This is the 2nd affidavit of
Brian Emerson in this case
and was made on 2/FEB/2021

No. S-210209
Vancouver Registry

IN THE SUPREME COURT OF BRITISH COLUMBIA

Between

ALAIN BEAUDOIN, BRENT SMITH, JOHN KOOPMAN, JOHN VAN MUYEN, RIVERSIDE CALVARY CHAPEL, IMMANUEL COVENANT REFORMED CHURCH and FREE REFORMED CHURCH OF CHILLIWACK, B.C.

Petitioners

and

HER MAJESTY THE QUEEN IN RIGHT OF THE PROVINCE OF BRITISH COLUMBIA and DR. BONNIE HENRY IN HER CAPACITY AS PROVINCIAL HEALTH OFFICER FOR THE PROVINCE OF BRITISH COLUMBIA

Respondents

AFFIDAVIT

I, **Dr. BRIAN EMERSON**, of 1515 Blanshard Street, Victoria, in the Province of British Columbia, Acting Deputy Provincial Health Officer, AFFIRM THAT:

1. I am the Acting Deputy Provincial Health Officer ("Deputy PHO") with the Office of the Provincial Health Officer, Ministry of Health, and, as such, have personal knowledge of the matters deposed to except where such are stated to be based on information and belief, in which case, I believe them to be true.

2. I make this affidavit in support the respondents Her Majesty the Queen in Right of the Province of British Columbia (the "Province") and the Provincial Health Officer ("PHO") application for interim and interlocutory injunctive relief pending a determination of the petition on its merits.

3. Knowledge about how SARS-CoV-2 is transmitted enables the PHO to determine what settings are most risky, what conditions are most risky, what behaviours are most

risky, and what protective measures should be put into place to reduce risk, and incorporate those factors into her decision-making and issuance of public health orders.

4. Over the course of the pandemic, the scientific community and public health officials have learned that the likelihood of transmission of SARS-CoV-2 is greater:

a. when people are interacting in communal settings (e.g. gatherings, events, celebrations) than in transactional settings (e.g. at retail outlets);

b. when people are close to each other;

c. in crowded settings;

d. in indoor settings due to less ventilation than outdoor settings; and

e. when people speak, and especially when they sneeze, cough, sing, chant or engage in excited expression (e.g. shouting or speaking at higher than conversational volume).

5. The likelihood of transmission also increases exponentially in a population when a number of people are simultaneously infected in a group setting, and subsequently infect their contacts, who infect their contacts and so on. This can quickly result in a scenario where local public health resources can be overwhelmed such that they are no longer able to trace all the contacts of such an exposure and require them to self-isolate. If this occurs, community spread can quickly become rampant, leading to increased case counts and, in time, has the potential to overwhelm our healthcare system as hospitalizations increase.

6. Based on the latest scientific and epidemiological evidence available to the PHO, factors leading to elevated risk of COVID-19 transmission risk in religious settings are understood to include that they:

a. generally occur in indoor settings;

b. often involve the assembly of a large number of people from different households;

c. usually last for an extended duration (defined as longer than 15 minutes) which results in a greater duration of exposure and therefore a higher risk of infection and chance of viral spread;

d. often include individuals within high risk groups, including older adults and those with comorbidities; and

e. often involve loud talking and singing, which may represent greater risk for viral transmission.

7. Clusters of COVID cases stemming from religious gatherings and religious activities have been noted since the onset of the pandemic globally, nationally and in British Columbia. As noted in paragraphs 102 to 108 of my Affidavit #1 made February 2, 2021 in this proceeding, British Columbia has seen cases and clusters of COVID-19 in religious settings, particularly in October and November 2020.

8. The BC experience is consistent with that in other provinces and globally. Through my work as Deputy PHO, review of the relevant scientific literature, and surveillance of media reporting, I am generally aware that a number of clusters have been linked to religious services and gatherings across Canada. More specifically, a multi-jurisdictional outbreak connected to a series of events in a faith community in Saskatchewan in September resulted in 174 cases in 19 communities – including more than a dozen cases in Northern BC; this included 68 cases among individuals attending events, and 106 infected through secondary transmission. In an Ontario community, more than 30 active cases were confirmed in relation to a church gathering, with an additional 300 people put into isolation. Additional clusters related to attendance at religious gatherings have occurred across the provinces in Kingston (24 cases), Lethbridge (15 cases), 2 outbreaks in Calgary (24 and 54 cases, respectively), and Edmonton (99 cases).

9. In addition, a global analysis of COVID-19 clusters found many examples of religious settings serving as venues in which transmission occurred. Although infrequent, religious venues were noted to provide a setting with large (greater than 100 cases) cluster sizes. Attached hereto and marked as **Exhibit "A"** is a true copy of an article titled "What settings have been linked to SARS-CoV-2 transmission clusters?" authored by Leclerc, Q. et al., Wellcome Open Res. 2020; 5: 83.

10. As the surveillance reports attached to my Affidavit #1 show, the moving seven-day average of new cases has begun to decline in British Columbia in recent weeks. This volume of cases is still significantly higher than what we were experiencing in the summer and early fall 2020, prior to the dramatic rise in cases in late October and November 2020.

11. Maintaining adherence to the PHO's orders is also critical right now as we have begun to see the emergence of COVID-19 variants that have been reported globally here in BC. To date, we have had 14 confirmed COVID-19 cases of the B.1.117 (U.K.) and four of the B.1.351 (South African) variants, for a total of 18 cases with these variants of concern in BC. These variants have been associated with increased transmission in a number of countries around the world, and we have implemented surveillance for them here in BC. All 14 of the B.1.117 variant cases have been in returning travellers or people who had contact with a traveller, while three of the B.1.351 cases were not travel related

and investigation into where they were acquired continues. Recent modelling suggests that if these variants were to become established or predominant in our province, case counts will rise quickly and significantly. Attached hereto and marked as **Exhibit "B"** is an article titled "What happens if a high-transmission variant becomes established, and is transmitted in the general community in Canada?" dated January 29, 2021 authored by Elisha Are and Caroline Colijn. It should be noted that this article has not been peer reviewed and there is much debate about how likely modelling is able to reflect reality, as there are many other variables to consider in predicting the trajectory of transmission in BC.

13. If our case volumes were to increase significantly, it would create a real risk of overwhelming our contact tracing capacity and healthcare system, which in turn puts at risk not only those requiring COVID-19-related care, but all users of our healthcare system. We have been fortunate so far during BC's second wave not to have had to cancel or delay scheduled surgical procedures for non-COVID-19 patients (other than some limited cancellations in the Northern Health Authority and Fraser Health Authority due to high hospitalization rates and outbreaks in hospitals), but if our hospitals were to become overwhelmed with COVID-19 patients, cancellations may be required. In addition, a substantial increase in transmission increases the risk of introduction of virus into facilities where the most vulnerable people in society live i.e. long-term care and assisted living facilities, correctional facilities, homeless shelters, and facilities for disabled people, with potentially higher risk of transmission leading to serious consequences such as death to people in those settings. Furthermore, high rates of community transmission means older people, especially those over age 65, who are at much higher risk, face a much higher likelihood of becoming infected and will suffer higher rates of hospitalizations, intensive care unit admissions, and deaths.

14. The PHO and her team of advisors—myself included—are continually analyzing the data and changing epidemiologic circumstances of British Columbia's COVID-19 pandemic and experiences from other jurisdictions with the goal of reducing the nature and scope of restrictions on gatherings and events, including religious activities.

15. In particular, we are currently engaged in reviewing and considering revisions to the PHO's January 8, 2021 Order, which is set to expire on February 5, 2021, including specifically, revisions to restrictions on religious, spiritual and faith-based gatherings and events.

AFFIRMED BEFORE ME at)
Victoria, British Columbia on)
2/FEB/2021.)
)
)
)
A commissioner for taking)
affidavits for British Columbia)

DR. BRIAN EMERSON

TAB A

Check for updates

RESEARCH ARTICLE

REVISED What settings have been linked to SARS-CoV-2 transmission clusters? [version 2; peer review: 2 approved]

Quentin J. Leclerc [1,2], Naomi M. Fuller [1,2], Lisa E. Knight[3], CMMID COVID-19 Working Group, Sebastian Funk [1,2], Gwenan M. Knight [1,2]

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v2 **First published:** 01 May 2020, **5**:83
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Latest published: 05 Jun 2020, **5**:83
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Abstract

Background: Concern about the health impact of novel coronavirus SARS-CoV-2 has resulted in widespread enforced reductions in people's movement ("lockdowns"). However, there are increasing concerns about the severe economic and wider societal consequences of these measures. Some countries have begun to lift some of the rules on physical distancing in a stepwise manner, with differences in what these "exit strategies" entail and their timeframes. The aim of this work was to inform such exit strategies by exploring the types of indoor and outdoor settings where transmission of SARS-CoV-2 has been reported to occur and result in clusters of cases. Identifying potential settings that result in transmission clusters allows these to be kept under close surveillance and/or to remain closed as part of strategies that aim to avoid a resurgence in transmission following the lifting of lockdown measures.

Methods: We performed a systematic review of available literature and media reports to find settings reported in peer reviewed articles and media with these characteristics. These sources are curated and made available in an editable online database.

Results: We found many examples of SARS-CoV-2 clusters linked to a wide range of mostly indoor settings. Few reports came from schools, many from households, and an increasing number were reported in hospitals and elderly care settings across Europe.

Conclusions: We identified possible places that are linked to clusters of COVID-19 cases and could be closely monitored and/or remain closed in the first instance following the progressive removal of lockdown restrictions. However, in part due to the limits in surveillance capacities in many settings, the gathering of information such as cluster sizes and attack rates is limited in several ways: inherent recall bias, biased media reporting and missing data.

Keywords

SARS-CoV-2, COVID-19, coronavirus, cluster, transmission, settings, lockdown

Open Peer Review

Reviewer Status ✓ ✓

	Invited Reviewers	
	1	**2**
version 2 (revision) 05 Jun 2020	✓ report	✓ report
version 1 01 May 2020	? report	

1 **Joël Mossong**, Laboratoire National de Santé, Dudelange, Luxembourg

2 **Samuel V. Scarpino**, Northeastern University, Boston, USA

Any reports and responses or comments on the article can be found at the end of the article.

This is **EXHIBIT " A "** referred to in the affidavit of DR. BRIAN EMERSON affirmed before me at Victoria, in the Province of British Columbia this 2 day of February, 2021.

A Commissioner for taking affidavits in British Columbia

This article is included in the Coronavirus (COVID-19) collection.

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Author roles: Leclerc QJ: Data Curation, Formal Analysis, Investigation, Validation, Writing – Original Draft Preparation, Writing – Review & Editing; **Fuller NM**: Data Curation, Investigation, Validation, Writing – Original Draft Preparation, Writing – Review & Editing; **Knight LE**: Data Curation, Investigation, Validation, Writing – Review & Editing; **Funk S**: Conceptualization, Methodology, Supervision, Validation, Writing – Review & Editing; **Knight GM**: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Supervision, Validation, Writing – Original Draft Preparation, Writing – Review & Editing

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REVISED **Amendments from Version 1**

This article has been updated in response to reviewer comments, and to include 49 new transmission events which have been added to our online database. We now discuss a total of 201 transmission events (previously 152), classified into 22 setting types (previously 18).

Any further responses from the reviewers can be found at the end of the article

Introduction

The novel coronavirus SARS-CoV-2, responsible for coronavirus disease 2019 (COVID-19), was first identified in Wuhan, China at the end of 2019, and has since spread around the world (European Centre for Disease Prevention and Control, 2020). The capacity of the virus for human-to-human transmission, coupled with the lack of immunity in the population due to the novelty of SARS-CoV-2, has led to the implementation of severe reductions in people's movements in an effort to reduce disease impact. These strong measures are broadly described as "lockdowns". Due to the highly restrictive nature of lockdowns, and their impact on people's health, wellbeing and finances, it is likely that such interventions cannot be sustained for prolonged periods of time, and will have to be lifted, at least to some extent, before an effective vaccine becomes available.

To successfully remove these lockdown restrictions while avoiding a resurgence in SARS-CoV-2 transmission, we must better understand in which types of settings the virus is most likely to be transmitted. Determining particular places that are linked to clusters of cases could reveal settings that are responsible for amplifying the heterogeneity in transmission that has been reported: potentially 80% of transmission is being caused by only 10% of infected individuals (Endo *et al.*, 2020). Notably, the difference in transmission risk between households and larger communal settings is unclear, as is the difference between indoor and outdoor transmission.

Quantifying these differences in transmission can be further facilitated by the fact that, in many countries now under lockdown, intensive contact tracing of imported cases was performed in the early stages of the epidemic, resulting in the detection of clusters of cases. This data, on the first detected clusters in a country, can give knowledge of the types of settings facilitating transmission before intensive social and physical distancing took place.

The aim of our work is therefore to gather information on reported clusters of COVID-19 cases to determine types of settings in which SARS-CoV-2 transmission occurred. This could inform post-lockdown strategies by identifying places which should be kept under close surveillance and/or should still remain closed to avoid a resurgence in transmission.

Methods

Outline

We searched for scientific literature and media articles detailing clusters of SARS-CoV-2 transmission (details below) and extracted data into a Google Sheets file (accessible at https://bit.ly/3ar39ky; archived as *Underlying data* (Leclerc *et al.*, 2020)). We defined "settings" as sites where transmission was recorded resulting in a cluster of cases. We restricted our definition of "cluster" to the first-generation cases that acquired the infection due to transmission in a single specific setting at a specific time. For example, if a person was infected on a cruise ship, and later infected additional people after disembarking, we would not consider that the latter were part of that "cruise ship cluster", since they were not infected on the ship. We recorded the country and further details about the type of setting, the numbers of primary and secondary cases in the cluster, cluster sizes, and attack rates. We defined a case as a person reported to be infected with the SARS-CoV-2 virus, regardless of symptoms.

Search strategy

References were found in four ways. Firstly, we performed a systematic literature review for COVID-19 clusters in PubMed on the 30th March 2020 (search term below). A total of 67 papers were found. Two reviewers (GMK and QJL) performed data extraction into the online database. We chose to only search this database and use peer reviewed articles as a quality threshold. We included data from English abstracts (where possible), but otherwise excluded non-English publications.

PubMed search: ("COVID-19"[All Fields] OR "COVID-2019"[All Fields] OR "severe acute respiratory syndrome coronavirus 2"[Supplementary Concept] OR "severe acute respiratory syndrome coronavirus 2"[All Fields] OR "2019-nCoV"[All Fields] OR "SARS-CoV-2"[All Fields] OR "2019nCoV"[All Fields] OR (("Wuhan"[All Fields] AND ("coronavirus"[MeSH Terms] OR "coronavirus"[All Fields])) AND (2019/12[PDAT] OR 2020[PDAT]))) AND cluster [All Fields]

Secondly, we used the online Google search engine to find media articles detailing settings of SARS-CoV-2 transmission in general. We searched for combinations of either "COVID", "COVID-19", "COVID-2019","severe acute respiratory syndrome coronavirus 2", "2019-nCoV", "SARS-CoV-2", "2019nCoV" or "coronavirus", and the words "transmission cluster" (e.g. "COVID transmission cluster" or "SARS-CoV-2 transmission cluster"). We only included online articles in English. From the collated list of settings, we then performed a further search for transmission in each of these settings (week beginning 6th April 2020).

Thirdly, we investigated whether information on the settings in which the first 100 "transmission events" in countries with current COVID-19 outbreaks existed by searching for publicly available data sources. As substantial investigation of cases often occurs early in an outbreak, any clusters linked to the first ~100 cases in countries outside China could give information on the transmission of SARS-CoV-2 in the absence of any social distancing measures.

Finally, following the original publication of this article on 01/05/2020, we included a "Suggested updates" tab in our publicly available database (https://bit.ly/3ar39ky). This allows other individuals to suggest new clusters we should include in our analysis. We review these suggestions regularly, and add

those with sufficient detail to our "Latest updated results" tab. In this revised version, we have updated our analysis to include suggestions we reviewed up to 26/05/2020.

Cluster characteristics and setting definition

With the above data, we then aimed to estimate both the final (proportion of people in that setting who became infected) and secondary (proportion of contacts of one case who became infected) attack rates in each setting. These were previously identified as key metrics, particularly within households, to estimate whether transmission is driven by a relatively small number of high-risk contacts (Liu *et al.*, 2020).

We defined a setting when several reports mentioned clusters linked to spaces with certain characteristics. For example, "Religious" includes churches and mosques, while "Public" here means public communal shared spaces such as markets or welfare centres. Where settings were a mixture of indoor and outdoor spaces, we used a mixed indoor/outdoor classification.

Results

We found evidence of SARS-CoV-2 transmission clusters for 201 events, which we classified into 22 types of settings (Table 1 and Table 2). All the studies with relevant data are compiled in an online database (accessible at https://bit.ly/3ar39ky; see also *Underlying data* (Leclerc *et al.*, 2020)). Many of the published reports with setting specific data came from China (47/201) and Singapore (51/201).

The vast majority of these clusters were associated with indoor or indoor/outdoor settings (21/22). Large clusters, such as those linked to churches and ships, were infrequently reported. Almost all clusters involved fewer than 100 cases (181/201), with the outliers being transmission in hospitals, elderly care, worker dormitories, food processing plants, prisons, schools, shopping and ship settings. Religious venues provided a further setting with large cluster sizes: there were separate clusters in South Korea, France, India and Malaysia (Ananthalakshmi & Sipalan, 2020; BBC, 2020; Salaün, 2020; Shin *et al.*, 2020). In addition to these settings with maximum cluster sizes of more than 100 cases per cluster, we identified five further settings with maximum cluster sizes between 50 and 100: sport (65 cases) (Korean Centre for Diease Control & Prevention, 2020), bar (80 cases) (Sim, 2020), wedding (98 cases) (Ministry of Health – New Zealand, 2020), work (97 cases) (Park *et al.*, 2020) and conference (89 cases) (Marcelo & O'brien, 2020).

We found a notably high number of transmission events reported in worker dormitories (21/201), although all of these were from Singapore. This type of setting had the second highest total cluster size out of all the recorded events we found, with 797 cases reported in the S11 dormitory cluster in Singapore (Data Against COVID19 SG, 2020).

We found only a small number of clusters linked to schools (8/201), and there the SARS-CoV-2 cases reported were most often in teachers or other staff. For example, for two school clusters in Singapore (Ministry of Health - Singapore, 2020), 16/26 and 7/8 cases were staff. Some children were also found to be infected in these clusters, as was the case in the Salanter Akiba Riverdale school in New York, USA (Ailworth & Berzon (2020)), although testing for infection was not always universal. In a retrospective close cohort study in a French high school however, 133 children and staff were seropositive for anti-SARS-CoV-2 antibodies, 92 of whom were pupils (Fontanet *et al.*, 2020).

We identified 9 clusters linked to food processing plants in 4 different countries (USA, Germany, Canada, Netherlands). These transmission events have led to large clusters, such as in a meat processing plant in South Dakota where a total of 518 employees were infected by SARS-CoV-2 (Cannon, 2020).

The setting with the greatest number of reported clusters of SARS-CoV-2 transmission was households (36/201). Again, most were from China (25/36) with all cluster sizes being less than 10. However, for 27 out of 36 studies, we were unable to calculate either the secondary or final attack rates due to a lack of information on total household size.

We aimed to estimate secondary and final attack rates in other settings but, as for households, we found that there was substantial missing data. In particular, the number of individuals in a setting was missing, and so we were unable to perform this analysis. Where attack rates could be estimated for individual clusters, these are reported in the online database.

Although information on the index and early cases in a setting was often reported, further information on the subsequently reported 10–100 cases in a country was difficult to extract. Moreover, the index cases were often quarantined and hence not linked to further transmission in most settings.

Discussion

In this review of SARS-CoV-2 transmission events, we found that clusters of cases were reported in many, predominantly indoor, settings. Note that we restrict cluster size to only include individuals infected within a specific setting, and exclude secondary infections which occurred outside the settings. Most clusters involved fewer than 100 cases, with the exceptions being in healthcare (hospitals and elderly care), large religious gatherings, food processing plants, schools, shopping, and large co-habiting settings (worker dormitories, prisons and ships). Other settings with examples of clusters between 50–100 cases in size were weddings, sport, bar, shopping and work. The majority of our reports are from China and Singapore.

Limitations

The settings collated here are biased due to the nature of our general search for SARS-CoV-2 transmission described above. Although based on a systematic review of published peer-reviewed literature, many of the reports included came from media articles where relevant epidemiological quantities were not always reported, resulting in many missing data. Many of the more detailed studies originated from the early outbreak in China, especially those providing household information. The settings

Table 1. Summary of gathered reported events as of 20th April 2020. Where only one study for this setting is reported, the minimum, maximum and median number of secondary cases in the cluster and/or total cluster size correspond to this single reported number (if given). Total cluster size accounts for all primary and secondary cases in the cluster. For references see the online database, accessible at https://bit.ly/3ar39ky.

Setting type	Number of reported events	Secondary cases			Total cluster size			Total number of cases across all clusters	Countries	Indoor / outdoor
		Min	Median	Max	Min	Median	Max			
Bar	12	2	9	16	3	13	80	319	Germany, Austria, Italy, Singapore, Japan, USA, Australia, New Zealand, Brazil	Indoor / outdoor
Building site	4	/	/	/	5	20.5	49	95	Singapore	Outdoor
Conference	5	/	/	/	3	10	89	148	Canada, Singapore, Japan, USA, New Zealand	Indoor / outdoor
Elderly care	17	/	/	/	5	19	167	638	UK, Canada, Scotland, France, Germany, Italy, USA, Japan, New Zealand, Luxembourg	Indoor
Food processing plant	9	2	2	2	3	84	518	1207	USA, Germany, Canada, Netherlands	Indoor
Funeral	1	3	3	3	4	4	4	4	USA	Indoor / outdoor
Hospital	9	1	3	14	2	10	118	224	China, Singapore, Italy, Taiwan, South Korea, Japan	Indoor
Hotel	2	/	/	/	3	5	7	10	Singapore	Indoor
Household	36	1	3	11	2	4	12	168	China, Italy, Vietnam, Taiwan, South Korea, Hong Kong, France	Indoor
Meal	17	1	3	10	2	5	47	134	Singapore, USA, Vietnam, China, South Korea, Japan	Indoor
Prison	4	351	351	351	66	226	353	871	USA, Ethiopia	Indoor
Public	4	/	/	/	10	10	27	57	China, Japan	Indoor / outdoor
Religious	15	1	18	52	2	23	130	570	USA, Singapore, South Korea, US, China, India, Netherlands, Germany	Indoor / outdoor
School	8	1	1	131	2	22	133	349	Singapore, France, USA, New Zealand, Australia, Sweden	Indoor / outdoor
Ship	5	619	619	619	78	662	1156	3597	Grand Princess, Diamond Princess, Ruby Princess, USS Theodore Roosevelt, Charles de Gaulle aircraft carrier	Indoor
Shipyard	1	/	/	/	22	22	22	22	Singapore	Indoor / outdoor
Shopping	9	5	10	19	7	20	163	361	China, Singapore, Peru, Mexico	Indoor / outdoor
Sport	6	1	1	1	2	7.5	65	95	South Korea, Singapore, Italy, Japan	Indoor / outdoor
Transport	1	1	1	1	3	3	3	3	China	Indoor
Wedding	3	/	/	/	13	43	98	154	Australia, New Zealand	Indoor / outdoor
Work	12	6	7	11	4	8.5	97	198	China, Singapore, South Korea, Germany	Indoor
Worker dormitories	21	/	/	/	3	24	797	1702	Singapore	Indoor

Wellcome Open Research 2020, 5:83 Last updated: 30 JUN 2020

Table 2. Definitions used for each of our transmission setting types. The definitions describe in what environment transmission was deemed to occur.

Transmission setting	Definition
Bar	Indoor space such as a bar, club, pub, small live music venues etc.
Building site	Outdoor space where construction work takes place.
Conference	Indoor professional event with many people interacting and meeting, shaking hands, eating together, team activities, etc.
Elderly Care	Care homes for the elderly; includes staff and residents. Transmission can occur between staff and residents but also from visitors.
Food processing plant	Any establishment that processes food for human consumption, such as a meat or vegetable packing plant.
Funeral	Indoor or outdoor burial ceremony; includes close contact with others such as hugging, shaking hands, eating together, singing, praying, etc.
Hospital	Any transmission that occurs within a hospital between patients and/or staff, in a COVID19 ward or not.
Hotel	Any transmission that occurs within the hotel e.g. hotel rooms, shared spaces, reception desk, etc.
Household	Transmission between individuals in a shared living space
Meal	When people eat together. Meals included took place in restaurants, hotels, cafes, home, etc. Transmission occurs over a meal by speaking, sharing foods, touching the same surfaces, etc.
Prison	Any transmission that occurs within a prison between prisoners and/or staff.
Public	Where transmission occurs on public property and does not fall into any of the other settings e.g. park, welfare centre, foodbank, etc.
Religious	Transmission occurs at a religious event such as at mass, services, prayer time, choir practice, etc.
School	Childcare or learning environments (schools, nurseries, kindergartens etc). Includes staff and children.
Ship	Any ship at sea. Includes crew and/or passengers onboard.
Shipyard	Large indoor or outdoor space where ships are made or repaired. Includes those working on the ship as well as customers
Shopping	A shop or shopping centre. Includes customers and those working in the shop.
Sport	Participation in a sporting activity indoor or outdoor e.g. gym or running.
Transport	Any means of public transportation, such as bus, plane, metro etc.
Wedding	Indoor or outdoor wedding celebration.
Work	In the workplace, typically an office.
Worker dormitories	A shared living space for workers.

we identified here therefore might not be representative of settings from a global perspective. Bias is present when relying on media coverage - a cluster is more likely to be reported if controversial or if there is an interesting social narrative. This is then compounded by the method search engines use to provide results where priority is given to high traffic stories. Overall, this can lead to some settings being overly represented in our database, which is why the numbers of clusters per settings should be compared cautiously.

Similarly, there is a bias in our reports which means that attendance in settings with many individuals is more likely to be linked to a cluster: recall bias (Spencer *et al.*, 2017). The accuracy of memories is influenced by subsequent events and experiences such that special, one-off events may be more likely to be remembered and potentially reported. If multiple single transmission events had occurred whilst walking in a park, for example, these would be less likely to be remembered, and more difficult to detect and hence record. Networks of close contacts also tend to be small, resulting in multiple opportunities for transmission, and hence potentially increase the importance of households or workplace for transmission instead of single outstanding settings of potential transmission. Hence, we cannot determine with any reliability the relative importance of the reported different types of settings beyond the record that clusters have been linked to such places.

Other events, such as large music concert (Dalling, 2020), political (Jones, 2020) and sporting (Hope, 2020; Roan, 2020; Wood & Carroll, 2020) gatherings, could potentially have been

linked to clusters of COVID-19. But, in the absence of rigorous surveillance systems and widespread testing that would allow countries to link and report the transmissions of such events, such connections remain speculation. An example of this lack of surveillance would be the UK, where only 4/201 clusters have been recorded The outlier for this is Singapore which appears to investigate clusters systematically and provides a well-designed online dashboard with details of all clusters detected (Data Against COVID19 SG, 2020).

In many settings, only symptomatic cases of disease severe enough to require hospitalization are tested and ultimately reported. This misses those infections that result in mildly symptomatic or asymptomatic symptoms, although there is mounting evidence for a significant proportion of infections to remain asymptomatic (Gudbjartsson *et al.*, 2020; He *et al.*, 2020; Lavezzo *et al.*, 2020). For some of the clusters, primarily households, all contacts were tested for infection; but for most of the data collated here, the number of COVID-19 symptomatic cases was the only information provided. These reported cases are a subset of all infections and in the absence of more comprehensive data, such as could be collated through widespread cluster investigation and community testing, we cannot conclude anything about clusters of infections, nor that we have included all relevant settings in which transmission can occur. We were also unable to estimate attack rates from the available data, meaning that comparison between rates of transmission in settings is impossible to achieve.

Settings associated with large cluster sizes

One type of setting that was associated with large numbers of eventual cases was religious venues. The common features of these meetings are the large number of attendees, confined spaces and physical contact. For example, there were eventually more than 5000 COVID-19 cases linked to transmission at the Shincheonji Church of Jesus in South Korea (Shin *et al.*, 2020). In this particular religious venue, no preventative action was taken despite knowing members were infected with SARS-CoV-2. In other venues, transmission events took place without prior knowledge of any infections and before the WHO declared pandemic status. Other large clusters in this setting type were associated with annual religious events that took place over a few days or weeks (Ananthalakshmi & Sipalan, 2020; BBC, 2020; Salaün, 2020). Attendees returned to their home countries where they continued to transmit. This generated many secondary cases internationally as well as locally. However, it is clear from smaller "first-generation" clusters, which our analysis focuses on, that these settings provide ideal conditions for transmission: we found 7/16 identified religious clusters had 10 cases or less, whilst 9/16 had 23 or more (see online database https://bit.ly/3ar39ky and *Underlying data* (Leclerc *et al.*, 2020) for more information). The number of cases in each cluster is an approximation, and little is known about the number of index cases in these religious meetings to begin with, with the exception of the South Korea cluster. Religious events are well known sources of heightened transmission; there is a focus on vaccination recommendations for attendees to the annual Hajj pilgrimage for example, which is currently being postponed for 2020 (Aljazeera, 2020).

Worker dormitories have been recognised as key places linked to transmission in Singapore, with 893 out of 942 new cases recorded on April 18th being residents in such dormitories (Asia, 2020). We found 21 reported clusters, one of which had the second largest cluster size of all the events we report here; 797 cases which from the data we believe is a first-generation cluster. Worker dormitories are similar to households (Dalling, 2020) in the sense that they are places where people live together and come in frequent close contact; however, the number of residents in dormitories is higher than in most other households. This probably contributes to the higher cluster sizes seen in this setting. Additionally, hygiene facilities can be limited in worker dormitories (Paul *et al.*, 2020), which could also explain the higher transmission. These points also apply to prisons, another type of large co-habiting setting for which we have identified 4 clusters with a maximum cluster size of 353 cases. It would be beneficial to compare attack rates across households, worker dormitories and prisons, to better understand which factors influence the risk of transmission between people who share a living space. Unfortunately, we were unable to identify the total number of residents in these dormitories and prisons, which prevented us from deriving attack rates and making this comparison.

In addition to religious events and worker homes, we also identified clusters of more than 100 cases in elderly care homes, hospitals and ships. These are all known to be at risk of clusters of infectious disease (Blanco *et al.*, 2019; Kak, 2015; Lansbury *et al.*, 2017). Moreover, people in these settings are often older than the general population and hence at greater risk of severe forms of COVID-19 disease (U.S Centers for Disease Control and Prevention, 2020). The increased mortality and likely dependence on availability of personal protective equipment (PPE) mean that healthcare clusters are more politically sensitive and hence more likely to be reported.

A more unexpected setting type is perhaps food processing plants, in which we identified clusters of up to 518 cases (Cannon, 2020). These plants have been the source of clusters in multiple countries. It is possible that the cold atmosphere in this setting has facilitated the spread of the virus (Molteni, 2020). Other possible explanations include the close proximity of workers for prolonged periods shared welfare spaces, as well as the need to speak loudly to communicate over the noise of the machines, which could lead to an increased projection of viral particles. Another explanation is that we may not be seeing clusters from other manufacturing settings with similar working environments, as fewer have been in operation due to lockdown guidelines during the pandemic, whereas food production has continued.

We identified seven additional setting types with cluster sizes above 50 or 100 cases (school, sport, bar, shopping, wedding, work and conference), which shared characteristics with the settings described above (see online database for more information https://bit.ly/3ar39ky and *Underlying data* (Leclerc *et al.*, 2020)). Notably, sport, bars, shopping areas and conferences are predominantly indoor settings, where people are in close proximity. For conferences and work, like religious events, transmission within the cluster is facilitated by the duration

of the events over several days, as well as the combination of interactions there (workshops, dinners etc…). This can also apply to weddings, where transmission is further increased due to the close-proximity interactions between people (kissing, hugging, dancing etc…). As for bars and shopping areas, these are places with important fluxes of people, which increases the diversity of contacts. Finally, schools, like religious groups, can sometimes represent tightly knit communities which facilitates disease transmission amongst individuals, as was the case with the Salanter Akiba Riverdale school in New York, with a cluster size of at least 60 cases (Ailworth & Berzon (2020)).

The first 100 transmission events & under reporting

The pursuit of the first 100 transmission events revealed little on settings of transmission. This reflects the wider issue we found of under reporting and is likely to reflect the fact that many public health surveillance systems were quickly overwhelmed and could not continue outbreak investigations. An example of this is the UK where only limited information on case follow-up and cluster investigation appears to be available. The impact of such under reporting is that we cannot say with certainty what contribution each setting had to overall transmission – we do not have the denominator information on time and contact in all settings. Nor do we have universal screening for detection of all infections, many of which will be asymptomatic. The importance of such universal testing for infection in interpreting whether transmission has occurred in a setting is highlighted by the difference between the low number of clusters linked to schools and the high level of infection reported in one French high school study (Fontanet *et al.*, 2020).

Further work could pursue data from early investigation of cases where available, to explore the relative importance of different settings to transmission. Importantly, this may counter a bias towards small cluster sizes: with a lack of follow-up only some of the cases actually linked to a setting may be reported and linked. Detailed outbreak investigations should also be explored to get information on the places where transmission is unlikely to have occurred, e.g. if a COVID-19 patient reports 30 contacts at place "A", "B" and "C", but only contacts in "C" subsequently become infected this reflects reduced risk in settings "A" and "B".

Implications for further work

We found that many clusters of cases were linked to indoor settings, but this may be because early spread in China was during their winter, with people naturally spending more time inside close spaces. Increasing evidence suggests that transmission of SARS-CoV-2 can occur via airborne droplets (Morawska & Cao, 2020); however, it is likely that outdoor transmission risk is lower (Nishiura *et al.*, 2020). Further work is needed to clarify this. We found only few clusters in school settings. However, there were many clusters associated with household transmission, and children could be the entry point for the virus into this setting. Although it should be noted in this context that the Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19) did not find a single instance where people recalled transmission from a child to an adult (WHO-China Joint Mission Members, 2020). More generally, the role of children in widespread transmission of the virus is unclear, and whether reopening schools could trigger increased introductions of the virus into households and further within-household spread will have to be carefully monitored.

Further investigation of settings that facilitate clusters of transmission could provide important information for containment strategies as countries lift some of the current restrictions. Previous work has suggested that there might be considerable heterogeneity in individual transmission, which would imply a disproportionate impact from preventing large transmission events from occurring (Endo *et al.*, 2020). Whilst widespread contact tracing is often considered part of future containment strategies, there is a need for this to be complemented with retrospective investigation of clusters in order to better understand the extent to which certain settings and behaviours are at particular risk of generating clusters of transmission. This could, in turn, inform contact tracing efforts and might be particularly relevant in the context of contact tracing using mobile phone apps, which has recently been suggested in support of more traditional contact tracing (Ferretti *et al.*, 2020). For example, past co-location in certain settings could be a trigger for notification of risk from an app instead of, or in addition to, individual contacts.

Online database of collected reports

The online database (accessible at https://bit.ly/3ar39ky) provides information on all collected reports, references and information on cluster sizes as well as notes about the study. This database will be kept as a static source linked to this report, but with an additional tab for newly reported settings. Readers can submit information in the "Suggested updates" tab and we will aim to update information if evidence for substantial new clusters are found linked to a setting that was not in this study.

Conclusions

In conclusion, we found evidence of SARS-CoV-2 transmission in many types of settings. Our results provide a basis to identify possible places that are linked to clusters of cases and could be closely monitored, for example by linking to app-based contact tracing, and/or remain closed in the first instance following the progressive removal of lockdown restrictions. However, reporting should be improved in the majority of settings, with implementation of systematic reporting on the number of potentially exposed individuals and the number of confirmed and suspected cases from these settings, to allow the estimation of attack rates.

Data availability

Underlying data

Figshare: COVID19 settings of transmission - collected reports database. https://doi.org/10.6084/m9.figshare.12173343.v3 (Leclerc *et al.*, 2020).

This project contains 'COVID-19 settings of transmission - database.xlsx', which contains the data extracted from the initial search, as well as an updated version of the dataset from 26/05/2020.

Up to date information on all collected reports is provided in an open-access online database (accessible at https://bit.ly/3ar39ky).

This database provides references and information on cluster sizes as well as notes about the studies.

Acknowledgments

We would like to thank Dr Joël Mossong for his review of our article. We would also like to thank all the anonymous individuals who suggested updates for transmission events in our online database.

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Open Peer Review

Current Peer Review Status: ✔ ✔

Version 2

Reviewer Report 30 June 2020

https://doi.org/10.21956/wellcomeopenres.17583.r39003

✔ **Samuel V. Scarpino**
Network Science Institute, Northeastern University, Boston, MA, USA

In this manuscript, the authors conduct a thorough literature review and identified SARS-CoV-2 transmission clusters. After assembling their data set, the authors discuss the possible similarities in settings associated with transmission. As stated, understanding how transmission risk varies across settings is critical for the safe relaxation of measures implemented to control the spread of COVID-19. This paper provides a valuable resource and synthesis of what is currently known. I should note that this article has already been evaluated and I believe the authors have adequately addressed the points raised by the previous reviewer. However, I do have a few additional comments/questions, which I hope the authors find constructive.

1. While Google Sheets is a convenient tool for entering and sharing small data sets, it is not "permanent" and also has the potential to be corrupted or heavily modified. There is also no easy way for authors to cite the "version" of the sheet used. The authors do provide a Figshare, but that appears to date back prior to the revised version. I would strongly suggest regularly archiving a version of the data set and assigning each update a version number. At a minimum, please provide a DOI for the revised data set.

2. I am concerned that one reason we don't see more evidence for transmission at schools is that schools were closed early in nearly all locations. To my knowledge, Sweden is not reporting data on whether there have been significant transmission in their schools (as the authors know not all of which are open). I believe the authors should provide a strong disclaimer, either in the abstract or early in the discussion that we really don't have much to go on w.r.t. schools. (Of course this is my opinion and likely subject to debate).

3. The authors state, "More generally, the role of children in widespread transmission of the virus is unclear, and whether reopening schools could trigger increased introductions of the virus into households and further within-household spread will have to be carefully monitored." But, I also feel that given the uncertainty in whether children are import for ongoing transmission, there are other settings we should caveat.

4. The authors note that they, "use peer reviewed articles as a quality threshold," and, while I strongly disagree with the exclusion of pre-prints, I think the authors should at least provide some information on how many studies or clusters were excluded. Given the long (and increasing lag) between pre-print and publication, is this study missing half of all clusters that are currently published or in-review? 10% 95%? Providing information around what's been excluded is standard practice for such reviews and feels critical in this case.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Epidemiology

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 05 June 2020

https://doi.org/10.21956/wellcomeopenres.17583.r38985

Joël Mossong
Epidemiology and Microbial Genomics, Laboratoire National de Santé, Dudelange, Luxembourg

My comments and suggestions have been adequately addressed.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Epidemiology of infectious diseases

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 18 May 2020

https://doi.org/10.21956/wellcomeopenres.17429.r38734

?

Joël Mossong
Epidemiology and Microbial Genomics, Laboratoire National de Santé, Dudelange, Luxembourg

This manuscript aims to provide a descriptive analysis of transmission settings of Covid19 based on published articles or media reports, which is of major interest for controlling the epidemic.

I have several major concerns:

1. Most settings reported herein are not representative of settings from a global perspective, most are from the initial epidemic in Asia (mainly from the Singapore dashboard and <20% of settings in the manuscript are outside of Asia). This needs to be added to the discussion as a major limitation.

2. Some important and widely reported outbreaks in particular settings are missing. e.g. the outbreak of the megachurch in Mulhouse France (https://www.dailymail.co.uk/news/article-8168819/French-megachurch-meeting-blamed-sparking-and the Ruby Princess outbreak (reported in

https://www1.health.gov.au/internet/main/publishing.nsf/Content/1D03BCB527F40C8BCA258503C [1]) or the cluster in the french ski resort (https://www.bbc.com/news/uk-51425702). This somehow questions the completeness of the systematic review. The authors could have widened their search terms to include the settings (church, ship, etc.) and outbreak when searching media reports.

3. Given that this manuscript from a team in the UK, it is surprising that only 4 outbreak settings were reported for the UK. The authors need to discuss why they were not able to find more reports from the local and national media outlets in English speaking countries like UK, Ireland, and possibly also Australia, Canada and the US.

4. The authors should discuss reasons for under reporting: public health surveillance systems in many countries were quickly overwhelmed to investigate transmission settings and chains of transmissions. Transmission clusters in elderly care and hospitals homes due to political sensitivity, linked to increased mortality, lack of adequate PPE equipment

5. Meat factories and slaughter houses have recently emerged as high risk setting in the US (https://edition.cnn.com/2020/04/08/business/meat-plant-closures-coronavirus/index.html) and Germany (https://www.dw.com/en/coronavirus-breaks-out-in-third-german-slaughterhouse/a-53389860). This setting should be included separately in Table 1.

Minor comments:

1. Add the sum of cases for all clusters per setting in table 1.

2. p.3.& p. 7 "the first 100 transmission events". While this is an interesting concept, it isn't really being addressed in this article. No country presented herein has collected more than 100 events. The paragraph in the discussion on this seems therefore irrelevant and could be deleted.

3. p. 7. The authors mention that there is increasing evidence for airborne transmission. The current consensus is that most transmission occurs via airborne droplets, which is different to aerosol transmission. I suggest to replace "be airborne" by "occur via airborne droplets".

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Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing interests: No competing interests were disclosed.

Reviewer Expertise: Epidemiology of infectious diseases

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 01 Jun 2020

Quentin Leclerc, London School of Hygiene & Tropical Medicine, London, UK

This manuscript aims to provide a descriptive analysis of transmission settings of Covid19 based on published articles or media reports, which is of major interest for controlling the epidemic.

Thank you for taking the time to review our article. Please note that we have now updated our analysis to include an additional 49 transmission events (201 events total) and 4 new settings type ("Food processing plant", "Prison", "Transport" and "Wedding"; 22 setting types total). Some of these new elements overlap with your suggestions. Our Discussion section has also been updated to reflect these new results.

I have several major concerns:

1. **Most settings reported herein are not representative of settings from a global perspective, most are from the initial epidemic in Asia (mainly from the Singapore dashboard and <20% of settings in the manuscript are outside of Asia). This needs to be added to the discussion as a major limitation.**

Thank you for raising this point. We already mentioned in the Discussion - Limitations section that many studies originated from the early outbreak in China, but have included an additional sentence there to clarify that this could prevent our results from being directly applicable to other countries. That said, please note that in our updated analysis, 98/201 (50%) events are from China and Singapore, compared to 92/152 (60%) in our original analysis, which improves the coverage of our results.
The added sentence is "The settings we identified here therefore might not be representative of settings from a global perspective."

1. **Some important and widely reported outbreaks in particular settings are missing. e.g. the outbreak of the megachurch in Mulhouse France (https://www.dailymail.co.uk/news/article-8168819/French-megachurch-meeting-blamec and the Ruby Princess outbreak (reported in https://www1.health.gov.au/internet/main/publishing.nsf/Content/1D03BCB527F40C8BC or the cluster in the french ski resort (https://www.bbc.com/news/uk-51425702). This somehow questions the completeness of the systematic review. The authors could have widened their search terms to include the settings (church, ship, etc.) and outbreak when searching media reports.**

Thank you for suggesting these additional clusters; we have now added the Ruby Princess and the French ski resort events.

Our initial analysis was focused on trying to find distinct *settings* in which transmission had occurred. Hence we were initially trying to prioritise examples of new *settings* linked to clusters rather than gathering all data on all outbreaks linked to all settings. This has changed somewhat with the open source database and we are happy to act as a gathering point for cluster data.

For the outbreak in Mulhouse, this falls into the category of events that we do not include in our analysis. This because we are interested in understanding transmission only within specific settings; for example, for a cruise ship, the cluster size we report corresponds to the number of people infected on that ship only, not the people that these might have infected after disembarking. If we included people infected by passengers after disembarking, this would not reflect the "cruise ship" setting, as this additional transmission could occur in a variety of other settings (household, meal etc...).

We had already highlighted this in the Methods – Outline section, but have now repeated that point at the beginning of the Discussion to hopefully make this distinction clearer ("Note that we restrict cluster size to only include individuals infected within a specific setting, and exclude secondary infections which occurred outside the settings.")

1. **Given that this manuscript from a team in the UK, it is surprising that only 4 outbreak settings were reported for the UK. The authors need to discuss why they were not able to find more reports from the local and national media outlets in English speaking countries like UK, Ireland, and possibly also Australia, Canada and the US.**

Our initial search was at the end of March. At that time, the number of confirmed cases in the UK was around 20,000, compared to more than 200,000 now. Therefore, there was little information at the time on clusters in these countries compared with Asia, which is why we were less likely to find media reports on that topic for the UK. For similar reasons, we had little information for English-speaking countries. In addition, because of the lack of widespread testing in the UK and/or follow-up of cases, information on clusters does not appear to be widely available in the UK.

As of 26/05/2020, we have now identified 39 transmission events in English-speaking countries (19% of all the transmission events we have identified so far). Therefore, our updated analysis is more geographically balanced.

1. **The authors should discuss reasons for under reporting: public health surveillance systems in many countries were quickly overwhelmed to investigate transmission settings and chains of transmissions. Transmission clusters in elderly care and hospitals homes due to political sensitivity, linked to increased mortality, lack of adequate PPE equipment**

Thank you for this suggestion. In line with your comments on the "first 100 transmission events" we have adapted the paragraph in the discussion to discuss reasons for under reporting.

We have also added a sentence to the paragraph on healthcare clusters in the discussion to reflect the likely increased reporting of clusters linked to these settings due to political sensitivity.

1. **Meat factories and slaughter houses have recently emerged as high risk setting in the US (https://edition.cnn.com/2020/04/08/business/meat-plant-closures-coronavirus/index.ht and Germany (https://www.dw.com/en/coronavirus-breaks-out-in-third-german-slaughterhouse/a-533 This setting should be included separately in Table 1.**

Thank you for raising this point. Our online database had been updated to reflect this, and we have now added the "Food processing plant" setting type in our analysis, and comment on this in the Results and Discussion sections of our article.

This also applies to our new "Prison", "Transport" and "Wedding" setting types.

Minor comments:

1. **Add the sum of cases for all clusters per setting in table 1.**

We have now implemented this suggestion in the revised article.

1. **p.3.& p. 7 "the first 100 transmission events". While this is an interesting concept, it isn't really being addressed in this article. No country presented herein has collected more than 100 events. The paragraph in the discussion on this seems therefore irrelevant and could be deleted.**

We agree it was frustrating not to find this data, which would have been an interesting angle, giving us "denominator" information. In line with the comments above we have adapted this paragraph to link to under reporting.

1. **p. 7. The authors mention that there is increasing evidence for airborne transmission. The current consensus is that most transmission occurs via airborne droplets, which is different to aerosol transmission. I suggest to replace "be airborne" by "occur via airborne droplets".**

Thank you for this suggestion, we have now rephrased this accordingly.

Competing Interests: No competing interests were disclosed.

Comments on this article

Version 2

Reader Comment 23 Jun 2020

Barney Duncan, Ex-Wellcome Biotechnology Ltd, Abermaw, Gwynedd, UK

Back in the 1980's Wellcome Biotechnology Ltd (owned & operated by the Wellcome Trust) expended much effort in trying to eliminate the use of blood fractions from nutrient media used for growing and maintenance of animal & human cell lines prior to innoculation with virus in the making of rabies and foot & mouth disease vaccines as well as interferon. At the time, it was found that without blood, cell growth and virus titres were poorer.

I have recently observed locally in North Wales 2 major clusters from the 2 Sisters Poultry processing plant on Anglesey and a meat processing plant in Wrexham. This caused me to look further into commonality of Covid outbreaks in other meat processing plants. It resulted in me coming across your paper.

I am mindful of the fact that the first outbreak was traced back to a food market in Wuhan China. The *coronavirus* likely jumped to people in a wet *market* there where meat, seafood, and live animals were handled.

I believe there may be real signifcance in the quantities of blood on workers overalls and working surfaces in slaughterhouses & meat processing factories. Blood deposits would surely provide a site where virus impregnated droplets from an infected worker could act as inoculum and allow virus to replicate rapidly

In consequence of these facts I would suggest the following recommendations for the next update

1 Add wet/cattle markets to the transmission settings list
2 Split food processing plant into two fractions meat and non-meat

Thank you to all participants/contributors to your paper. It is most creditable & worthwhile and I believe will prove most valuable line of research.

Barney Duncan
Chemical Engineer (ret'd)

Competing Interests: None unless you consider being a Wellcome pensioner influences my judgement but I'm sure Bill Castell (former CEO of Wellcome Biotechnology and Chairman of Wellcome Trust) could & would readily dispel any such notions !

Reader Comment 08 Jun 2020

David Henry, Bond University, Gold Coast, Queensland, Australia

This is an important topic. I am concerned about your search. I may have missed it, but I think having done this scoping exercise that you should rerun your searches with specific terms (and synonyms) for the settings of interests: schools churches, weddings, meatworks (lots of synonyms) etc. I am guessing that you will get a lot more hits. I don't think that 'transmission cluster' is a sufficiently sensitive term. I'd also like to see a PRISMA flow diagram.

Competing Interests: None

Version 1

Reader Comment 21 May 2020

María Margarita Ronderos Torres, Independent Consultant in Epidemiology, Colombia

I would like to draw to your attention the football match between Atalanta from Bergamo and Valencia from Spain on the 19th Feb at the San Siro Stadium in Milan. Aprox 40,000 fans from the Region attended the match. 35% of the Valencia team delegation when returning to Spain tested positive for COVID19. The region only went into lockdown on the 4th of March. This gave ample time (1.5 t 2 incubation periods) for household transmission with high intergeneration mix and known high elderly population. Further study is needed but this could be very well explain the explosion of cases that followed and is in line with your proposed explanation for super spread of the virus.

Competing Interests: NO competing interests

TAB B

High-transmission variants in Canada

February 02, 2021

What happens if a high-transmission variant becomes established, and is transmitted in the general community in Canada?

Elisha Are, Caroline Colijn

Here we illustrate the kind of reported case trajectory that we may see if a higher-transmission variant, such as the B.1.1.7 variant that has been rising dramatically in frequency in the UK, becomes established in Canada. Volz et al estimate that B.1.1.7 has a substantial transmission advantage - a 40-80% increase in the reproduction number, for example. An increase like that in the transmission rate is worse than a higher severity or mortality rate, because so many more people can get infected.

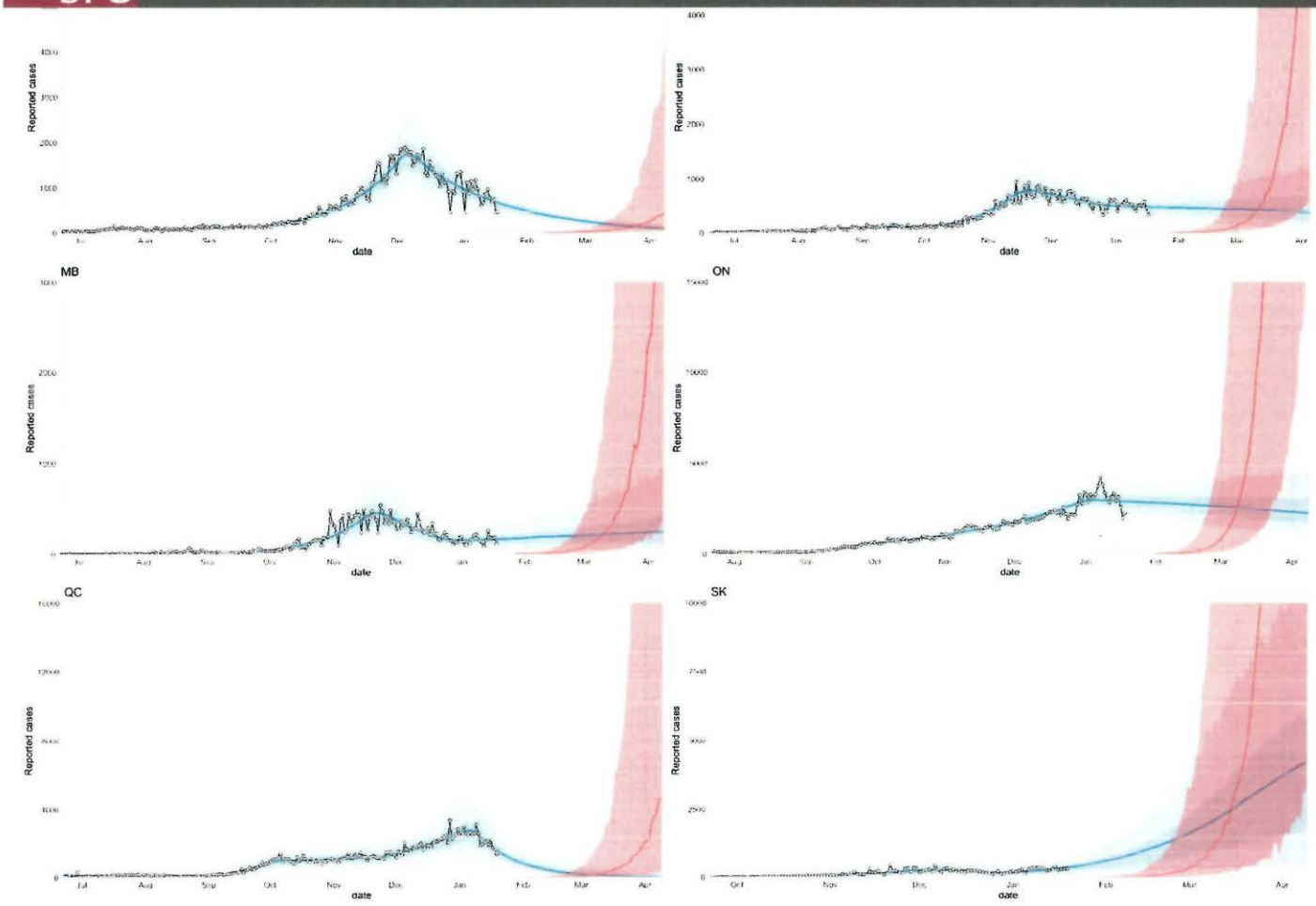
In most of Canada we have been able to control COVID-19 -- at least, the variant(s) we have today -- albeit with strong distancing measures (stay-at-home orders in Ontario, curfews and other rules in Quebec, restrictions on socializing with anyone outside your household - these are all familiar). But a variant with a 40+% increase in transmission rate (or similar increase in R) likely would not be contained with measures we have in place today.

What would it look like if a variant with a 40% higher transmission rate got established here, under the current COVID-19 controls? We modelled this by adding growth of a new higher-transmission variant like B.1.1.7 to our regular covidseir model fits for Canada's six provinces with substantial COVID-19 cases. The underlying model is described here (with further details below).

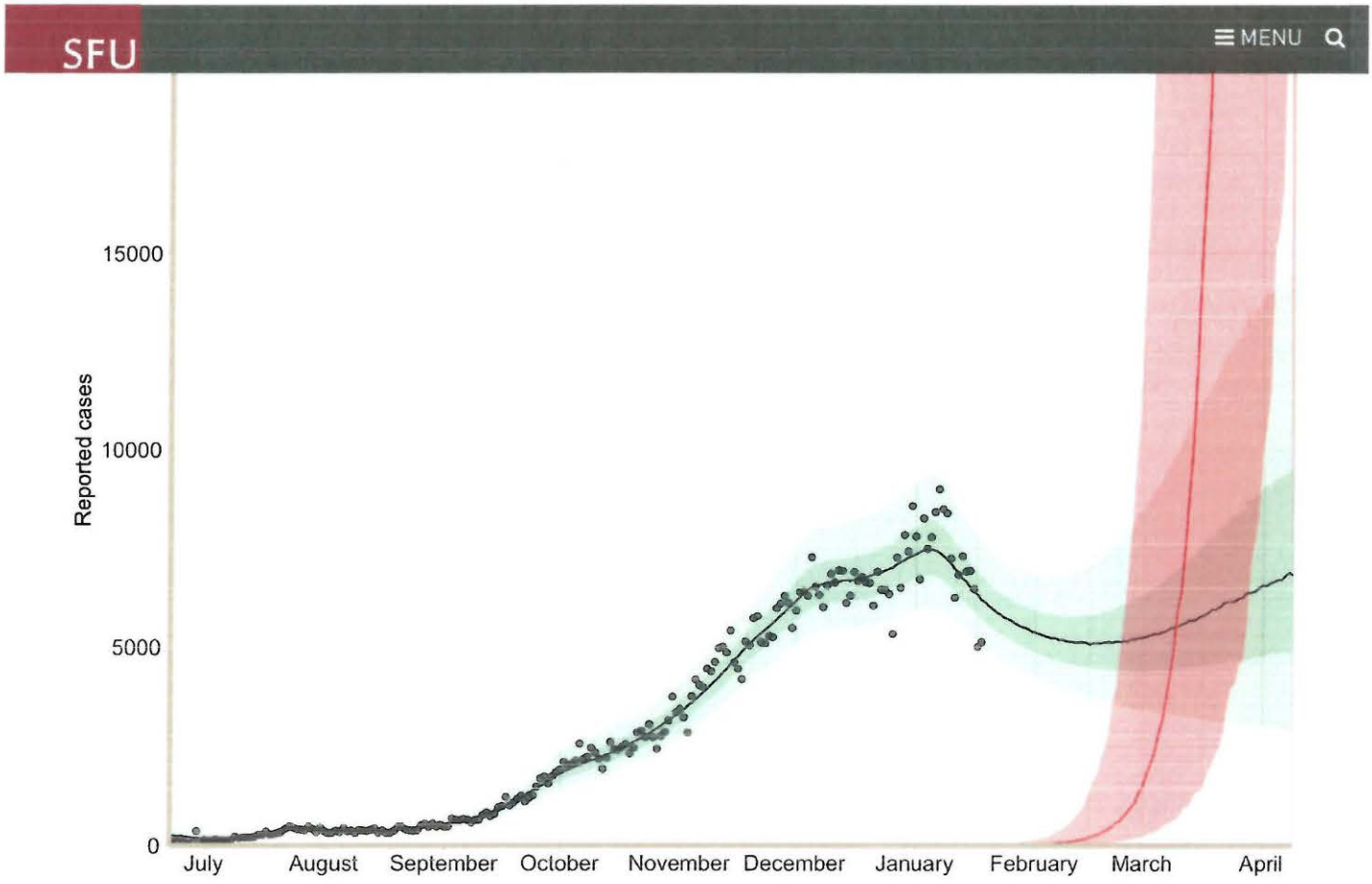
These are the results:

This is **EXHIBIT " B "** referred to in
the affidavit of DR. BRIAN EMERSON
affirmed before me at Victoria,
in the Province of British Columbia
this 2 day of February, 2021.

A Commissioner for taking affidavits in British Columbia



And here is the compiled Canada-wide version:



What does it mean?

The punch line is that **failure to prevent or contain this now spells disaster in March.** While we don't see much impact for ~6 weeks, when it comes it comes steeply, with a doubling time of 1-2 weeks, compared to doubling times like 30-40 days recently in provinces like Ontario. Exponential growth is fast - when you're halfway to the maximum capacity you can tolerate (in hospitalization, ICU, contact tracing capacity, or wherever the bottlenecks are), you only have one doubling time left. But it might have taken 8 doubling times to get to halfway.

Methods

HIere's how the modelling works. We first use covidseir to fit the reported case trajectory for each province (separately). The covidseir model is a compartmental SEIR model that has two populations: those who are able and willing to participate in distancing (most of the population), and those who are not (for work or other reasons). When distancers do go out and have contact with others, they are less likely to contact other distancers (because they're at home). The fitting is done in RStan, and the process estimates several parameters, including the underlying basic reproduction number (from the initial rise in March 2020) and the strength of distancing -- in terms of the fraction f of the regular contact rate, among distancers. Lower fractions mean stronger distancing measures (or people

We then project forward under the current estimates. We also model a strain like B.1.1.7 with a higher transmission rate - affecting both sub-populations, though the "distancers" still have a reduced contact rate. While we have made a good effort to fit the data, and

- The time of introduction of the new variant is the same in all the provinces -- random, uniform in Jan 5 - Jan 25, 2021. This isn't the time of introduction, but the time that community transmisison becomes established.
- Currently, we are not able to detect whether each reported case is a variant type (B.1.1.7 or otherwise); we do some whole-genome sequencing and some qPCR testing that can detect B.1.1.7 via the S gene dropout, but it is very possible that there are a number (50? 100?) B.1.1.7 cases circulating that we don't know about. If it were established earlier or later than January, shift the red curves earlier or later to imagine what the model would look like.
- In this modelling, the control measures currently in place continue indefinitely. This is not realistic, but serves to illustrate the impact of a higher-transmission variant even if we keep doing the stringent things we are doing today.
- Places like AB and MB get a double benefit - their current measures impact both variants, delaying the rise of the high-transmission variant. This does not necessarily contain B.1.1.7 (or any similarly high-transmission type)
- We have modelled a mean 40% increase in the transmission rate, compared to the COVID-19 circulating in Canada today
- Unfortunately the models are not linked - we have used the approximation that few Canadians have had COVID-19, so there is little immunity. The two variants are not experiencing much competition for hosts. If the new variant rises to high levels in this modelling, it does not suppress the 'regular' COVID-19 as it would if competition began to take place.
- The new variant's trajectory does not reflect a build-up of immunity due vaccination. However, current vaccination strategies are not targeting transmission and we have limited natural immunity, so in the time frame of now to March, this is not an unrealistic assumption.

So what can we do?

We should take steps to prevent introductions of new variants into Canada: tighten rules on travel, define essential travel and stop non-essential travel. We should step up quarantine and isolation of travellers. We should improve detection, using tests that can detect B.1.1.7 (qPCR and whole genome sequencing) and other variants (mainly whole genome sequencing) -- though B.1.1.7 is the one for which we have strong indications that it has higher transmission. But we must also be willing to act to curtail the spread of high-transmission variants - B.1.1.7 at the moment - in Canada.

If and when we find out that COVID-19 vaccines can impact transmission -- and we think it is likely that they will -- we could use vaccination as one of the tools in the transmission toolkit, for example by vaccinating truckers who need to cross the Canada/US border.

There have been a few detected B.1.1.7 cases already in Canada, and so far we hope that community spread has not yet been established. But we should be considering reducing travel within Canada, not just from outside it, because we may still need to prevent spread of B.1.1.7 between Canadian jurisdictions. And we should consider screening domestic travellers for B.1.1.7 if we can.

There may be time still to head off introductions and community transmission until many more of us are vaccinated. But that is months away, and right now, vaccination is not going to impact transmission in the 6-8 week time frame.

The Covid Strategic Choices group has a petition on this topic - see here for more details.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