CIHR-PHAC-CADTH

Best Brains Exchange

Transmission Routes for COVID-19: Implications for Public Health

September 28 and October 1, 2020

About CADTH: CADTH is an independent, not-for-profit organization responsible for providing Canada's health care decision-makers with objective evidence to help make informed decisions about the optimal use of drugs, medical devices, diagnostics, and procedures in our health care system.

Funding: CADTH receives funding from Canada's federal, provincial, and territorial governments, with the exception of Quebec.

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Executive Summary

A division exists among experts on the definition of an aerosol, the degree of infectivity of the SARS-CoV-2 in aerosols, when aerosols are generated, and what role aerosols may be playing in human-to-human transmission. It has also become apparent that the spectrum of expertise that can help inform decisions on routes of COVID-19 transmission should be broadened. The Canadian Institutes of Health Research, in collaboration with the Public Health Agency of Canada (PHAC) and CADTH, hosted a virtual Best Brains Exchange (BBE) on September 28th and October 1st, 2020. Invited experts from epidemiology, virology, infection prevention and control, occupational health and safety and engineering were joined by policy-makers, researchers, implementation experts, and other key partners in public health to discuss the transmission routes of COVID-19 and the implications for public health.

The presentations and discussions were focused on the following pre-identified areas:

- Using a common lens, review the science of:
  - the circumstances under which aerosols are generated
  - the infectiousness and transmissibility of COVID-19 through all forms of respiratory secretions.
- Provide evidence-based advice on the proportional effectiveness of infection prevention and control measures to prevent the transmission of COVID-19 in health care settings and shared indoor spaces.
- Establish a foundation for a collaborative approach to ensure the achievement of future evidence-based public health strategies and interventions to protect the health of all Canadians.

The meeting featured presentations by experts, followed by group discussions related to the presentation content and questions posed by the moderator.

Through the meeting, themes emerged around how aerosols are defined and managed differently by aerosol and medical scientists; measures to reduce the risk of infection in buildings and measures to protect health care workers (HCWs) from acquiring COVID-19; and finally, knowledge gaps and research needs, including the need for clearer communication to HCWs and the general public, were identified.

The meeting provided participants with a more holistic and increased understanding of the various perspectives and considerations around transmission routes for COVID-19. Consensus agreement among participants was not achieved on transmission modes of SARS-CoV-2 nor the appropriate mitigation strategies applicable in all contexts. Next steps include using perspectives from this meeting in concert with ongoing evaluation of emerging science to inform PHAC’s guidance on prevention of transmission of COVID-19.

PHAC will continue to engage the meeting participants, expert presenters, and other relevant organizations as new evidence becomes available and guidance documents are identified for updating.

List of Abbreviations

AGMP	aerosol-generating medical procedure
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BBE	Best Brains Exchange
CDC	Centers for Disease Control and Prevention
CIHR	Canadian Institutes of Health Research
ECDC	European Centre for Disease Prevention and Control
HCW	health care worker
HVAC	heating, ventilation, and air conditioning
IPC	infection prevention and control
NASEM	National Academies of Science, Engineering, and Medicine
PHAC	Public Health Agency of Canada
PHE	Public Health England
PPE	personal protective equipment
REHVA	Federation of European Heating, Ventilation and Air Conditioning Associations
RNA	ribonucleic acid
SARS-CoV-2	severe acute respiratory syndrome coronavirus 2
WHO	World Health Organization

Introduction

On September 28th and October 1st, 2020, the Canadian Institutes of Health Research (CIHR), in collaboration with the Public Health Agency of Canada (PHAC) and CADTH — the Canadian Agency for Drugs and Technologies in Health — hosted a virtual Best Brains Exchange (BBE). This meeting, entitled Transmission Routes for COVID-19 — Implications for public health, was held from 1:00 p.m. to 3:30 p.m. EDT each day.

Invited experts from epidemiology, virology, infection prevention and control, occupational health and safety and engineering were joined by policy-makers, researchers, implementation experts, and other key partners in public health to discuss the transmission routes of COVID-19 and the implications for public health, with a focus on the best available evidence related to the risk of aerosol transmission of COVID-19.

This report is intended to provide an overview of the proceedings, including presentations, an anonymized record of the discussions, and a platform to suggest collaborative strategies to more broadly encompass the spectrum of expertise in this area.

Best Brains Exchange

The BBE program is CIHR's flagship Knowledge Translation platform. BBE's are invitation-only meetings that bring together policy-makers and researchers to discuss a health topic of shared interest and high priority to the organizing partners.

These informal gatherings promote interaction among experts, presentation of best evidence, and mutual learning between researchers, implementation experts, and policy-makers, and help to:

- provide senior policy-makers with high-quality, timely, and accessible research evidence and advice from leading researchers and implementation experts
- engage researchers and policy-makers in an open dialogue about the validity and applicability of the evidence to the current policy context
- foster relationships between policy-makers, researchers, and implementation experts with shared interests.

Background and Policy Context

At the time of this meeting, PHAC had developed guidance using the paradigm that COVID-19 is predominantly spread through droplet and contact routes. This defined the infection control measures recommended in guidelines to prevent ongoing transmission of the virus.

Many international organizations— including the World Health Organization (WHO), Public Health England (PHE), and the Centers for Disease Control and Prevention (CDC) — have started to identify specific circumstances in which aerosols may be playing a role in COVID-19 transmission. This understanding broadened the context of potential COVID-19 transmission beyond aerosol-generating medical procedures (AGMP). Where organizations acknowledge circumstances, beyond AGMP, where transmission of COVID-19 may occur through aerosols, their guidance on prevention strategies reflects this understanding.

As a legacy from the severe acute respiratory syndrome coronavirus (SARS), there remains ongoing debate regarding the mechanism of transmission of coronavirus infections and how best to protect HCW and the public against infection. Increasing epidemiological evidence generated by contact tracing and outbreak investigations have yielded results that suggested the possibility of aerosol transmission. However, in these studies there was not always phylogenetic data to support the hypothesis or sufficient epidemiologic information to exclude droplets as also playing a role in the transmission. Sparse recent data suggests that virus can be cultured from aerosols and it has been posited that the previous infrequency of viral isolation from aerosols may be the result of technical limitations. Finally, as the pandemic has progressed, there have been an increasing number of high profile publications suggesting that aerosol transmission of COVID-19 is plausible.

Need for Evidence on the Topic

All would agree that COVID-19 is transmitted by respiratory particles. That being said, a division exists among experts on defining the spectrum of respiratory particles, what is an aerosol, the degree of infectivity of the virus in aerosols, and what role aerosols may be playing in human-to-human transmission. Guidance in public health and other fields is written to be broadly applicable in general circumstances; however, there may be specific circumstances where broad guidance needs reconsideration. For example, if guidance is written based upon a model in which a given activity does not produce an aerosol, then measures put in place to mitigate transmission will reflect that model. However, if the model is shown to be incorrect and in fact aerosols are generated by that activity, and under certain circumstances are infectious, then the prevention advice will need to reflect the new model. Achieving an understanding of the nature of respiratory particles produced by humans and their potential to transmit COVID-19, is therefore fundamental to producing accurate guidance on transmission prevention.

Through presentations from national and international experts, robust discussion, informed by commentary from multiple jurisdictions, this BBE was intended to examine the best available evidence on routes of COVID-19 transmission, to find areas of agreement and to identify the areas where there are unknowns – with the goal of creating the framework for policy moving forward.

This report is based on anonymized notes from the meeting, as all BBEs operate under Chatham House Rules. As such, only presenters are identified by name in this report and questions, answers, and comments, are paraphrased or captured thematically but not ascribed to anyone.

Opening and Welcome Remarks

Opening: Dr. Sarah Viehbeck, Associate Vice-President, Research Programs – Strategy, CIHR

Dr. Viehbeck opened with the land acknowledgement of the traditional Algonquin territory of the Anishnabeg (Anishinaabe) and the lands of all Indigenous peoples across the country. She indicated that the goal was to achieve the BBE objectives by using a deliberative dialogue approach and recognized that CIHR is committed to mobilizing the best available evidence upon which policies and practices can be based. Dr. Viehbeck thanked PHAC and CADTH for their collaboration in identifying and driving the issue and the need for this BBE.

Welcome: Dr. Theresa Tam, Chief Public Health Officer, PHAC

Dr. Tam welcomed everyone and acknowledged the role of key partners. She shared that it is difficult to digest that it has been nine months since COVID-19 took over our collective lives. Dr. Tam stated that we are adding to our knowledge daily at a great pace of expertise and scientific discovery; however, there are still many unknowns. She noted that the best science happens when those with different expertise come together and that the goal is to come to the best possible understanding of this important discussion on the role of aerosol transmission. Dr. Tam encouraged participants to speak in good faith and have an honest discussion for a solid interpretation of the evidence. She thanked the organizers of the BBE including CIHR and all participants. She was very impressed by the expertise of the internationally recognized speakers and participants, and looked forward to learning more from the findings of the day.

Moderator Dr. John Lavis, Director, McMaster Health Forum and Professor, Department of Health Evidence, and Impact, McMaster University

The Moderator Dr. John Lavis, Director, McMaster Health Forum and Professor, Department of Health Evidence and Impact, McMaster University was introduced. Dr. Lavis is a leading expert in linking science and policy together. He provided an overview of the meeting objectives and the format stating that it is important to look at what is causing people from different paradigms to look at the body of evidence and draw different conclusions from it. Dr. Lavis encouraged participants to think about how they can engage in a more dynamic way, taking into consideration the multidisciplinary perspectives. He also encouraged participants to keep the chat box discussion focused on the item being discussed.

Meeting Objective and Structure

The first session (day 1) was to focus on the science and involved a discussion of a couple of questions emerging from the science (1a and 1b that follow), with a goal to find out if we have agreement; and where we don't have an agreement, what does that mean for the science and policy?

The second session (day 2) was to focus on the implications of the evidence and whether PHAC should be thinking differently about the guidance it offers. There were two focused questions in this regard (2 and 3 that follow).

1. Using a common lens, review the science of:

   a) the circumstances under which aerosols are generated

   b) the infectiousness and transmissibility of COVID-19 through all forms of respiratory secretions.

2. Provide evidence-based advice on the effectiveness of proportional actions to prevent COVID-19 transmissions in health care settings and shared indoor spaces.
3. Establish a foundation for a collaborative approach to ensure the achievement of future evidence-based public health strategies and interventions to protect the health of all Canadians.

The BBE discussions were structured to achieve the meeting objectives. Scheduled presentations were followed by some time for questions and answers. Additional questions were addressed as group discussions and open to participants, nor are their comments attributed.

This report chronologically summarizes the presentations given during the meeting, ensuing question-and-answer sessions, as well as group discussions. Next steps are identified.

Presentation 1: The Current Context: Gaps and Opportunities

Dr. David Fisman, Professor, Division of Epidemiology, Dalla Lana School of Public Health, University of Toronto

The coronavirus has many paradoxes — with a case fatality ratio of 1%, it is a virulent pandemic pathogen characterized by asymptomatic and pre-symptomatic spread. Many transmission chains culminate in dead ends, and yet it can cause super-spreader events. It appears to "skip" children except when resurgences are driven by school openings. This makes it challenging to communicate nuanced public health guidance.

There is geographical variability in disease manifestations, including severity and apparent ability to control it. This has resulted in public health leaders being accused of "backtracking" or caught in contradictions, which diminish credibility and public buy-in. Data from China (January and February) looking at contact tracing showed small transmission chains and large bursts. A pathogen's basic reproductive number, R_0, is a measure of central tendency and doesn't capture variability. Where $R_0 > 1$ on average, there is pandemic potential, as is the case here, but the longer the tail of the R_0 distribution, the more over-dispersed the R_0 is.

COVID-19 is over-dispersed so super-spreader events are interspersed with individuals who are associated with few or no transmission events; most secondary infections come from a minority of primary infections. The implications of this in terms of disease importation is that the likelihood of chains of transmission from a single case is very low, but the probability of a large outbreak goes up with multiple importations. For example, there were introductions into Massachusetts state where the dominant strains came from super-spreader events from nursing facilities and homeless shelters (with strain origins from Europe and New York).

Can rare conditional aerosol transmission explain the 3 C's (crowded places, close contact setting and confined and enclosed spaces)?

Since the beginning of the pandemic, crowded places, close contact settings, and confined and enclosed spaces have been notable as sites of super-spreader events since early on in the pandemic. A well-studied super-spreader event in Massachusetts (the Biogen conference) was the site of a super-spreader event (N = 90) that was controlled. A contemporaneous super-spreader event in Massachusetts involving skilled nursing facilities and homeless/public housing outbreaks was not controlled.

In Massachusetts, early introductions from China and Italy appear to have had little secondary transmission. This was similar in Canada. In Quebec, predominant strains are emerging, seemingly from New York. Based on the "dominance" of super-spreader event associated strains (as characterized by deep sequencing) it seems that super-spreader events set the stage for invasion by this disease in jurisdictions where prevalence of infection is low.

Quantitative risk analysis

Available quantitative risk models support the idea that conditional aerosol transmission (in the presence of an individual with high viral load in respiratory mucus, early in infection, who exposes others in a 3 C's environment) explains the over-dispersion of R_0. (A fourth "C," continuous exposure, also increases risk.)

The total volume of aerosol generated by an individual is a function of activity; the volume of aerosol generated increases exponentially from breathing to speaking, to coughing, to sneezing. Exposure can be estimated as the volume of aerosol generated multiplied by respiratory mucus viral load. The "dwell time" for that aerosol is greater in a poorly ventilated, than a well-ventilated, space. This is the rationale for wearing masks.

With COVID -19, it is likely that masks may be providing bi-directionally protection — for source control, as well as to protect the wearer — which may both explain the impact of even cloth masks on ecological data and also suggests that we may see null effects from trials of surgical versus N95 masks in health care, as protection of the wearer may be less important than source control. In settings where there is low occupancy and less proximity, there is less risk. In settings where there are no face coverings, prolonged exposure, and poor ventilation, there is a higher risk.

In Ontario, mask mandates were staggered. Each public health unit set up their own mask mandate and we were able to see the impact on the number of cases of COVID-19. This created a natural experiment that clearly demonstrates the impact of masks. Dr. Fisman proposed that COVID-19 is becoming a very predictable communicable disease and if we can predict it, we can control it. He proposed that we look at the economic importance of settings and their vulnerability to airborne transmission events to decide what to keep open and what to close (high-risk settings). Consider closing low-economic impact/high transmission risk industries (such as adult entertainment) and compensating owners to remain closed (such as is done in Japan). Efforts can then be concentrated on places that are economically important but high risk, while enhancing ventilation and testing.

Questions/Discussion Summary

Over-dispersion and heterogeneity of the R_0

When there is a burst in cases and contact tracing is no longer possible, the stochastic nature present when disease transmission started, is lost. It becomes very difficult to control and results in a pandemic. When the numbers come down, that presents an opportunity to control it; this window has closed in Ontario and Quebec.

Communicating effectively to inform the public

Public health messaging is often political. There is a loss of information when communicating public health recommendations. It is important to explain the distribution in a way that is meaningful to the public. Giving contradictory guidance has made the public question its validity (e.g., 30 children in a classroom versus no indoor gatherings of more than 10 people allowed). It is important to provide honest messaging about how COVID-19 does and does not transmit. One of the difficulties is the reluctance to name where the outbreaks are taking place (e.g., weddings). People can make better-informed decisions if we tell them what we are actively investigating. Places that have had the least number of cases have used science to control transmission.

Respiratory protection programs — surgical masks versus respirators

It was noted that HCWs are over-represented in surveillance data in Ontario and transmission risk is much greater with AGMP. Health care settings have the advantage of good ventilation and providing personal protective equipment (PPE) for workers. In addition, patients have a decline in viral load through the course of infection; they generally arrive at those settings when they no longer have peak viral load. There is a lag of seven to eight days from symptom onset and the time to intubate. Many patients are culture-negative after nine days. In comparison, at meat-packing plants where they do not have PPE or good ventilation and where workers are present during the pre-symptomatic stage with peak viral load, there is a higher risk than in health care settings.

The quality of research on super-spreader events was mentioned, noting that meat-packing plants have protocols in place, whereas church events do not. There has been a large impact on the arts and entertainment industry, where the performers are blamed for spreading COVID-19, but it is important to think about what actually happens there (no protocols, hugs, laughing, crying, etc.).

Questions: Are small particle aerosols important or not? Is it proximity that is risky? What part of being close is important?

Response: Aerosol science is beyond the purview of the infectious disease community. People who work with aerosols can answer that question. There has been work in the Netherlands, where sequencing has been done to see the outbreak from different perspectives. We may be dealing with a cluster. We need to start using the tools we have (stool polymerase chain reaction testing, parallel serologic testing, etc.). The index case is based on symptoms, but it may not actually be that index case that introduced the disease.

Time for this session elapsed at this point.

Part 1: The Science and Human Influence of the Transmissibility of COVID-19

Presentation 2: Modes of Transmission of SARS-CoV-2: Some Thoughts from a Public Health Virology Perspective

Dr. Marion Koopmans, Professor and Director, WHO Collaborating Centre for Emerging Diseases, Erasmus Medical College and Scientific Director, Emerging Infectious Diseases, Netherlands Centre for One Health

Dr. Koopmans spoke about a paper she co-authored entitled *A new twenty-first century science for effective epidemic response*, where the authors made recommendations for key areas to integrate into epidemic responses by identifying the need for:

- a revision of public health preparedness
- a cross-disciplinary engagement for emergency preparedness
- the critical importance of community engagement.

These items are difficult to do during a crisis. She stated that in order to understand transmission, we need to look at how multifactorial it is. This includes infection biology and immunity, the contribution of key modes of transmission in risk settings, the role of animals in transmission, virus properties, and human behaviour.

Human factors contributing to transmission

This includes time since illness onset, symptoms, health condition, immune status and response, age, behaviour, and socio-economic status.

What we know from science:

- The virus replicates in the upper and lower respiratory tract (more replicable in upper respiratory tract).
- Shedding peaks at the late incubation period.
- Infection is asymptomatic or (apparently) mild in the majority of persons.
- The virus is spread through droplets and is stable for prolonged periods of time in droplets, aerosols, and on surfaces.

What is the load of virus that people expel?

Looking at the kinetics of shedding by age, there is a wide distribution of ribonucleic acid (RNA) viral load at the time of diagnosis for different age groups, with no clear difference between the age groups. Only smaller studies have looked at shedding, so evidence is limited. Stratification for risk factors, comorbidities, and severity is patchy, and infectiousness testing is sparse.

Environmental contamination may occur, but is it relevant for transmission? What do you detect if you monitor by PCR?

There is a need to compare both PCR and culture results for accuracy in interpretation of environmental results. Studies show that the probability of infectiousness decreases with decreased RNA load.

What we know from debates:

- The definition of droplets and aerosols differs in different research communities.
- Everyone agrees that persons infected may spread virus-laden droplets of a wide variety of sizes.
- Physicists seem to settle on the understanding that heavier droplets are subject to particle dynamics and will settle around a patient. The lighter ones may not settle and are subject to airflow dynamics.
- IPC specialists seem to have consensus around the very limited role of small airborne bioaerosols in transmission.

- Outbreak investigation studies have provided suggestive evidence for a role of small bioaerosols in transmission, although this is difficult to isolate from other modes of transmission.
- Laboratory studies have shown that the virus can remain infectious in small airborne bioaerosols for several hours to days.

Dr. Koopmans explained that how we view the risks from a public health perspective depends on quite a few assumptions for which data are sparse. It also depends on the assumed behaviour of those with symptoms. For example, for large droplet and aerosols, the distance travelled decreases with sneezing, coughing, and exhaling (in descending order). Thus people with symptoms are told to stay home to avoid dispersal of the virus.

Outbreak reports

One outbreak investigation report (nursing home) concluded that transmission was most likely related to ventilation. Another report on the same outbreak found that although ventilation could not be ruled out, there were other contributing factors — transmission was likely caused by an undetected, symptomatic, cognitively impaired patient; a symptomatic HCW not reporting for testing; and a lack of HCW compliance during breaks.

In an outbreak thought to be one large common source event, sequencing showed three different sequence clusters. The virus was detected in ventilation ducts and in two of the patient rooms. Virus detected in inlet air fans were the same as found in cluster A, whereas the bulk of cases were cluster B; therefore, it is difficult to say that the bulk of the cases were because of the ventilation.

Stability of SARS-CoV-2 in different environmental conditions

This depends on where particles settle. The virus can remain infectious longer in colder temperatures.

Virus diversity

There are two variants of the virus; there is higher transmissibility with one but no difference in the clinical impact. A variant with Spike D614 mutation seems to be on the rise in Europe and the US, and gives the virus a replicative advantage. An exhaustive sequencing endeavour in the UK looked and compared the distribution across age groups for 613 G and D. The G variant seems to have displaced the D variant and appears to be more transmissible, with no difference in variability.

Animal models to study transmissibility

There is debate about whether ferrets are good animal models to study transmission. A study showed transmission via contact and air. It was noted that, for the church and meat-packing facilities outbreaks, the sequencing tells a different story than initially thought.

Presentation 3: The Science and Control of Airborne Infection Transmission

Dr. Lidia Morawska, Queensland University of Technology, Australia; WHO Collaborating Centre for Air Quality Management & Air Pollution Control

Dr. Morawska started by noting that aerosol and medical scientists have different definitions of aerosols, which causes confusion. Aerosol sciences makes no distinction between particle sizes. An aerosol is an assembly of liquid or solid particles suspended in a gaseous medium long enough to enable observation or measurement; and a droplet is a liquid particle. In medical sciences, aerosols are smaller particles and droplets are larger particles. For the purposes of this talk, they all will be referred to as particles.

The source

Particles are generated by human respiratory activities. The majority of particles are < 1 µm (and the vast majority are < 10µm). Such small particles are light and can stay suspended in the air for a long time. All respiratory activities, including breathing, generate particles, but vocalization generates higher emissions than other activities.

Particle fate in the air and risk of infection

Smaller particles contain higher loads of SARS-CoV-2. Smaller particles come from deeper parts of the respiratory tract. To the contrary, larger particles originate from the mouth and have less virus. Therefore, breathing or speaking are the main source of small, virus-laden particles. Particles stay suspended in the air for a long time in the indoor environment (one to two hours), unless they are removed by ventilation.

Outbreaks and airborne transmission

While all three modes of transmission occur, airborne emerges as the most significant in typical public settings. Examples include the Skagit Valley choir and Diamond Princess cruise ship. What does this mean for risk mitigation?

Risk mitigation — infection control pyramid

Dr. Morawska presented the infection control pyramid in order of most to least effective: elimination, engineering controls, administrative controls, and PPE. Important engineering controls include sufficient and effective ventilation, avoiding air recirculation, particle filtration/air disinfection, and avoiding overcrowding. An important factor is flow direction and flow distribution. For mechanical systems, ASHRAE, REHVA, and others have already recommended control measures based on the existing evidence on airborne transmission and provided guidelines on their implementation.

Dr. Morawska noted the need for more advanced guidelines and recommended that control measures take into account knowledge about airborne infection transmission. There is also a need for an airborne infection risk tool; one such tool has been developed by her team and is based on which prospective and retrospective assessments can be done.

Beyond COVID-19, a paradigm shift is needed in how we treat the transmission of respiratory infections because the sequence below has emerged as the most significant mode of transmission in many settings:

- Infected people exhale particles that stay in the air.
- Susceptible people inhale them and can get infected.
- Many public indoor places provide perfect environment for transmission.
- One infected person can share the virus through the air with all those in the same enclosed space.

Specific controls to mitigate risk should be context-specific (one solution doesn’t fit all).

Discussion — Current Evidence and Proportional Risk

Dr. Lavis asked participants for their responses to and perspectives on the following three questions:

1. Do aerosols contribute to transmission and, if so, under what circumstances?
2. Are aerosols a significant factor in super-spreader events?
    a) In which community scenarios?
    b) In which health care scenarios?
3. Are differences in perspectives on the aforementioned questions a nomenclature issue or a difference in fundamental concept, and where is the common ground?

The following is a summary of participant responses.

Comments regarding aerosol transmission:

- Some participants stated that aerosols contribute to transmission.
- Asymptomatic and pre-symptomatic transmission is extremely important. By definition, they don’t produce large particles. But speaking still produce aerosols. It is not only AGMPs that cause aerosol transmission, but coughing and sneezing also produce aerosols. The risk to HCWs will be higher with proximity and duration. Around the world, HCWs are infected out of proportion. They make up 20% of infections in Ontario. Some get infected from the community, but we need see how we can do more to prevent aerosol transmission.

- We should ask the question — does rare conditional aerosol transmission explain the three C's (transmission in crowded places, close contact settings and confined spaces)? There is fear in the community that accepting this will almost make the virus appear more infectious or that there will be policy changes that cannot be implemented. Change in policies may be targeted to where HCWs need protection.
- There are many questions that still need to be answered. Although aerosols may be generated and distributed, is the infectious dose enough to cause disease?
- Aerosol transmission is not mutually exclusive to other modes of transmission. Ventilation has no effect on large droplet and fomites, so surgical masks do have a filtering capacity against droplets. If aerosols play no role in viral transmission, there is no basis to recommend that people should stay at home, or that ventilation is needed. We wouldn't even need a mask; a face shield alone would suffice.
- In health care settings, transmission is not primarily by aerosols. What does this actually mean from a practical standpoint? To its detriment, infections among HCWs are attributed to absence of N95 respirators. In long-term care, we have seen that it's multifactorial, not solely due to aerosol transmission.

Comments regarding droplet transmission:

- Some participants stated that the main mode of transmission is by droplets.
- HCWs across Canada have used surgical masks and reserved respirators for AGMPs. The transmission has been predominantly HCW to HCW. There has been little transmission from patients to HCW, although this could be because they are not taking care of patients during the most infectious stage. Ventilation in health care settings is also helpful. But there is a limit to how much ventilation can help decrease risk if one is standing right in front of a patient. What is the effect of distance and ventilation on the circumstance in which one is close to someone's airway?
- The differences in the perspectives are stumbling blocks to the answer. A well-known communicable disease manual describes droplet spread as when the droplet lands on eyes, nose, and mouth.

Comments regarding both aerosol and droplet transmission:

- There is a misconception that we cannot tease apart droplet versus aerosol transmission. This has led to the formation of groups for droplet versus aerosol transmission and a smaller pool of people saying there are arguments for both. Epidemiology investigations show that droplets are the majority of cases, but aerosols play a part depending on the circumstances.
- Does the discussion around aerosol transmission matter if non-medical masks are sufficient to drop rates? There are differences in definitions and in experimental versus observational evidence.
- All routes of transmission are important; circumstances will determine which are most important. Regarding ventilation and spread, some work shows plume dispersion — when a cough travels it travels on its own momentum until it slows down and room ventilation takes over.
- The issue of dichotomous aerosol and droplet spread is understandable. There is a difference between health care and non–health care settings. When discussing how this virus spreads, it is important to identify considerations depending on the situation and acknowledge what we are uncertain about at the moment.
- Infectious dose is not the same with aerosols and droplets. Inoculated monkeys were sicker if inoculated by aerosols compared to droplets.

Comments regarding fundamental concepts:

- It is important that people understand the different types of masks and their limitations.
- It is important to recognize that we did nothing about controlling ventilation in the first phase of the outbreak, but we did control transmission. The things we did do, such as messaging about social distancing, worked. We need to think about the circumstances where aerosol transmission applies and what to do about it. But we can still control transmission without focusing on aerosols; some areas to focus on include hand hygiene, social distancing, and masks.
- We are looking at exceptions to try to prove aerosol transmission. The role of droplet and aerosol transmission can be difficult to understand in an outbreak. We need to take an empiric approach. Aerosols can contribute to transmission, but to what extent? HCWs are swabbing hundreds of people a day (wearing surgical masks) but no HCW transmission has occurred from this. We see staff-to-staff transmission, as well as situations with undiagnosed COVID-positive patients and an ensuing lack of appropriate precautions by HCWs. It remains unknown whether this means it is not aerosol transmission or if it is good ventilation combined with low viral load by the time we get to the patients.

The Implications of the Evidence on Public Health — Day 2

Dr. Lavis indicated the need to capture dissenting views on the evidence and encouraged speakers to articulate their perspectives. He also indicated that deliberations will be very short, highlighting the need to be pragmatic with decisions and discussions, as this will be brought to the evidence synthesis teams. He outlined the focus of the discussions for the day:

What are the most important changes that need to be made to current PHAC guidance to reflect new understandings?

- in the community
  - keeping masks on indoors even if 2 m spacing
  - making changes to enclosed indoor spaces
- in health care
  - using N95 masks - in what contexts and under which circumstances?

The final discussion was to focus on:

What are the interdisciplinary gaps in knowledge that must be prioritized to better understand transmission (yet are unlikely to be addressed with traditional funding calls)?

How can we better support the integration of thinking from various expertise including laboratory, infection prevention and control (IPC), engineering, data modelling, outbreak studies, and evidence synthesis, into future guidance in the shorter-term and in the longer-term (e.g., changes to education and training)?

Presentation 4: Mitigating the Proportional Risk of the Transmission of COVID-19: Perspectives from Across Infection and Control Contexts

Mr. K. William Dean, P.Eng., Vice-President, ASHRAE Inc.

Mr. Dean brought an engineering perspective and provided background on ASHRAE, which was founded in 1894 and currently has members in more than 130 countries, including 16 Canadian chapters. ASHRAE focuses on “a healthy and sustainable built environment for all.” ASHRAE provides general ventilation and air quality requirements in Standards 62.1, 62.2, (ventilation and fresh air within spaces), and 170 (health care applications). Mr. Dean’s presentation focused on air distribution control measures.

The current state: evidence and opinion

Ventilation systems cannot interrupt the rapid settling of large droplets but can cause the movement of aerosols. Dissemination of smaller infectious aerosols, including droplet nuclei, can be affected by airflow patterns. Depending on environmental factors, large droplets (100 µm in diameter) may shrink by evaporation before they settle, thus becoming an aerosol (< 10 µm). Ventilation systems can influence the transmission of droplet nuclei infectious aerosols. Directional airflow can create clean-to-dirty flow patterns and move infectious aerosols to be captured or exhausted. Even the most robust HVAC system cannot control all airflows and completely prevent the dissemination of an infectious aerosol or disease transmission by droplets and aerosols. Air distribution systems are developed primarily for comfort, asepsis, and odour control in hospitals and other health care applications. An HVAC system’s impact on containment will depend on source location, strength of the source, distribution of the released aerosol, droplet size, air distribution, temperature, relative humidity, and filtration. High air velocity creates drafts, so while more effective for dealing with aerosols and some droplets, they would become too uncomfortable for occupants.

The current state: circumstance and context

Strategies for prevention and risk mitigation in health care buildings takes a team — we need the designers, owners, operators, industrial hygienists, IPC specialists, and others to all work together and help in this overall effort. There are a number of indoor environmental situations that present a potential risk of infectious aerosol dissemination; for example, air distribution directionality (position of people within a space), various heating and cooling sources, fans, ceiling fans, and convective air flows at exterior walls and windows (especially in Canada where temperature changes are large) will have a big impact. The movement of people and equipment within the space effects the air flow, as does differential room pressurization — the transfer of air from higher pressure spaces to adjacent areas at lower pressure.

Capturing aerosols at the source is critical (similar to using a fume hood), but in buildings it's not always obvious where the source is located. Temperature and relative humidity have a significant impact on aerosols, as we have seen in other presentations.

The current state: prioritizing interventions

A number of specific HVAC strategies can be considered (evidence level A, where evidence-based; or level B, where empirical data, only):

- Enhanced filtration in occupant-dense and/or higher risk spaces has proven to be effective in intervening in transmission (evidence level A).
- Ultraviolet germicidal irradiation as a supplement to supply airflow is also effective (evidence level A).
- Local exhaust ventilation for source control to ensure air flows from the source and away from others (evidence level A). Regarding previous mention of certain areas that are not seeing transmission (such as testing centres) — this could be because they ensure the workers are in the best, cleanest air areas.
- Personalized ventilation systems for high-risk tasks (evidence level B).
- Portable free-standing HEPA filtration units (evidence level B).
- Temperature/humidity control (level B) — important in survivability of the pathogen.

To prioritize interventions, start with capturing aerosol at the source. In health care buildings, deliver clean air to HCWs, maintain intensive care units where infectious aerosols may be present at negative relative pressures, use UVGI, provide 100% exhaust of patient rooms, increase outdoor air exchange rate (this goes against some other ASHRAE advice, it increases overall operating cost to the building), exhaust toilets and bed pans, maintain temperature and humidity at recommended levels, deliver clean air to caregivers, make sure there are no leakages in heat recovery systems to allow exhaust air to come back into the supply air. In addition, with patient turnover, ensure the grilles (particularly exhaust) are cleaned.

Looking to the future

ASHRAE will be conducting research projects in several areas including investigating the impacts of operating room air change rates on patient outcomes; the effectiveness of location of supply, return, and exhaust registers in-patient rooms; the quantification of relative airborne infection control performance; and the cost-effectiveness of specific engineering strategies.

ASHRAE's COVID preparedness resource page can be found here: ASHRAE.ORG/COVID19.

Presentation 5: Preventing SARS-CoV-2Transmission in Health Care Settings

Dr. Matthew Muller, Medical Director, Infection Prevention and Control and Infectious Diseases Physician, Unity Health Toronto

Dr. Muller brought an IPC expertise, stating some findings from the literature to provide background and context. SARS-CoV-2 RNA can be found in the air > 2 metres from patients, everywhere including common areas, nursing stations, and staff rooms. It is found in small quantities in the air and is difficult but not impossible to culture from the air.

What we know about transmission

- Transmission is primarily via prolonged close contact (not one to two minutes) within six feet.
- Household attack rates is ~ 20% (actually a wide range).
- Super-spreader events are associated with prolonged exposure in closed and crowded environments and may be associated with poor ventilation and high-risk activities — e.g., singing. Examples include meat-packing plants, dormitories, prisons, long-term care facilities, choir practice, cruise ships, etc.

There is a need to interpret all the evidence together.

Risk of transmission for train travellers

A large study of thousands of COVID-19–positive individuals who travelled by train found that secondary infections were heavily concentrated in those in adjacent seats who had longer trips (i.e., many hours). Based on this and most other published evidence, the first conclusion is that transmission is primarily via prolonged close contact. This is consistent with droplet transmission but not airborne transmission, as it is typically seen with viral infections such as measles and varicella. We use N95 respirators and airborne infection isolation rooms under negative pressure for patients with these viruses but not for COVID-19. The requirement for prolonged close contact with respect to COVID-19 transmission could be explained by droplet transmission or limited aerosol transmission where the infectious dose is very high. Aerosols are rapidly diluted in large or well-ventilated areas such as health care settings. However, "opportunistic" airborne transmission may occur in closed, crowded, and poorly ventilated spaces, especially with high-risk activities.

Health care worker risk

Studies state that HCWs are at higher risk than the general public. However, Schwartz et al. in Ontario, showed that risk declined over the course of the pandemic (wave 1), as strategies to reduce health care worker risk were implemented in health care settings. Several studies showed similar risks for clinical and non-clinical staff such as administrative staff. This suggests that a substantial proportion of health care worker transmission is due to community transmission. Health care workers with a positive household or staff contact are at high risk, as well as those with risk factors for community exposure. With IPC measures (droplet and contact precautions), there has been limited transmission on COVID-19 units.

This is a community-based pandemic, with most transmission centred around home exposures and social activities. Health care workers get infected through various mechanisms including from the community (homes, social activities, grocery stores, etc., just like others); community transmission are due to occupational-related tasks (e.g., the need for nurses to take the subway to work); and HCW-to-HCW transmission is quite prominent because staff do not see each other as a risk. In the past, HCWs mainly used IPC strategies to protect themselves and their patients from transmission from patient to staff and from staff to patient. Less emphasis has been placed on staff-to-staff transmission. This is important because COVID is most contagious right before symptom onset, so HCWs that come to work just before illness onset or with mild symptoms will be highly infectious; whereas because COVID-19 tends to progress gradually over the first week of illness, most patients do not interact with the health care system until they have been unwell for many days and those actually requiring admission to an acute care facility are often admitted to hospital in the second week of illness when infectivity may be significantly reduced. In cases where HCWs were infected by patients, these were most often patients not yet known to have COVID-19 rather than those who were known and placed in appropriate precautions. This is both because these unrecognized patients may have mild or atypical symptoms and are early in their disease course (and are therefore at the peak period of infectiousness), and because staff obviously would not be following all of the protocols used for COVID-19 cases when COVID-19 is not suspected. For example, HCWs may indicate they forgot to wash their hands or wear face shields with a patient not known to have COVID-19 but who subsequently turns out to be COVID-19–positive and this is more common when they do not think the patient has COVID-19. It is also common to see HCWs share an office with no mask and car pooling occurs between HCWs without masking. During the time of fewer cases, there was also the problem of misattributing patient symptoms to another diagnosis such as a heart attack instead of COVID-19, which again can lead to HCW exposure to an unrecognized case.

Hierarchy of controls

The approach used to protect HCWs in order of decreasing effectiveness is elimination, substitution, engineering or environmental controls, administrative controls, and PPE. Some examples of things done to protect HCWs include elimination strategies that reduce the risk of having COVID-19 patient or staff cases in the health care environment. Some examples of elimination strategies include virtual visits, screening people prior to and at the time of a health care visit and sending them elsewhere if they have symptoms, and having staff that do not need to be in the hospital work from home. Engineering or environmental controls include providing physical barriers between patients and health care workers such as triage nurses and receptionists, and ensuring facilities meet CSA standards for ventilation. While PPE is important, it is at the bottom of the hierarchy. Universal patient and staff masking will significantly decrease transmission because it protects against transmission from unrecognized patient and staff cases. Face shields for all clinical care is another strategy that may prevent transmission from unrecognized cases. Additional precautions (hand hygiene, mask, gown, glove, face shield, private room) can also significantly reduce risk but is only effective for recognized COVID-19 cases who are often less infectious than unrecognized and staff cases. Many of these measures will actually protect against transmission from either aerosol or droplet (e.g., patient and staff masking).

Presentation conclusion

Respiratory transmission is the primary mechanism of transmission and is consistent with droplet or aerosol transmission. In health care settings, the transmission risk is from unrecognized patient, staff, and visitors. During "wave one," control measures aimed at protecting HCWs from recognized and unrecognized cases were effective at appropriately resourced facilities. Transmission risk was negligible when trained staff provided care to known COVID-19 patients using masks, face shields, gowns, and gloves.

Questions/Comments Summary

- **Question to Dr. Muller:** Are we doing everyone a service by generalizing our hierarchy of controls to the community (PPE as last thing to consider) when we don't really have the ability to quickly change our homes or put administrative measures in place publicly? Non-medical masks are the best thing we can quickly implement here. Have we used too much language to say it's a last resort when it's really easier to use this than other things in the public?

  Response: The hierarchy of controls mentioned was referring to health care settings and not so much community settings. Although all elements of the hierarchy are important, using something that can protect everyone (universal masking) is also important; it will help everyone equally.

- **Question to Dr. Muller:** What is the definition of a droplet in health care settings, noting that there's no sharp wall at 5 microns and how do you reconcile it with aerosol science?

  Response: This is a nomenclature issue; it is not a straightforward definition but a continuum. In IPC, "airborne" refers to infections such as measles; we need to take the most serious precautions. Respiratory infections require droplet precautions and this is what has worked for COVID-19 — it has been effective at interrupting transmission. We have years of IPC experience with influenza, where we use different strategies, and with measles, where we use negative pressure rooms, so health care workers are trained and have access to PPE.

- **Additional comment:** The Occupational Safety and Health Administration differentiates between masks and respirators. Masks are designed for personal protection.
- **Question to Dr. Muller**: In reference to the cigarette smoke example, is someone not exposed to more cigarette smoke if they are close rather than 6 m away?

  Response: The further you are from a smoker, the better

- **Question to Dr. Muller:** Regarding universal masking in institutions and outpatient care settings, is there any difference for settings with lack of familiarity or settings with more spread?

  Response: We want to provide a proportional response by looking at prevalence and stricter measures when the risk is higher. One challenge is that things move quickly and there is no agreement on low, medium, and high prevalence. If in an area of low prevalence, the value of having everyone wear mask in public spaces is less; however, it is important to have people do it before cases get too high.

Presentation 6: The Science is In — What Next? Mitigating the Proportional Risk of the Transmission of COVID-19: Perspectives From Across Infection Prevention and Control Contexts

Mr. John Oudyk, Occupational Hygienist, Hamilton Clinic of the Occupational Health Clinics for Ontario Workers (OHCOW)

The current state — evidence and opinion

The National Academies of Sciences, Engineering, and Medicine (NASEM) workshop has addressed the main questions with the best available evidence. Highlights include:

- a new proposed definition of droplet >100 um (with ballistic trajectory dispersion versus turbulent/laminar flow dispersion)
- differentiation between "plume" and "room" dispersion aerodynamics (plume is independent of room air flow patterns)

- “close-range” airborne transmission is probably the dominant mode of transmission (“close contact” airborne)
- differentiating between “obligate” (measles, TB), “preferential” (smallpox, anthrax), and “opportunistic” (influenza, SARS) airborne paths of transmission.

The reproduction number, R_0, is not a property of the disease but the product of the interaction between disease, host (including susceptibilities and behaviours), and environmental conditions. The R_{eff} for the Skagit choir outbreak was between 32 and 52; but if the infected choir member had stayed home, it would have been one, two, or three additional cases. The initial R_{eff} on the Diamond Princess was 14.8. After the protective measures were implemented, it fell to 1.78. Person-to-person infectious disease transmission was described as a wicked problem — difficult to define, complex, can never be solved. They require a multidisciplinary approach, often with multiple independent stakeholders. We need to combine all pieces of the puzzle to get the full picture. What if it’s a 3(+) dimensional problem with a continuous set of variables rather than discreet or categorical ones?

Applying controls changes the relative contributions of transmission paths

Certain conditions are recognized as contributing to close-range airborne transmission (3 or 4 C’s): super-spreader, crowding, patients not wearing masks the right way, poor ventilation, AGMPs. Rachel Jones’ paper discussed relative contributions of transmission routes (contact, droplet, airborne) for COVID-19 among health care personnel providing patient care. Considering that things can change so much, we need to be prepared for all possible combinations rather than wait for the science. The NASEM workshop identified six C’s — crowded places, close contact, continuous exposures, coverings, cold air temperatures (high humidity?), closed space, and circulation (outdoor air supply). Public compliance with distancing levelled the curve. When community risk is low, masking is symbolic, a sign of solidarity. With medium risk, it becomes etiquette and source control. With high risk, when combined with six C’s, it can be both source control and protection for the worker.

Health care workers and the Chinese response

WHO stated that, while HCWs represent less than 3% of the population in the large majority countries and less than 2% in low and middle income countries, around 14% of COVID-19 cases are among HCWs. In China, two hospitals were built rapidly, the first being built within 10 days. More than 42,000 HCWs were recruited to help the existing 110,000 and more than 90% of Wuhan residents were tested.

Response to scientific uncertainty

Justice Campbell recognized the conflict between IPC and health and safety, and recommended the precautionary principle. While originally the Campbell Commission recommendations were implemented, the changes were gradually eroded and health and safety took a “back seat” (which is where we are now). The Chinese layered the PPE (N95 mask and surgical mask, three layers of gloves, full scrub suit with two layers of boot covers, hood with two layers of head covering, etc.). Looking at the curve of Chinese HCW infections, in about three weeks, the rate came down to 0. There was not a single infection among the 42,000 HCWs recruited to help in Hubei province between January 24 and April. Overall in China, 4% of infection occurred in HCWs, whereas in Canada it is fairly close to 20% (calculated rate). Thus, the rate of HCW infection in Canada is six times greater than it was in China.

Health care workers in Canada

With the help of Peter Smith, the number of HCW-related infections in Ontario was calculated from the 2016 census data and recent Labour Force Surveys (482,000 HCWs in Ontario). With 7,044 Ontario HCWs infected, HCWs are four times more likely to be infected than the general population — which translates to 75% of HCW infections being work-related. These are not all due to long-term care; one Toronto hospital reported 4% infection rate (~400 HCWs), which was 14 times higher than the general rate in Toronto. Across-Canada survey found high levels of fear (11%) among HCWs, with 43% being extremely concerned about bringing the virus home, resulting in many anxiety and depression issues. There has been a failure of the “scientific reviews” in these areas: a lack of sound scientific reasoning, selection bias and misinterpretation, biased standards of evidence (“droplet” needs no evidence but “airborne” needs randomized controlled trials), citing papers as evidence for positions which the papers actually contradict, misrepresenting or ignoring the IPC successes in other countries, and not recognizing our own IPC failures when they occur.

Presentation conclusion

Policy-makers need to recognize the airborne element of the complex transmission picture and change the guidelines now. Apply the precautionary principles when dealing with uncertainty, ensure adequate PPE supply and IPC procedures to prevent all workplace infections, and monitor progress by counting and publishing HCW infections. Review where the “scientific reviews” went wrong and respond accordingly, and expand the tool box (e.g., combine genetic sequencing with contract tracing, take exposure measurements, use quick antibody tests, etc.). Layer the public responses to the regional risk using a graduated continuum/hierarchy/spectrum of controls.

Presentation 7: Infection Prevention and Control for COVID-19: Virology Perspectives. Transmission Routes for COVID-19, Implications for Public Health

Dr. Jason Kindrachuk, Assistant Professor – Viral Pathogenesis, Department of Medical Microbiology and Infectious Diseases, University of Manitoba; and Canada Research Chair, Molecular Pathogenesis of Emerging & Re-emerging Viruses

Dr. Kindrachuk provided perspectives from his expertise in microbiology.

What we know

A new review will be published soon on the pathogenesis and virology of SARS-CoV-2. A distinctive difference exists between SARS-CoV-2 and SARS, which can guide our understanding in transmission events. There are large differences in viral load kinetics and duration of infectivity. This has massive implications for public health in understanding transmission. For COVID-19, we know the biomechanics were a little bit slower so we tend not to see disease until the second week of infection, and this gives us a greater length of time to be able to try and identify the cases. We now know transmission is likely occurring at the peak of viral load, which tends to come right before symptom onset or at the same time as symptom onset. There is increased infectivity with COVID-19 compared to SARS; data suggests upper respiratory cells and ACE2 receptors are in high concentrations within these cells. But it also seems as though it has a much higher binding affinity. We do not know everything, but we know masking distancing, ventilation, and hygiene continue to be critical to IPC.

What we do not know

We do not know the infectious dose for SARS-CoV-2. For SARS, 16 years later, we can estimate that it is 100s to 1,000s of particles. In addition, COVID-19 is still at infancy in understanding droplets versus aerosol; is one contributing more? This has massive implications. Other unknowns include what factors contribute to aerosol generation and transmission, and the diversity of clinical presentation and outcomes. A few hospital and animal studies looked at whether they could recover infectious virus from aerosols. RNA is not infectious virus. It has been found pretty much everywhere sampled, but it was challenging to find any infectious virus. Animal models have looked at both ferrets and hamsters to determine whether there is airborne transmission. They identified (with some discrepancies) that there was transmission through the airborne route. However, the distance within which they were testing did not allow for differentiating between droplet and airborne. The updated CDC guidance, which was retracted, is not helping with public messaging. We need the groups to work together. Evidence suggests that it is likely a combination of both droplet and airborne that play a role in transmission. There is uncertainty in the overall contribution of aerosols versus droplets. The virus is most commonly spread "between people who are in close contact with one another (within about 6 feet)." Fomites are not driving transmission but may contribute.

Current gaps in public knowledge

The public perception of what "airborne" is could cause anxiety (and N95 will be deemed necessary). We need to change wording so that this doesn't happen. Other gaps include aerosol transmission during daily activities and medical procedures, infectious aerosol generation in asymptomatic and pre-symptomatic infections, the impact of droplet versus aerosol infection in vulnerable populations, biological characteristics underlying super-spreading events, and disinfection procedures required for inactivation of infectious aerosols.

We need to talk in terms of inhalation rather than airborne. This requires taking a step back and trying to describe transmission to the public while we are still trying to understand it. How do droplet and aerosol transmission differ and how are they similar? Which types of activities push us more toward aerosol transmission? Is there enough infectious virus in aerosols to transmit and make people sick? What are the impacts of droplets and aerosols transmission and differences in the overall pathogenesis? Are they critical to us? We also need to start to address the biological processes that underlie super-spreader events.

Questions/Comments Summary

Question: If we find there is enough infectious dose in aerosols to spread infection, what are people's thoughts on recommending eye protection for the general public in communities with higher risk?

Response by Dr. Kindrachuk: We are trying to define if ocular infection can actually happen. Animal models looking at SARS-CoV-2 transmission found that exceedingly high amounts of virus is needed to get infection through the ocular route; there is debate about whether or not it is even a portal. We think it is possible; however, a recommendation for eye protection is context dependent. It is not a one-size-fits-all approach to preventing infections. Infection rates will differ depending on the environment and the individual.

Question: From an industrial hygienist perspective, respiratory transmission is equivalent to inhalation. The preference is to move away from droplet and aerosols, and describe it as a "continuum," using the term "particles" instead of "droplets." They are particles of different sizes. Where is the evidence that some kind of transmission occurs when it lands on someone's face versus inhaled? Isn't it all the same? Why are these different?

Response by Dr. Oudyk: Regarding droplet versus aerosol, the infectious dose by inhalation of the smaller particles is higher than instillation of the liquid into the nose of animals (dropping the liquid in the animal's nose). People are thinking it is the same for the humans. Inhalation goes deeper into the lungs.

Response by Dr. Kindrachuk: This is still not fully understood. When looking at primates, the expectation was infection with aerosol particles, but the opposite occurred. Not sure how much we should look at these animal models. There is no direct animal model that we can use to answer all our questions.

Presentation 8: The Place of Sufficient Uncertainty and Its Implications on Public Health Mitigation Strategies

Dr. Michael Bell, Deputy Director, Division of Healthcare Quality Promotion, Centers for Disease Control and Prevention

Infection control background

The field of IPC is not static, and may never be in a final state. Infection control began with basic rules in recognition of the transmission of infectious diseases. Fecal precautions were established in the 1960s and 1970s as a way to deal with infectious diarrhea. We now have a more tailored approached (enhanced precautions), such as universal gloving, etc.

Health care environment

Health care is an extraordinarily complex system. It is composed of a number of individuals including some who are not professionally trained, different kinds of interactions, patients, staff, visitors, and other workers. It also involves different types of movement within and across facilities, with a great number of transmission and risk events than we see anywhere else, and we can't detect them all.

Pathogens are of variable transmissibility; e.g., membranes versus lungs. We are never dealing with just one pathogen; we want to eliminate many other organisms at the same time. There is a need for practicality and implementation in a uniform and systematic way so everyone is doing the same thing. We want to ensure we are not hindering patient care because if can't care for them, we might as well not be there.

Transmission

Dr. Bell gave the example of toddlers sneezing in your face — you can feel the droplets directly land on your membranes — that is a transmission event. But that does not mean it is the only mechanism of transmission. There is a need for practicality, for systematic implementation which allows us to monitor, where everyone is doing the same thing at the same time. What are the most impactful and meaningful things we could do — we don't have unlimited resources, so we need to make sure what we do use the resources on has the most impact across the board. If we can only do a few things, we need to be sure the things we're doing are the valuable things.

Health care workers' backgrounds vary tremendously; there is therefore a need to go toward understanding and comprehension among everyone more than just having rules for everyone to follow. There is concern when following Ebola rules for COVID-19; this is a different disease. A disease-by-disease approach is not something we have developed yet in the US. The evidence is not perfectly linked to the outcomes observed — this means we're missing a link (it does not mean one party or the other is wrong); we need to extrapolate and fill in the gaps. Although inhalation of fine particles is bad, we see institutions that aren't using respirators and see no transmission; there is something in between that we are missing. We need to avoid this narrowly focused data and put it toward the real world.

We tend to look at things in isolation, yet the cumulative and interactive nature of the protocols needs to be considered knowing that it is being implemented in the real world amid a bunch of other infections.

Shift to non-binary thinking

We need to move toward non-binary thinking. It is safe to say there are big droplets, and complex aerosols in different sizes, and they depend on air flow. Settling occurs (does not happen instantaneously and during that time it can be moved by ventilation or something else). Decay and infectivity changes depending on UV, temperature, etc. Thus, something infectious can be changed into something not any worse than dust.

In the US, when we see higher-risk pathogens, we say let's assume there is near-range inhalation potential. Without picking this apart, we say "use a respirator" to be safe; you do not need a negative pressure room, though (we do not see any evidence that it is moving all around). Although we're finding RNA everywhere, it is not infectious. Eye protection is very important. The eyes are mucous membranes, and tear ducts, and that's linked to nose and throat. So if something lands in your eyes, that delivers infections.

The masks versus respirators concept is an outdated argument. There is regulatory language around this that is too focused and limited. There is evolvement involving looking at a variety of devices that are not fitted — i.e., different masks that fit in different ways. This does not mean that everything other than N95 is zero safety. Other things are helping, as well. Non-zero is important in the general population. Using modelling based on US data, 50% filtration can be use as just a source control.

Data gaps around understanding the AGMP concept

We are saddled with this concept because of assumptions that this is what happened in some cases with first SARS, but it could have been something else causing these outbreaks (e.g., ventilation). This requires a systematic assessment, as some things do not generate that much aerosols. A nebulizer generates aerosol — this is its job; but how much of the aerosol is from the respiratory tract or just the medicine aerosolizing? That is unanswered right now and will be helpful to know.

Broader occupational health infectious disease data

Teachers are also worried. Who else should we be looking at when it comes to occupational health? What are the permissible exposure limits? Compare relative occupational exposure. A good example is asbestos: we are "allowed" to inhale a certain amount (not zero). With infectious disease, we are trying to go to zero. Are we able to do this yet? No.

It would be interesting to hear about a more constant and targeted use of these, such as universal masking for source control. There are benefits beyond COVID, even with regular cloth masks. There is opportunity for better product in the market for sure.

The questions we have are far from answered. As we change how we deliver care, we will find more things we need to do and plan for. As procedures improve, we may see a different contribution of things like masks and respirators.

It is best to think of this as one more step in a series of adjustments that keep making things better.

Discussion — Prioritizing How Best to Move Forward Collaboratively: Keeping Canadians Informed and Safe during the COVID-19 Pandemic, Together

Dr. Lavis posed questions to all participants as part of this discussion session. Individual responses are listed below and do not necessarily reflect the viewpoint of any person other than the speaker.

Question 1: What are the most important changes that need to be made to PHAC guidelines? Additional context: In community? In health care?

N95 respirators

PHAC needs to focus on N95 as it is a hot topic in the provision of health care. However, the focus should not be limited to N95s. It is important to look at N95 versus medical mask or universal patient masking.

Communication concerns

Communication of guideline recommendations need to change from categorical to probabilistic / nuanced with specifics such as 2m distancing. It should also be noted that there may be a need to make changes depending on the situation (work, school); for example, 2m spacing is being prohibited, yet it informed guidance for post secondary institutions. The effectiveness of cohorting should be assessed. Future guidance should provide insights regarding who the target audience is (or the focus) for public health interventions – the 'who' of transmission is as important as the modes of transmissions.

Health care workers

PHAC needs to focus on health care workers. Do we think health care as an occupation is higher risk than other occupations and how can we protect workers in general?

There was no consensus agreement on this question.

Question 2: Do people agree or disagree with keeping masks on indoors even if there is 2m spacing? Should we remove recommendations for masking indoors around people you know (e.g., should a mask be worn if in an enclosed area with 9 family members)? Note that 'crowded' is a difficult term to interpret.

Comments for "agree"

Masks should be kept on indoors (especially when talking) even with 2m spacing, irrespective of crowding or ventilation. People often have conversations without the speaker wearing a mask and there is movement of air carrying particles. There is no scientific basis for the 2m distancing, particles extend beyond that, up to 7m. In addition, there is transmission by asymptomatic people, even with no coughing or sneezing, they still generate aerosol size particles.

Mask should be kept on in high prevalence areas, when outside bubble. For social gatherings such as Thanksgiving, there should be no group gathering with individuals who are not currently housemates because people have to take their mask off to eat. This is within the context of a bundle, it is implicit, and is just an incremental change.

Comments for 'disagree'

Unintended consequences need to be considered in making this decision. Ideally, would like to have a full discussion, indicating who supports this approach and who does not.

Communication and language concerns

Additional text is needed regarding having other people around (not just around being indoors). For example, if working alone in a lab at night, does masking apply? Crowded is indeed difficult to interpret. Recommendations need to be carefully worded (may require some kind of caveat) to prevent a false sense of security. It may appear that if within 2m space you are protected; this may be to a certain degree, but not fully.

Not enough information to make a decision

This is difficult to answer alone. Questions need to be bundled (in the context of other public health measures), taking into account hand hygiene and 2m distancing. A substantive statement is needed to be able to make a decision today with significant consequences for daily living. The statement / issue is too black and white a recommendation for a nuanced situation.

In the community, it is important that we first optimize the measures we have already recommended. Most of the expected gain from non-medical masks would apply to crowded indoor spaces where distancing is not possible. This needs to be optimized; however, exceptions should be considered in scenarios where more aerosols might be generated (e.g., choir practices). In such situations (but not generally), one may want to mask even at slightly greater distance.

There was no consensus agreement on this question.

Question 3: What types of changes, if any, should we consider for enclosed indoor spaces? Do you think we need to change our recommendations about HVAC systems in indoor environments?

Need guidance

Given the limited evidence of transmission of infection between rooms, we could look at other issues such as making use of more outdoor air instead of filtering. Careful consideration is necessary given limitations of HVAC systems.

There is a need for better guidance on this, using evidence from super-spreader events. Dense populations in poorly ventilated areas lead to increased risk (e.g., bus transmission incident in China). With respect to schools, consider recommending higher air changes per hour which ASHRAE recommends.

Resource considerations and other implications

Are we making this mandatory or recommended? If mandatory, we need to be really careful about not requiring things that might be “nice to have” but take away from overall needs. The focus should remain on the most important things, especially for those with limited resources. For this reason, this needs to be presented as a recommendation. People should be provided with pragmatic advice regarding things they want to consider in the short term. In the long term, there may be implications for building codes. There is some concern that people will have difficulty choosing where to put funding. Whatever the decision is, some context is needed around this. For example - Are you buying alcohol-based hand rub or placing ultraviolet filters in your ceiling? The concern is that people may invest in something differentially and not others. This is not always the best thing to do.

Some evidence (cohort and randomized trials) is needed before we start making recommendations which will require investing money and resources into something that is not necessary.

There was no consensus agreement on this question.

Question 4: Under what contexts and circumstances should N95 masks be recommended? Any reactions to the framing of this question? Do we need to move in this direction?

Specify where N95 is needed

Everyone agrees N95s are appropriate for AGMPs, but coughing and sneezing are not aerosol-generating. Some of the confusion comes from original SARS where some HCWs were infected despite appropriate PPE. The list of AGMPs keeps growing and is not based on actual evidence. Taking the precautionary principle approach was once a preferred approach due of SARS 1. Note that this is a specialized area and the bigger question is "who else needs to be wearing these N95s?"

N95s should be used when caring for patient early on in asymptomatic or pre-symptomatic infection. There is good evidence that N95s are not needed to care for COVID patients. Situations that may require an N95 include crowded waiting rooms with potential for unrecognized super-spreader or asymptomatic patients.

Observations following thousands of continuous hours, routine patient care and meticulous methods, show the rate among HCWs is two times lower than among the general population. Occupational infections are so low, therefore changing to N95s is not warranted based on the evidence. No changes are warranted to recommendations at this time. Some evidence is necessary to inform any decision to make changes. Foothills Hospital outbreak was a small outbreak, there was probably a lot of community acquisition involved.

No changes are warranted to recommendations at this time. People that want the N95s can get them, those that want to keep medical masks, can do that. Overall, no changes to N95 recommendations are warranted at this time because epidemiology does not support it and unintended consequences are not being considered in the analysis.

If we focus only on N95 respirators, other key interventions will be missed which are likely going to be more effective; for example, universal masking of all patients, independent of their symptoms.

Recommend N95 for patient care

Coughing produces aerosols. It has been shown that more aerosols are generated during an AGMP than when breathing, but breathing is longer (continuous). Patient viral load is different – some are very contagious, most are not. We do not have a guaranteed way of knowing who is contagious and who is not. Therefore, we need to use N95s more widely. The cumulative risk is rising.

Canadian Standard CSA Z94.4-18 provides respirator selection guidance for biological aerosols. N95 filtering face pieces are the minimum level that should be used for AGMPs, in zones with good ventilation. If ventilation is poor, higher levels of protection are advised, such as full-face or powered air purifying respirators.

Use a balanced approach

Managing unrecognized positive cases — whether patient, staff or family member — is an important consideration. This is part of the usual risks in life and unrecognized risks are the greatest. The intent is to identify cases quickly and then mitigate risk of transmission. A good analogy is a motor vehicle crash — it cannot be recognized in advance, so we implement interventions to mitigate risk such as seatbelts, preventing impaired driving etc. However, practicality prevails, we continue to drive, and not in steel enforced tanks. There must be a balance between the precautionary and practical approach. This is a very well-known assessment used in environmental health.

Flagging knowledge gaps / research needs

There are big interdisciplinary gaps in knowledge that must be prioritized to better understand transmission. Experts are trying to understand the amount of virus that needs to be present in droplets or aerosols to render it infectious. How much virus does it take to infect a person? This research needs to be done working across the aisles of various disciplines, it is a global problem and requires global solutions. In addition, there is a need to understand how to define droplet and aerosol. Definitions are currently not aligned across scientific disciplines. This heterogeneity of definition is hindering us.

Resources are needed to invest into obtaining high-quality evidence from randomized controlled trials and the installation of UV lights. High-quality evidence should be available before giving recommendations. Adequate funding and resources for outbreak investigations are needed. Other countries are doing this. An item of concern is investing in expensive interventions without evidence, rather than in interventions that have been proven to work.

Studying outbreaks is very important, information presented on day 1 regarding contribution of super-spreaders to outbreaks is important to understand. There are lots of gaps outside health care settings, in closed air spaces. These situations provide learning opportunities. Some groups have indicated that they do not know if ventilation is effective. In hospitals, it has been shown to be effective so we need to take that knowledge and apply it to other settings. The evidence does not reflect that HCWs caring for a wide variety of patients with routine precautions (exclusive of N95s) are at increased risk.

WHO has no occupational health experts employed. They are trained in figuring out exposures using a risk based approach - a risk assessment tool to determine under what situation a respirator is needed. A plea was made to listen to the occupational hygiene community.

There is a huge interdisciplinary structural gap. Researchers have expressed frustration that they cannot get through to public health to contribute to the work. This is because public health is currently putting out a fire so these researchers will be coming in to “redesign fire hoses” in the middle of the fire. Nonetheless, if the opportunity can be created, it could be helpful and solutions accelerated. This may be an interesting research proposal.

Communication and behaviour change

If we are going to make strides, we need to be better in communicating what the public needs to know and how they can protect themselves. Each jurisdiction has different wording and nuances. We need the public to know the difference between self-isolation and self-monitoring. If social distancing is the way to go, that needs to be clearly communicated. Clear direction from multiple disciplines (public health, behavioural science and virology) will be valuable.

Some work is required in the area of identifying how to influence citizens and HCW behaviours, in terms of new and existing routines. There is little evidence around supporting behaviour change and maintenance. There is a need for new routines and effective ventilation in schools, and behavioural scientists need to figure out how kids may mess up and proactively deal with that.

A question was raised about the relationship between CIHR and the Natural Sciences and Engineering Research Council (NSERC); recognizing that cross fertilization is needed between aerosol scientists and others.

There was no consensus agreement on this question.

Due to time constraints, the group did not get to the question “How can we better support the integration of thinking from laboratory, IPC, engineering, data modelling, and outbreak studies into future guidance — short term or long term.”

Next Steps and Closing Remarks

The two-day session provided participants with an enhanced perspective from the multiple fields of expertise that are contributing to our understanding of COVID-19. More specifically, participants were provided with syntheses of the best available evidence related to the risk of aerosol transmission of COVID-19. Among the participants, there was no general agreement on the contribution to the role of aerosol transmission of COVID-19 nor the guidance that should be offered in health care facilities in the community. However, no participant who attended, left without a deeper understanding of the complexity of the underlying issues and the challenges in creating the structures to solve those issues.

A thematic review of the meeting discussion sessions is provided in Table 1, and a brief summary of the meeting outcome in Table 2 (appendix).

Potential near-term next steps include complementing perspectives from this meeting with a review of current evidence to inform future updates on PHAC's COVID-19 IPC guidelines for health care settings.

Dr. Lavis was thanked for excellent moderating that ensured meeting objectives were met. Appreciation was also extended to the meeting planning committee for their collaborative efforts in driving the need for this meeting and all participants for attending and contributing to a constructive dialogue on a fast emerging and controversial topic.

PHAC is grateful to all who presented and participated in the BBE, Dr. Lavis for moderating, CADTH for its co-sponsorship, and CIHR for developing, supporting, and hosting the event.

PHAC will continue to engage meeting participants, BBE presenters, and other relevant organizations as new evidence becomes available and guidance documents are identified for updating.

Appendix

Table 1: Thematic Review of Meeting Discussion and Question and Answer Sessions

Themes	Summation of themes of discussion and Q & A comments
Masks and respirators	Need to know more on how COVID-19 is transmitted; including the role of small particle aerosols. More evidence is needed for informed decision-making. Changes need to be stated as "recommendations" and not "mandatory."
Masks in public	Masks should always be worn in indoor spaces. Masking and distancing are key measures. Focus should be on crowded indoor spaces and places where spreading is more likely via aerosols (e.g., choirs). More communication is needed to help identify high-risk public spaces.
Modes of transmission	Need to factor asymptomatic and pre-symptomatic transmission. Need to factor additional modes of transmission other than droplet. Need more information on infectious dose. Need to identify patients quickly and mitigate risk of transmission.
Health care workers	Risk to health care workers is high due to duration and proximity.
Infection prevention and control	Ventilation is important. Stricter measures are needed when risk is high. PHAC needs to focus on this issue.
Research needs	Need more information on outbreak investigations, transmission risk, infectious dose and usefulness of ultraviolet light. Public Health should work with researchers to bridge gaps in knowledge.

Table 2: Summary of Meeting Objectives and Outcomes

Meeting objectives for participants	Anticipated outcome	Actual outcome
Use a common lens to review the science of the circumstances under which aerosols are generated	Collective acknowledgement of those areas where there is uncertainty and recognition that in some circumstances new evidence may be required to change recommendations	Key areas of uncertainty were identified. It was acknowledged that aerosol transmission occurs but the conditions for transmission remain unknown.
Use a common lens to review the science of the infectiousness and transmissibility of COVID-19 through all forms of respiratory secretions	A landscape of COVID-19 transmissibility viewed from the perspective of different fields of study and also from both stakeholders and policy-makers	A broader perspective was gained by participants.
Provide evidence-based advice on the proportional effectiveness of infection prevention and control measures to prevent the transmission of COVID-19 in health care and shared indoor spaces	Increased understanding of how various expert perspectives affect the interpretation of available evidence	A better understanding was gained of differences in considerations and definitions used by aerosol and medical scientists.
Establish a foundation for a collaborative approach to ensure the achievement of future evidence-based public health strategies and interventions to protect the health of all Canadians	A path forward to an ongoing approach incorporating the best available evidence, as viewed across a spectrum of expertise, on the routes and risk of infection with COVID-19 and the proportional mitigation strategies	A clear path forward was not identified at the meeting. PHAC will continue to engage this discussion.

PHAC = Public Health Agency of Canada.