably those with high risk chronic conditions) to stay home with limited activities is not supported by evidence. In fact, those who work in continuing care facilities and hospitals can unintentionally be the source of infection in these locations.

We are working hard to ensure that every protection possible is put into place to prevent these introductions, but no measures will be perfect. In addition, we heard very clearly that the quality of life for those in continuing care was

severely worsened when no visitors were allowed in, highlighting the tension between COVID protection and overall wellbeing in these high risk locations.

In addition, those over the age of 60 are often still working, contributing in many diverse fields, and the impact of having them all stay home would be significant. For example, more than 30% of Alberta physicians in 2018 were over the age of 55, and 10% were older than 65[12], and removing them from the work force would be a poor choice in a time when health care is under significant pressure.

Finally, allowing the virus to spread rampantly in the age group under 60 would almost certainly result in impacts on critical services as those who are ill, even if the symptoms are mild, would need to be home for 10 days to prevent spread to those at high risk (for example, in health care settings) and critical sector continuity would be put at risk.

Balancing COVID-19 restrictions with protecting our overall health

So, is there anything that can be taken from the Barrington document? First, the societal risks of public health measures that it outlines are real, and are exactly the reason that in Alberta we moved early on to targeting restrictions only where and when they are needed. The Barrington document implies that "lockdown" is binary – all or none, and that no restrictions should be in place for the young. This is a false dichotomy. The best way to prevent severe illness and death from COVID-19 is to prevent large spreading events, quickly identify cases, trace and isolate contacts, and keep the spread of the virus to a manageable level. This is exactly what we are doing.

Second, we already have policies that accept some risks of transmission in younger populations knowing that the benefits of activities outweigh the risks for those populations. Examples include opening schools and supporting youth sports. We can learn from what is working well in these areas and continue to judiciously expand activities in low risk populations as long as spread remains manageable.

We are not in lockdown in Alberta. We are using targeted measures to keep spread manageable and to ensure that our health system can cope with demands. We must continue to pursue this balanced approach, learning as we go along how best to minimize both the risks of public health measures and the risks of COVID-19. Herd immunity by natural infection is not a wise, or possibly even an achievable, goal to pursue.

References

1. Great Barrington Declaration
2. Lessons for COVID-19 Immunity from Other Coronavirus Infections (PDF, 1.7 MB)
3. Genomic evidence for reinfection with SARS-CoV-2: a case study
4. Symptomatic SARS-CoV-2 reinfection by a phylogenetically distinct strain
5. COVID-19 Re-Infection by a Phylogenetically Distinct SARS-CoV-2 Variant, First Confirmed Event in South America
6. Coronavirus Disease 2019 (COVID-19) Re-infection by a Phylogenetically Distinct Severe Acute Respiratory Syndrome Coronavirus 2 Strain Confirmed by Whole Genome Sequencing
7. COVID-19 herd immunity in the Brazilian Amazon
8. Brazil city 'might have reached herd immunity'
9. A city in Brazil where covid-19 ran amok may be a 'sentinel' for the rest of the world
10. In Brazil's Amazon a COVID-19 resurgence dashes herd immunity hopes
11. Hotspots of resurgent Covid erode faith in 'herd immunity'
12. COVID-19 Alberta statistics
13. Symptom Duration and Risk Factors for Delayed Return to Usual Health Among Outpatients with COVID-19 in a Multistate Health Care Systems Network
14. Long covid: How to define it and how to manage it

15. A case of probable Parkinson's disease after SARS-CoV-2 infection
16. New-Onset Diabetes in Covid-19
17. AHS Physician Workforce Plan and Forecast: 2018-2028 (PDF, 1.4 MB)

Dr. Deena Hinshaw

Dr. Deena Hinshaw was appointed Alberta's Chief Medical Officer of Health on January 28, 2019.

Learn more

THIS IS EXHIBIT " Y " referred to in the Affidavit / Declaration of Dr. Deena Hinshaw
affirmed
Sworn / Declared before me this 12th day of July A.D., 2021
H Veale
A Commissioner for Oaths in and for the Province of Alberta.
A Notary Public.
Heather L. Veale
Barrister & Solicitor

JOHN SNOW MEMO

DECLARATION SUMMIT

JOHN SNOW MEMO

MORE THAN 6,900 scientists, researchers & healthcare professionals have now signed the John Snow Memorandum.

We vet every signature, so it may take 72 hours for your name to appear.

Thanks for your support, and please continue to share with your colleagues.

THE JOHN SNOW MEMORANDUM

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has infected more than 35 million people globally, with more than 1 million deaths recorded by the World Health Organization as of Oct 12, 2020. As a second wave of COVID-19 affects Europe, and with winter approaching, we need clear communication about the risks posed by COVID-19 and effective strategies to combat them. Here, we share our view of the current evidence-based consensus on COVID-19.

SARS-CoV-2 spreads through contact (via larger droplets and aerosols), and longer-range transmission via aerosols, especially in conditions where ventilation is poor. Its high infectivity[1] combined with the susceptibility of unexposed populations to a new virus, creates

conditions for rapid community spread. The infection fatality rate of COVID-19 is several-fold higher than that of seasonal influenza[2] and infection can lead to persisting illness, including in young, previously healthy people (ie, long COVID[3]). It is unclear how long protective immunity lasts[4] and, like other seasonal coronaviruses, SARS-CoV-2 is capable of re-infecting people who have already had the disease, but the frequency of re-infection is unknown[5]. Transmission of the virus can be mitigated through physical distancing, use of face coverings, hand and respiratory hygiene, and by avoiding crowds and poorly ventilated spaces. Rapid testing, contact tracing, and isolation are also critical to controlling transmission. The World Health Organization has been advocating for these measures since early in the pandemic.

In the initial phase of the pandemic, many countries instituted lockdowns (general population restrictions, including orders to stay at home and work from home) to slow the rapid spread of the virus. This was essential to reduce mortality[6],[7] prevent health-care services from being overwhelmed, and buy time to set up pandemic response systems to suppress transmission following lockdown. Although lockdowns have been disruptive, substantially affecting mental and physical health, and harming the economy, these effects have often been worse in countries that were not able to use the time during and after lockdown to establish effective pandemic control systems. In the absence of adequate provisions to manage the pandemic and its societal impacts, these countries have faced continuing restrictions.

This has understandably led to widespread demoralisation and diminishing trust. The arrival of a second wave and the realisation of the challenges ahead has led to renewed interest in a so-called herd immunity approach, which suggests allowing a large uncontrolled outbreak in the low-risk population while protecting the vulnerable. Proponents suggest this would lead to the development of infection-

acquired population immunity in the low-risk population, which will eventually protect the vulnerable. This is a dangerous fallacy unsupported by scientific evidence.

Any pandemic management strategy relying upon immunity from natural infections for COVID-19 is flawed. Uncontrolled transmission in younger people risks significant morbidity[3] and mortality across the whole population. In addition to the human cost, this would impact the workforce as a whole and overwhelm the ability of healthcare systems to provide acute and routine care.

Furthermore, there is no evidence for lasting protective immunity to SARS-CoV-2 following natural infection[4] and the endemic transmission that would be the consequence of waning immunity would present a risk to vulnerable populations for the indefinite future. Such a strategy would not end the COVID-19 pandemic but result in recurrent epidemics, as was the case with numerous infectious diseases before the advent of vaccination. It would also place an unacceptable burden on the economy and healthcare workers, many of whom have died from COVID-19 or experienced trauma as a result of having to practise disaster medicine. Additionally, we still do not understand who might suffer from long COVID[3]. Defining who is vulnerable is complex, but even if we consider those at risk of severe illness, the proportion of vulnerable people constitute as much as 30% of the population in some regions[8]. Prolonged isolation of large swathes of the population is practically impossible and highly unethical. Empirical evidence from many countries shows that it is not feasible to restrict uncontrolled outbreaks to particular sections of society. Such an approach also risks further exacerbating the socioeconomic inequities and structural discriminations already laid bare by the pandemic. Special efforts to protect the most vulnerable are essential but must go hand-in-hand with multi-pronged

population-level strategies.

Once again, we face rapidly accelerating increase in COVID-19 cases across much of Europe, the USA, and many other countries across the world. It is critical to act decisively and urgently. Effective measures that suppress and control transmission need to be implemented widely, and they must be supported by financial and social programmes that encourage community responses and address the inequities that have been amplified by the pandemic. Continuing restrictions will probably be required in the short term, to reduce transmission and fix ineffective pandemic response systems, in order to prevent future lockdowns. The purpose of these restrictions is to effectively suppress SARS-CoV-2 infections to low levels that allow rapid detection of localised outbreaks and rapid response through efficient and comprehensive find, test, trace, isolate, and support systems so life can return to near-normal without the need for generalised restrictions. Protecting our economies is inextricably tied to controlling COVID-19. We must protect our workforce and avoid long-term uncertainty.

Japan, Vietnam, and New Zealand, to name a few countries, have shown that robust public health responses can control transmission, allowing life to return to near-normal, and there are many such success stories. The evidence is very clear: controlling community spread of COVID-19 is the best way to protect our societies and economies until safe and effective vaccines and therapeutics arrive within the coming months.

We cannot afford distractions that undermine an effective response; it is essential that we act urgently based on the evidence.

To support this call for action, **sign the John Snow Memorandum**.

The John Snow Memorandum was **originally published in *The Lancet* on 14 October 2020** .

SIGNATORIES

Prof. Kristina Alexanderson, Stockholm, Sweden

Dr. Rochelle Ann Burgess, Lecturer in Global Health, Institute for Global Health, University College London, UK

Prof. Laura Bear, Professor and Head of Department, Department of Anthropology, London School of Economics, UK

Prof. Reinhard Busse, co-director, European Observatory on Health Systems and

Dr. Christian L. Althaus, Head of Interfaculty Platform for Data and Computational Science (INPUT) Institute of Social and Preventive Medicine (ISPM), University of Bern, Switzerland

Dr. Simon Ashworth, Clinical Director of Critical Care, Imperial College Healthcare NHS Trust, UK

Dr. Nahid Bhadelia, Medical Director, Special Pathogens Unit, Boston Medical Center; Associate

Dr. Nisreen Alwan, Associate Professor in Public Health, University of Southampton; Honorary Consultant in Public Health, University Hospital Southampton NHS Foundation Trust, UK

Dr. Rupert Beale, Group Leader, Cell Biology of Infection, Francis Crick Institute, UK

Prof. Debby Bogaert, Scottish Senior Clinical Fellow, Professor of Paediatric Infectious Diseases, Center for

Policies; Professor and Head of the Department of Health Care Management, Technische Universität Berlin, Germany

Prof. David Fisman, Professor, Division of Epidemiology, University of Toronto, Canada

Prof. Lynn R Goldman, Professor of Environmental and Occupational Health, Michael and Lori Milken Dean of the Milken Institute School of Public Health, George Washington University, US

Mr. Adam Hamdy, Ligandal Genetic Medicine, San Francisco, US

Professor, Section of Infectious Diseases, National Emerging Infectious Diseases Laboratories, Boston University School of Medicine, US

Dr. Colin J. Carlson, Assistant Research Professor, Centre for Global Health Science and Security, Georgetown University, US

Prof. Tim Colbourn, Associate Professor, Institute for Global Health, University College London, UK

Prof. John Drury, Director of Research and Knowledge Exchange in the School of Psychology, University of Sussex, SPI-B advisory sub-group of SAGE,

Inflammation Research, University of Edinburgh, and Honorary Consultant in Paediatric Infectious Diseases, Royal Hospital for Sick Children, Edinburgh, UK

Dr. Yves Charpak, Fondation Charpak, l'esprit des sciences, France

Prof. Anthony Costello, Independent SAGE, UK

Prof. Jennifer Dowd, Associate Professor of Demography and Population Health, Deputy Director, Leverhulme Centre for Demographic Science, University of Oxford, UK

Prof. David Hunter, Richard Doll Professor of Epidemiology and Medicine; Director, Translational Epidemiology Unit, Nuffield Department of Population Health, University of Oxford, UK

Prof. Paul Kellam, Professor of Virus Genomics, Imperial College London and VP of Infectious Diseases and Vaccines, Kymab Ltd, UK

Prof. Ilona Kickbusch, Founding director and Chair, Graduate Institute of International and Development Studies, Switzerland

Dr. Krutika Kuppalli, Assistant Professor,. Independent SAGE, UK

Prof. Isabella Eckerle, Head of the Centre for Emerging Viral Diseases, University Hospitals of Geneva and University of Geneva, Switzerland

Prof. Karl Friston, Wellcome Principal Research Fellow and Scientific Director, Wellcome Trust Centre for Neuroimaging; Professor, Institute of Neurology, University College London, UK

Prof. Trisha Greenhalgh, Professor of Primary Care Health Sciences, Nuffield Department of Primary Care Health Sciences, University

Prof. Jacques Fellay, Associate Professor, Groupe Fellay, EPFL; Head of Precision Medicine at the University Hospital (CHUV) in Lausanne, Switzerland

Dr. Valentina Gallo, Neuroepidemiologist , University of Groningen, The Netherlands

Dr. Deepti Gurdasani, UKRI Health-Data Research UK Fellow, and Senior Lecturer in Machine Learning, Queen Mary University of London, UK

Dr. Emma Hodcroft, Molecular Epidemiology Postdoctoral Fellow, Biozentrum, University of Basel, Switzerland

Department of Medicine, Medical University of South Carolina, US

Prof. Jose M Martin-Moreno, Professor, Department of Preventive Medicine and Public Health, University of Valencia, Spain

Prof. Alan McNally, Professor in Microbial Evolutionary Genomics, Director of Institute of Microbiology and Infection, College of Medical and Dental Sciences, University of Birmingham, UK

Prof. Julian Mamo, President, Chronic Diseases Section, European Public Health Association, Associate Professor, Department of

of Oxford, Co-Director, Interdisciplinary Research In Health Sciences (IRIHS) Unit, UK

Prof. William Hanage, Associate Professor of Epidemiology, Harvard T.H. Chan School of Public Health, Center for Communicable Disease Dynamics, US

Dr. Zoë Hyde, Researcher, Western Australian Centre for Health and Ageing, The University of Western Australia, Australia

Dr. Michelle Kelly-Irving, Inserm research scientist, Epidemiology and Public Health Unit,

Prof. David Ingleby, Centre for Social Science and Global Health, University of Amsterdam, The Netherlands

Prof. Kamlesh Khunti, Professor of Primary Care Diabetes & Vascular Medicine, University of Leicester and Independent SAGE, UK

Prof. Florian Krammer, Professor of Microbiology, Icahn School of Medicine at Mount Sinai, US

Prof. Marc Lipsitch, Professor of Epidemiology, Harvard T.H. Chan School of Public Health, Director, Center for Communicable

Public Health, Faculty of Medicine & Surgery Medical School, Mater Dei Hospital, Msida, Malta

Prof. Jacob Moran-Gilad, Professor of Clinical Microbiology, School of Public Health, Faculty of Health Sciences, Ben-Gurion University, Israel

Dr. Ali Nouri, President of the Federation of American Scientists, US

Dr Alexandra Phelan, Assistant Professor, Center for Global Health Science & Security, Georgetown University, US

Dr. Saskia Popescu, Term Assistant Inserm & Université Toulouse III, France

Prof. Sir David King, Former UK Chief Scientific Adviser, Independent SAGE, UK

Prof. Alastair H Leyland , Professor, Institute of Health and Wellbeing, Associate Director, MRC/CSO Social & Public Health Sciences Unit, University of Glasgow, UK

Prof. Martin McKee, Professor of European Public Health, London School of Hygiene and Tropical Medicine, Research Director, European Observatory on Health Systems and Policies, and Disease Dynamics, USA

Dr. Paul McLaren, Adjunct Professor, Department of Medical Microbiology and Infectious Diseases, University of Manitoba, Canada

Dr. Maimuna S. Majumder, Computational Health Informatics Program (CHIP), Boston Children's Hospital, Research Associate, Harvard Medical School, US

Prof. Melinda Mills, Nuffield Professor of Sociology at Nuffield College and Head of the Department of Sociology, Director, Leverhulme Centre for Demographic Science, University of Oxford, UK

Professor, Biodefense Graduate Program, George Mason University, US

Prof. Stephen Reicher, Bishop Wardlaw Professor, School of Psychology and Neuroscience, University of St. Andrews, UK

Dr. Johanna Riha, Research Fellow, United Nations University-International Institute for Global Health (UNU-IIGH), Kuala Lumpur, Malaysia

Prof. Carlo Signorelli, Professor of Hygiene and Public Health at the University of Parma University of Vita-Salute San Raffaele of Milan, Italy

Independent SAGE, UK

Dr. Michael Mina, Assistant Professor, Center for Communicable Disease Dynamics, Department of Epidemiology, Harvard T.H. Chan School of Public Health, USA

Prof. Susan Michie, Professor of Health Psychology, University College London and Independent SAGE, UK

Prof. Elias Mossialos, Brian Abel-Smith Professor of Health Policy, Deputy Head of Department, London School of Economics, UK

Prof. Stuart Neil, Professor of Virology, Head of Infectious Diseases Department, King's College London, UK

Prof. Christina Pagel, Professor of Operational Research, Clinical Operational Research Unit, University College London and Independent SAGE, UK

Dr. Dominic Pimenta, Hospital doctor, Chairman, Healthcare Workers Foundation (HEROES), UK

Dr. Angela L. Rasmussen, Associate Research Scientist, Center for Infection and Immunity, Mailman School of Public

Prof. Devi Sridhar, Professor and Chair of Global Public Health, University of Edinburgh, UK

Prof. Walter Ricciardi, Professor of Hygiene and Public Health, Director of the Department of Public Health and Deputy Head of the Faculty of Medicine, Università Cattolica del Sacro Cuore, Rome, Italy

Prof. Joshua Silver, Professor of Physics, University of Oxford, UK

Prof. Charles Swanton, Group Leader CEGI Laboratory, Francis Crick Institute, UK; Cancer Research UK Lung Cancer Centre of Excellence, UCL

Prof. Anna Odone, University of Pavia, Italy

Prof. Deenan Pillay, Professor of Virology, Division of Infection and Immunity, University College London and IndieSAGE, UK

Dr. Viola Priesemann, MPRG Group Leader & Fellow of the Schiemann Kolleg, Max Planck Institute for Dynamics and Self-Organization & Bernstein Center for Computational Neuroscience, Göttingen, Germany

Prof. Ken Rice, Professor of Computational Astrophysics, Institute for Astronomy, Health, Columbia University, New York, US

Prof. Harry Rutter, Professor of Global Public Health, University of Bath, UK

Prof. Gabriel Scally, Visiting Professor of Public Health, University of Bristol, Member of Independent SAGE, UK

Prof. Anthony Staines, Professor of Health Systems, Dublin City University, Ireland

Prof. Robert West, Emeritus Professor of Health Psychology, University College London, UK

Cancer Institute, London, UK

Prof. Rochelle P. Walensky, Chief of the Division of Infectious Diseases, Massachusetts General Hospital, Professor of Medicine, Harvard Medical School, USA

Dr. Hisham Ziauddeen, Clinical Senior Research Associate, Dept. of Psychiatry & Wellcome Trust-MRC, Institute of Metabolic Science, University of Cambridge, UK; Honorary Consultant Psychiatrist CAMEO, Cambridgeshire and Peterborough Foundation Trust, UK

University of Edinburgh, UK

Prof. Tara Smith, Professor of Epidemiology, Kent State University College of Public Health, US

Prof. Kevin Watkins, CEO, Save the Children, UK

Dr. Clare Wenham, Assistant Professor of Global Health Policy, London School of Economics and Political Science, UK

Prof. Gavin Yamey, Professor of Global Health and Public Policy, Duke University, USA

Dr. Kit Yates, Co-Director of the Centre for Mathematical Biology, University of Bath, and IndieSAGE, UK

Click here to see the organisations that have officially endorsed the John Snow Memorandum.

GET INVOLVED

This is a collaborative, inclusive initiative and we invite colleagues from around the world to signal their support for the memorandum by becoming signatories.

If you are a scientist, medic, researcher, modeller, healthcare or public health professional and would like to support the memorandum, please fill in the contact details below and click the 'Sign The Memo' button. Your signature will be checked and added to this website.

Your details will not be passed to any third party and will not be used in connection with anything else.

If you represent an organisation that would like to endorse the memo, please email info@johnsnowmemo.com

SIGN THE JOHN SNOW MEMO

* indicates required

Email Address *

Title (Prof., Dr., Ms., Mrs., Mr. etc.)

First Name *

Last Name *

Institution/Organisation *

Department

Declaration of Interests

SIGN THE MEMO

We're receiving a lot of signatures for the John Snow Memorandum, and the volume of traffic means it can take up to 3 hours for your confirmatory email to arrive. If you have difficulties using the embedded sign up form, you're welcome to use this **stand-alone HTML version instead**.

REFERENCES

1. Hao X, Cheng S, Wu D, Wu T, Lin X, Wang C. *Reconstruction of the full transmission dynamics of COVID-19 in Wuhan.* Nature 2020; 584: 420–24.

2. Verity R, Okell LC, Dorigatti I, et al. *Estimates of the severity of coronavirus disease 2019: a model-based analysis.* Lancet Infect Dis 2020; 20: 669–77.

3. Nature. *Long COVID: let patients help define long-lasting COVID symptoms.* Nature 2020; 586: 170.

4. Chen Y, Tong X, Li Y, et al. *A comprehensive, longitudinal analysis of humoral responses specific to four recombinant antigens of SARS-CoV-2 in severe and non-severe COVID-19 patients.* PLoS Pathog 2020; 16: e1008796.

5. Parry J. *COVID-19: Hong Kong scientists report first confirmed case of reinfection.* BMJ 2020; 370: m3340.

6. Flaxman S, Mishra S, Gandy A, et al. *Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe.* Nature 2020; 584: 257–61.

7. Dehning J, Zierenberg J, Spitzner FP, et al. *Inferring change points in the spread of COVID-19 reveals the effectiveness of interventions.* Science 2020; 369: eabb9789.

8. Clark A, Jit M, Warren-Gash C, et al. *Global, regional, and national estimates of the population at increased risk of severe*

COVID-19 due to underlying health conditions in 2020: a modelling study. Lancet Glob Health 2020; 8: e1003–17.