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A Consideration of the Rationale Provided to Downgrade PPE Precautions for COVID-19

Public Health Ontario (PHO) has updated their review of the evidence for the case against the airborne transmission of the COVID-19 virus: https://www.publichealthontario.ca/-/media/documents/ncov/wwksf-routes-transmission-mar-06-2020.pdf?la=en ("COVID-19 – What We Know So Far About... Routes of Transmission", July 16, 2020 (posted online July 31) – referred to as the "PHO document" in this review)(1). This document has two previous versions (dated March 6 and April 28) which were quite similar. This revision represents a more detailed rewriting of the document, so I have also extensively revised my previous version of the critique to update them with the new information available.

Beginnings: When we first heard about the outbreak of pneumonia disease in Wuhan, China the reports suggested the outbreak was associated with the Huanan Seafood Wholesale Market, although this market is no longer thought to have been the epicenter of the pandemic(2). Early speculation suspected the species of origin was the pangolin, a creature most of us had never heard of that looks like an armadillo or an anteater. Bats were also mentioned, however, there was thought to be an intermediate species between the bats and humans. At this point in time the most likely transmission path for the pneumonia was assumed to be animal-to-human which was later disproven(3).

On December 30, 2019, Dr. Li Wenliang sent a message to colleagues warning them of a possible outbreak of a SARS like disease(4). Local government officials coerced him to sign a retraction. He was one of eight people who were detained by local authorities for "spreading rumours". On January 12, Dr. Wenliang was hospitalized with symptoms of the disease. He died on February 7, 2020, at the age of 33 and according to his obituary in the Lancet, the circumstances of his death were to be investigated by "the National Supervisory Commission, the country's highest anti-corruption agency". Municipal leaders were later disciplined for how they handled the situation.

Early on in the pandemic, one of the issues of scientific contention was whether this new disease could be transmitted from human-to-human. The association with the wet market in Wuhan and the speculation around which species was responsible for transmission diverted attention from the possibility of human-to-human transmission. The early signs of human-to-human transmission are usually "close contact" transmission to those who have no connection to the animal-to-human transmission path, namely, family members of the patient or healthcare workers (HCWs) attending the patient. With family members there can always be the doubt whether they also had direct or indirect contact with the animal of suspicion, however, unless the HCW also frequented the wet animal market, any case of a HCW is a clear indication of human-to-human transmission. Thus, HCWs are essentially treated as the "canaries in the coalmine" (canaries were used in the coal mines in England to warn miners of dangerous concentrations of carbon monoxide, if the canary was overcome by the gas, then

the miners knew they had to quickly evacuate[5]). As such, the "canary in the coalmine" has become the symbol of early warnings in health and safety.

Despite a number of HCWs becoming infected during the early days of the pandemic (e.g. Dr. Wenliang's January 12 hospital admission), Chinese and WHO officials continued to say that there was insufficient evidence to support human-to-human transmission. It wasn't until January 20th that officials finally admitted that human-to-human transmission was occurring[6]. That decision was made based on the infection experience of HCWs. An early case series report of the first 138 patients with COVID from one of the hospitals in Wuhan indicated that 40 (29%) of the patients were HCWs[7].

When human-to-human transmission was finally officially accepted, the Chinese government acted promptly to declare the new disease a Class B disease (same category as SARS and MERS) but they declared the protective measures to be applied would be those prescribed for Class A infectious diseases (cholera and plague)[7]. Wang et al.[8] report that by February 24 there were 2,055 HCWs infected, comprising 2.6% of all confirmed infections in China. Most of these infections occurred between January 18 – February 5. Wang et al. attributed the early infections to inadequate personal protection, intense workloads, extended shifts, shortages of personal protective equipment, and inadequate training. A later report[9] put the confirmed number of HCW infections at 2,457 workers (3% of all confirmed cases up to March 26) including 17 deaths.

A number of handbooks for dealing with the pandemic in hospitals were published in China and some of these were translated into English. One of these was produced by the First Affiliated Hospital — Zhejiang University (FAHZU)[10]. It describes the personal protective equipment required for the protection of HCWs. These measures include the use of N95 respirators for anyone treating a patient with COVID, along with multiple layers of other equipment. A recent paper (Ng-Kamstra et al., 2020)[11] in the Canadian Medical Association Journal (CMAJ) claimed that despite "complex and extensive" protective measures "thousands of health care workers acquired the virus" in China[11], implying the Chinese preventive efforts were unsuccessful. In what seems to be a characteristic misrepresentation of papers being referenced, the handbook cited by Ng-Kamstra et al. actually states the opposite in the Foreword:

> "Over the past 50 days, 104 confirmed patients have been admitted to FAHZU, including 78 severe and critically ill ones. Thanks to the pioneering efforts of medical staff and the application of new technologies, to date, we have witnessed a miracle. No staff were infected, and there were no missed diagnosis or patient deaths."[10]

Obviously, this report is specific to the FAHZU, but it does demonstrate that a zero infection rate of exposed HCWs is possible.

Further, from January 24 to March 8 the government of China recruited 42,600 HCWs to assist the 100,000+ HCWs in Hubei province. These HCWs used the protective measures similar to those described in the Handbook. A number of publications report that, as of April 16 (when the last recruits finished their work in Hubei), none of those HCWs had been infected.[12-14]

Transmission pathways: Generally, in the infection prevention and control (IPC) community, there are 3 major pathways of transmission: droplet, contact and airborne.

Droplet is considered transmission by exposure to particles generally larger than 5-10 micrometres (microns, or µm – the diameter of hair is generally 50-100 µm) and are thought to fall out of the air quickly within a distance of 1-2 metres (m) from the source (i.e. the patient coughing or sneezing). These particles are expelled by the patient, and are either inhaled or splash onto the mucous membranes on the HCW's face (nose and eyes). The prescribed protection for droplet transmission focussed on preventing these particles from reaching the face (i.e. a face shield/goggles and a surgical/procedural mask). There is no concern about smaller particles less than (<) 5-10 µm so the mask is not meant to filter out these smaller particles (although it does to a limited degree). The idea is to provide a barrier that will prevent the face being hit by these larger particles.

Contact transmission occurs when the HCW touches the expelled particles (called fomites) which have fallen on to surfaces (such as a HCW's exposed skin on the hands or the protective clothing covering the skin e.g. gloves). The HCW then touches their face and infects themselves. This is called direct contact, but this category of transmission is sub-divided into two groups, direct and indirect contact. Indirect contact happens when a surface (other than a HCW, e.g. hand sanitizer bottle) is contaminated and the HCW touches that surface and then touches the susceptible regions of their face (eyes and nose). Extensive cleaning and disinfection are needed to prevent this type of transmission. Ebola is a classic example of a disease that can be spread by contact transmission.

Airborne transmission is the category reserved for those disease that can be transmitted by the smaller particles < 5-10 µm and can travel a distance infecting those farther away from the source. Two of the classic examples of this type of transmission are tuberculosis and measles. In order to be infected by these pathogens, you don't even have to be in the same room as the person who is the source of the particles. These smaller particles are swept up by air currents and can be carried to other parts of the building through ventilation systems or other air pathways and infect those who inhale these particles at a "far" distance from the person emitting the particles containing the pathogen. While this definition is well understood by the IPC community, outside that community and especially among particle scientists, this distinction of "close contact" and "distant" infections is blurred by their view of particle dynamics as a continuum rather than dichotomous. Particle scientists (and others with passing familiarity with the science such as occupational hygienists) view particle size distributions as a continuum – emitted particles being a continuous range of sizes from very small to large depending on the source characteristics.

Categories or a Continuum? So, whereas the IPC community see distinct categories differentiating droplet from airborne transmission based primarily on the distance between the source and the recipient, aerosol scientists see a continuous spectrum of particles being emitted, the larger of which quickly "fall" out of the air, but the smaller of which get swept up with the air currents and distributed throughout the room and possibly entrained into the ventilation system. Thus, when the IPC community calls something airborne, they are using a category that was established about 100 years ago to describe infections that occur at a distance from the source; however, when particle scientists hear the word airborne, they don't segregate between large and small particles except as a part of a spectrum of particle sizes often classified into groups based on where in the lungs these particles settle. Here we see the basis of confusion which impacts the differing recommendations for respiratory protection for HCWs.

For the IPC community, if the category of transmission is deemed to be droplet, then the prevention strategy is based on preventing particles from impacting the face (face shield, surgical mask). On the other hand, particle scientists will look at the emitted particles and, if they see particles in the respirable range (< 5-10 µm), they will recommend inhalation protection as well i.e. respirators (N95 masks or others with similar or higher filtering efficiencies such as N99s, P100s, PAPRs, etc.) that will prevent these smaller particles from entering the lungs. Surgical masks (prescribed to prevent splashes of large droplets from hitting vulnerable parts of the face) will also filter out some of these smaller particles, but not as efficiently as N95 respirator masks. Surgical masks were initially designed to prevent the emissions from the person wearing the mask to infect others (e.g. preventing pathogens exhaled by a surgeon from infecting the wound of their patient), they were never designed to protect the person wearing the mask from inhaling the emissions from those patients (N95s were designed to do that).

Mark Nicas & Rachael Jones in their modelling paper[(15)] suggested a better way of looking at the problem of transmission, i.e. to assume that all infectious agents can theoretically be transmitted along all the pathways and that the job of researchers is to quantify what proportion of the transmission follows each path. Jones recently applied the method she and Nicas pioneered to SARS Cov-2, suggesting (given the limited knowledge at the time), the proportion of transmission attributable to droplet was estimated to be 35%, 57% due to inhalation, and 8.2% due to contact [(16)]. It should be noted that different environments may favour different paths of transmission. For instance, in a crowded, poorly ventilated space with the presence of a super-spreader (a person who emits particles with an extremely high viral load), the close-range airborne transmission path may predominate, whereas in a highly ventilated infection containment hospital room (AIIR) with HCWs wearing appropriate PPE, the predominant route might be contact or droplet, or a combination of the two, while close range airborne transmission might be minimal.

Ontario Background: Ontario has a particularly unique history given the SARS outbreak in 2003. While the history and fall-out of this episode is explained elsewhere in this report, one of the scientific issues associated with the outbreak was how the virus was transmitted. Initially droplet transmission was assumed, but when these proved inadequate to prevent HCWs from being infected, contact and airborne transmission pathways were considered. The Toronto SARS experience in 2003 is often cited as proof that N95s are no better than surgical masks, however, if you look at the studies published at the time you get a different picture:

> "Experiences in Toronto (5), Taiwan (4), and globally (9) indicate that the primary mode of SARS transmission is through direct contact and respiratory droplets. However, the cluster of SARS cases in Toronto healthcare workers after the intubation of a patient (10), as well as other reported super-spreader events, suggest the possibility of limited airborne transmission under certain circumstances."[(17)]

> "During the Toronto outbreaks of SARS, we investigated environmental contamination in SARS units, by employing novel air sampling and conventional surface swabbing." … "These data provide the first experimental confirmation of viral aerosol generation by a patient with SARS, indicating the possibility of airborne droplet transmission, which emphasizes the need for adequate respiratory protection, as well as for strict surface hygiene practices." … "Confirmation that the SARS virus can be shed into the air of a patient room will guide the response to any future SARS outbreaks."[(18)]

> "When we compared use of N95 to use of surgical masks, the relative SARS risk associated with the N95 mask was half that for the surgical mask; however, because of the small sample size, the result was not statistically significant. Our data suggest that the N95 mask offers more protection than a surgical mask." [(19)]

In Ontario, prior to March 9, 2020, the prescribed protection for COVID-19 included an N95 respirator for all healthcare encounters with a patient suspected or known to have COVID-19. This was a hold-over from the 2009 H1N1 pandemic experience. At that time N95s were recommended for any new, unknown influenza type pathogen. Thus, at the beginning of the pandemic experience in Ontario which began in late January 2020, all HCWs working with patients with COVID were required to wear N95s (or PAPRs) in addition to their droplet and contact precautions.

In early March, a newspaper article[(20)] reported that IPC experts in Ontario were objecting to the fact that Ontario was the only province requiring the use of N95 respirators for all COVID contacts, whereas other provinces deemed surgical masks to be sufficient except for AGMP exposures. As proof of the effectiveness of surgical mask in preventing HCW infections, the IPC experts noted that none of the HCWs in BC (who were using only droplet precautions i.e. surgical masks rather than N95s) had been infected (again recognizing the role of HCWs as the "canaries in the coalmine"). This pressure from the IPC community in Ontario convinced the government officials to downgrade the PPE requirements for HCWs in Ontario (March 9, 2020).

However, within days of the published newspaper article (before March 9th), it was noted in the press that two HCWs in BC had been infected[(21)]. Since the IPC experts quoted in the newspaper article had set the BC HCW infection experience as their standard of proof of the efficacy of the surgical mask to protect against infection, one would expect this new evidence of HCW infections might raise questions about the adequacy of the droplet and contact precautions. However, the HCW infections in BC did not precipitate a change in revised policy.

Earlier Versions of the PHO Document compared to the Latest Revision: Just days before the downgrading of HCW protective measures, Public Health Ontario (PHO) produced a document explaining the rationale for the change. The document "COVID-19 – What We Know So Far About... Routes of Transmission" (March 6, 2020)[(22)], explained how they came to the conclusion that:

> "There is currently no evidence that COVID-19 is transmitted through the airborne route. As more epidemiological data emerge on cases globally, information is becoming available that suggest that airborne transmission is not occurring:"[(22)]

This statement is followed by 5 bullet points which provide the scientific evidence against airborne transmission:

1. "WHO China Joint Mission on COVID-19 summarizing 75,465 cases indicates that airborne spread has not been reported"; "The absence of significant clusters in other settings [*outside of households*] suggests that the mode of COVID-19 transmission is not airborne." [*added explanation*]
2. "active follow-up of individuals exposed to first ten cases of COVID-19 in the United States describes secondary transmission only to close household contacts."

3. “Healthcare workers caring for COVID-19 patients in other jurisdictions, including British Columbia, have not acquired COVID-19 while using Droplet and Contact Precautions recommended in the province.” (citation is a newspaper article quoting IPC folks)
4. “The lack of transmission to passengers seated nearby cases who have travelled on airplanes, does not support an airborne transmission route of COVID-19.”
5. “In two studies conducting air sampling around confirmed cases, COVID-19 has not been detected.”

In an updated version of this document dated April 28[23], rationale #5 was expanded and altered, and a sixth item was added (all others were left identical to the original including rationale #3 despite the opposite being the case):

5. “Studies have inconsistently detected virus in air sampling”
6. A review of an investigation of a COVID-19 outbreak in a restaurant in Guangzhou, China

Rationale #3 seems to be the most absurd of the six. The reference cited was a newspaper article (Weeks – “Ontario’s coronavirus policy for health workers not supported by evidence, experts warn” (Globe & Mail, March 3, 2020)) which quoted IPC staff:

> “Ontario is the only province recommending airborne precautions. B.C. uses droplet precautions and none of the COVID-19 cases there have spread to health-care workers.”[20],

and:

> “But the evidence shows that droplet precautions are sufficient at protecting workers from infection. For instance, B.C. hospital workers who are treating COVID-19 patients have been using droplet precautions since the outbreak began and, so far, none has contracted the infection.”[20]

On March 7, 2020 Global News[21] reported an outbreak in Lynn Valley Care Centre where two residents and one worker had tested positive. By March 21st, 18 healthcare workers associated with the Care Centre were infected (at that time making up 33% of the total infections associated with the outbreak)[24]. Just over a month later it was reported[25]: “Dr. Bonnie Henry said that as of April 28, health-care workers represented about 21 per cent of the virus cases reported in the province.”, and: “Of the 428 health-care workers who have tested positive for the virus, 33 were hospitalized and one died.”[25]. Dated the same day (April 28) the PHO updated their document[23] titled “COVID-19 – What We Know So Far About... Routes of Transmission” which still contained the statement: “Healthcare workers caring for COVID-19 patients in other jurisdictions, including British Columbia, have not acquired COVID-19 while using Droplet and Contact Precautions recommended in the province (Weeks).”[23]

Not until July 31, 2020 (dated July 16) was this revised PHO document[1] finally posted removing this section. While the identification of HCWs as an indication of the effectiveness of preventive measures is appropriate (probably the best criteria), the fact that the levels of infection among the HCWs were ignored and misrepresented as there being no infected HCWs in BC is an affront to the 428 HCWs who were infected and the one HCW in BC who had died by April 28, not to mention those infected afterwards. In this updated document there is a single reference to the COVID-19 risk HCWs face:

> "More information on what is currently known about COVID-19 and the risks to healthcare workers can be found in the WWKSF document on the Risks to Health Care Workers."

This quote references another PHO document[26] dated Feb 27, 2020, before any Canadian HCWs were known to be infected which hasn't been updated since (as of Aug 13), and so does not discuss the fact that any HCWs in Ontario have been infected.

In previous versions of this document[27] and a related presentation[28], we reviewed the logic and the science behind the six rationale for declaring SARS-CoV-2 not to be transmitted by airborne transmission. The following table is a summary of the previous critiques:

Rationale/Evidence:	**critique**
1. WHO-China Joint report	- no evidence provided for any claims - "appeal to authority"
2. no HCWs infected among the first 10 US COVID cases	- assumes "close contact" excludes airborne - "jumping to conclusions" – as of Aug 12[29] there are 130,829 US HCWs infected with 618 deaths
3. no HCWs using droplet precautions have been infected	- over 6500 Ontario HCWs (presumably following droplet precautions) have been infected - provides evidence for the failure of droplet precautions
4. lack of transmission during travel	- "evidence of absence" fallacy - subsequent studies confirm transmission
5. inconsistent air sampling results	- "verification" fallacy - selection bias (positive studies not included)
6. Restaurant in Guangzhou	- insufficient follow-up - subsequent study contradicts PHO interpretation

Both earlier versions of the PHO document[22,23] unequivocally stated:

> "There is currently no evidence that COVID-19 is transmitted through the airborne route. As more epidemiological data emerge on cases globally, information is becoming available that suggest that airborne transmission is not occurring." (Mar 6 & Apr 28, but no longer in Jul 16)[22,23]

However, when discussing the details further on in the document, the tenor of the claims seems to have been adjusted over time:

> March 6: "Airborne spread has not been documented for COVID-19."[22]

> April 28: "Airborne spread has not been documented for COVID-19, but aerosols may be generated during aerosol generating medical procedures which could theoretically lead to transmission through this route."[23]
>
> July 16: "Airborne spread has not been a dominant or common mode of transmission. Aerosols may be generated during aerosol generating medical procedures (AGMPs), which may increase the risk of transmission."[1]

While the tone has changed from a confident denial to a more conditional statement (allowing only for the exception of AGMPs), there has been no change in the guidelines to reflect this grudging admission. The evidence against airborne transmission is largely based on the argument that it is droplet transmission and therefore can't be airborne (except under AGMP circumstances). Again, the categories seem to interpreted as being mutually exclusive, not a continuum.

The Evidence Supporting Droplet Transmission: There are four main references provided to support the premise that SARS-CoV-2 is transmitted via the droplet pathway. These references were also included in both earlier versions of the PHO document. Interestingly, the evidence presented for droplet transmission is extremely weak, and often contradicts the recommendations found in the references cited. For instance, the report by the European Centre for Disease Prevention and Control (ECDC - "Risk assessment: outbreak of acute respiratory syndrome associated with a novel coronavirus, China: first local transmission in the EU/EEA – third update"[30] (Jan 31 – in it's 11th update as of Aug 10) is referenced and it actually states:

> "Although there is no evidence of airborne transmission so far, ECDC recommends a cautious approach for all patient contacts, with placement of patients in airborne isolation rooms with negative pressure and use of FFP2 or FFP3 respirators with appropriate fit testing."[30]

What is so significantly different from the PHO approach, is the way the ECDC document deals with uncertainty. Namely, using the precautionary principle they suggest, using N95 respirators (i.e. FFP2/3 which are equivalent to N95s).

The Imai et al. document[31] (also from January 2020) is also cited as evidence for droplet transmission, however, the word "droplet" is not even found in the reference.

The Schnieder et al. reference[32] is a textbook on the control of infectious disease which was published in 2016 – the chapter cited deals with SARS and MERS which we have noted above as being in dispute with respect to the role of airborne transmission.

The Wilson et al. citation[33] actually contains the following quote:

> "The weight of combined evidence supports airborne precautions for the occupational health and safety of health workers treating patients with COVID-19."[33]

Thus, two of the four references cited contradict the point that they were cited for. One of the other two does not address the topic, and the last reference is purely an analogy to SARS and MERS published prior to COVID. Not particularly convincing evidence to support the contention that SARS-CoV-2 is transmitted by droplet and therefore airborne protections aren't needed (except for AGMPs).

Three bullets supporting this overall view are listed next, the first being: "The majority of COVID-19 cases have been linked to person-to-person transmission through close direct contact with someone with respiratory symptoms"[1]. It is interesting to note that "close direct contact" seems by definition to exclude airborne transmission, although no rationale is ever given for this underlying assumption (other than exclusive categories, but, as mentioned above, what if a continuum is the more appropriate model of transmission?). A paper[34] by Chen et al. cited later in this PHO document deals specifically with this issue:

> "Close contact in itself is not a transmission route, but a facilitating event for droplet transmission. Note that the use of "droplets" in the remaining text refers to all sizes, down to and including all fine droplets, such as the sub-micron ones. Two major sub-routes are possible in close contact transmission. The large droplet sub-route refers to the deposition of large droplets on the lip/eye/nostril mucosa of another person at close proximity, resulting in his or her self-inoculation. Dry surroundings enable the exhaled droplets to evaporate, and some rapidly shrink to droplet nuclei. The fine droplets and droplet nuclei can also be directly inhaled, which is the short-range airborne sub-route." … "The work presented here poses a challenge to the traditional belief that large droplet infection is dominant."

Again, the PHO document provides evidence that contradicts the point for which the paper is referenced.

The other two bullets in this section deal with contact tracing studies establishing the phenomenon of pre-symptomatic and asymptomatic transmission of SARS-CoV-2. Similar to the other close contact tracing studies, it is hard to see how this constitutes evidence for droplet transmission (and disproves airborne transmission), without the assumption of the equivalence of "close contact" with "droplet transmission" (i.e. a circular argument).

When Every Piece of Evidence can be Interpreted as Supporting one's Claim: Karl Popper (a philosopher of science) noted[35] that if every and any piece of evidence can be interpreted as supporting a particular hypothesis (even those which on their face seem to contradict the hypothesis), then we are no longer dealing with a testable (falsifiable) scientific statement, but rather with dogma and opinion. It is clear from the progression of the 3 versions of the PHO document that we are dealing with a "moving target". For instance, the lack of infections among HCWs using droplet precaution was stated as proof that droplet precautions were adequate and airborne precautions were not needed. However, once the number of infected HCWs (using droplet precautions) could no longer be ignored, this criterion was dropped, rather than try to understand why over 6500 HCWs in Ontario were infected using the precautions prescribed – it appears this very significant failure is being ignored.

Continually Raising the Bar: Another example of the "moving target" standard of evidence is the initial claim that air sampling efforts were not able to measure virus in the air around patients with COVID-19. This is a classic example of the fallacious argument namely that "the absence of evidence is evidence of the absence". Two of the studies cited[36,37] as being unable to detect any airborne virus, specifically stated in the body of the text that they presumed they had not collected a sufficient amount of air in order to detect airborne viral RNA – which is not mentioned in the PHO discussion of these studies.

Later, when studies were published[38-40] that were able to demonstrate the presence of viral RNA in the air, the PHO pointed[1] out that such studies are obviously inconsistent with the negative studies – this

inconsistency, in itself, is taken as evidence against airborne transmission. The argument then became, inconsistent evidence is evidence of the absence, which is a verification fallacy. If one presents the premise that "all swans are white", it doesn't matter how many observations of white swans you collect, the observation of a single black swan is sufficient to refute the premise.

Once further studies were published[41,42] and researchers were able to show the presence of viral RNA in air samples, the PHO counter argument became that the viral RNA collected was not infectious (the collected samples with viral RNA were unable to cause infections in test cells). Recently this has also been refuted, with two reports of researchers being able to culture viral infections from the material collected in air samples. In response, an Ontario IPC expert[43] has now publicly suggested the amount of viable virus detected in the air is insufficient to cause an infection. As each piece of new evidence refuting the PHO position emerges, the bar for sufficient evidence keeps rising.

The "Need" for an RCT: In fact, some PHO staff have suggested the only sufficient evidence would be a large, well-done randomized control trial (RCT). However, as has been pointed out, performing such a study adequately would be nearly impossible given the number of variables contributing to all the paths of transmission. You can randomize individuals wearing masks or respirators (although ethically this is problematic given the knowledge we now have), however, to expect randomization to take care of the differences in contact and droplet transmission paths, the differences in IPC practices in institutions, differences in ventilation rates, exposures to COVID patients, other factors shown to affect infection susceptibilities, etc., it will be very difficult to conduct an RCT that won't be subject to significant scientific objections. Even if such a study were possible, and it showed there was no benefit to wearing a respirator over a mask, one could ask the question, what actions would such a finding imply? A failure in practice does not mean a failure of the device if it has been shown to provide the protection required in laboratory conditions. It may mean a failure in implementation of the protective equipment, poor ergonomic design, a failure in user support/training/education, a failure in the match of the product to the demands and conditions of use, a lack of addressing the full spectrum of the hierarchy of controls, etc.

The Evidence from Contact Tracing & Transportation Investigations: Four contact tracing studies[44-47] are cited by the PHO as evidence that the virus does not transmit along an airborne path since most transmissions occurred mostly within as opposed to outside households. The interpretation of these studies falls prey to the fallacy of "affirming the consequent". Namely, "household contacts" assumes "close contact transmission", which in turn is assumed to exclude airborne transmission, and thus by default supports droplet transmission – a circular argument. Interestingly, two of the four contact tracing studies cited[46,47] only investigated household contacts, so clearly there could not be any non-household contacts in half of the studies referenced. Furthermore, these studies were done during the time of a severe lock-down period in China and Taiwan – thus, it was very difficult to have any non-household contacts. If one had performed a time study of the total time spent with all contacts (inside and outside the household), the percentage of time spent among household contacts was likely similar to the percentage of transmissions – the 78-85% household transmission frequency corresponds quite reasonably to the percentage of time one would expect to spend with household contacts as compared to non-household contacts during a lock-down period. Thus, if the chances of infection were similar, no matter whether at home or not, the percentage of time spent with these contacts would be directly proportional to the frequency of transmission. If, due to the lock-down (very strictly enforced in China)

you spend 80% of your time with household contacts, then it shouldn't be a great surprise if 80% of transmission are among household contacts.

In another study, not cited in the PHO document, Liu et al.[48], looking at 11,580 contacts of 1361 cases between Jan 10 – Mar 15, calculated secondary attack rates by spouse: 23.3%; non-spouse family members: 10.6%; close relatives: 7.0%; other relatives: 4.1%; social activity contacts: 1.3%[48]. One sees in the progression that the results parallel the proportion of one's contact time that one would expect was spent with such contacts.

Cultural factors also play a role. All the contact tracing papers cited by the PHO were from China and Taiwan yet an Italian contact tracing study[49] calculated the following secondary attack rates: cohabitant: 14.1%; non-cohabitant (friend/family): 12.9%; work colleague: 15.8%; other: 9.0%[49]. Again, this perhaps can be explained by a cultural difference in the time spent with different contacts (and the effectiveness of the implementation of social lock-down policies between countries). While these are all fascinating findings and may have valuable implications for prevention, it is difficult to see how the attack rates in different cultures with different contact proves any of the routes of transmission, let alone disproving airborne transmission.

Transmission during Transportation: Liu et al.[48] also looked at contacts from different modes of transportation: flight: 0.8%; train: 1.2%; other public transportation (bus, cab, subway): 2.1%; private car: 4.2%; "Dream Cruises": 9.5%[48]. The early PHO document versions focused a lot of attention on a letter to the editor of a scientific journal they themselves authored[50], about the lack of transmission in an aircraft with a single infected passenger. Again, we have the "absence of evidence" fallacy being used to prove the case against airborne transmission. The current version of the PHO document cites two additional studies[51,52] as corroborating evidence however, one of the studies concludes:

> "…we believe that the most plausible index case resulting transmission of SARS-CoV-2 in the other nine passengers was patient 1, the 45-year-old man from Wuhan, who had onset of fever during this flight." [52]

As per Liu et al.[48] above, air traffic seems to be the mode of transportation with the least risk compared to riding trains, taking buses/subways/cabs, sharing a private car with someone with an infection or, worst of all, cruises, which rival the attack rate of non-spouse family members. Zang et al.[53] traced a large number of passengers and crew after requirements to wear face masks were implemented:

> "We screened 4492 passengers and crew with suspected COVID-19 infection, verified 161 confirmed cases (mean age 28·6 years), and traced two confirmed cases who may have been infected in the aircraft. The overall attack rate was 0·14‰ (95% CI 0-0·34‰)." … "We found that the universal use of face masks on the flight, together with the plane's ventilation system, likely prevented all secondary cases of COVID-19."[53]

If the transmission of SARS-CoV-2 is not by airborne pathway, then why are masks and ventilation so effective in preventing infection?

The Restaurant in Guangzhou Outbreak: The PHO document mentions the Lu et al.[54] study: "COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020", and marvels at how such a study could be interpreted as supporting airborne transmission when the authors conclude: "We conclude that in this outbreak, droplet transmission was prompted by air-conditioned ventilation. The

key factor for infection was the direction of the airflow."[1] However, the authors also pointed out: "Our study has limitations. We did not conduct an experimental study simulating the airborne transmission route" [1], which the PHO reiterated in their critique of the paper: "A weakness of this report is that the authors did not conduct any aerodynamic testing to support their hypothesis. In addition, the authors focused on potential droplet transmission at the restaurant and did not explore other possibilities, such as indirect transmission of fomites." [55] What the PHO ignored was a follow-up study by Li et al.[56] which addressed these limitations and, in doing so, came to a different conclusion:

> "We collected epidemiological data, obtained a video record and a patron seating-arrangement from the restaurant, and measured the dispersion of a warm tracer gas as a surrogate for exhaled droplets from the suspected index patient. Computer simulations were performed to simulate the spread of fine exhaled droplets. We compared the in-room location of subsequently infected cases and spread of the simulated virus-laden aerosol tracer. The ventilation rate was measured using the tracer decay method." … "In summary, our epidemiologic analysis, onsite experimental tracer measurements, and airflow simulations support the probability of an extended short-range aerosol spread of the SARS-CoV-2 having occurred in the poorly ventilated and crowded Restaurant X on January 24, 2020." … "Specifically, although close contact and fomite exposure may play a major role in the transmission of SARS-CoV-2, extended short-range aerosol transmission of the virus is possible in crowded and poorly ventilated enclosures. Our study suggests that it is crucial to prevent overcrowding and provide good ventilation in buildings and transport cabins for preventing the spread of SARS-CoV-2 and the development of COVID-19."[56]

Another set of outbreaks not mentioned in the PHO documents are related to choirs. A number of case studies have suggested airborne transmission during choir practices combined with the presence of a "super-spreader". As noted above by McDonald et al.[17] (in the context of SARS1): "the cluster of SARS cases in Toronto healthcare workers after the intubation of a patient (10), as well as other reported super-spreader events, suggest the possibility of limited airborne transmission under certain circumstances."[17]

Reproductive Number (R_0): Another argument against airborne transmission is the low Reproductive number (R_0) which is the average number of people infected by a single person with the infection. An R_0 of 2-3 means that for every person infected they each will infect 2 or 3 other persons. Measles (a recognized disease spread through airborne transmission) has an R_0 of between 6.1-27.0[1]. The PHO cite[1] the R_0 number for COVID-19 as being between 2-3, however, a recent review[57] suggests:

> "A total of 20 R0 for SARS-CoV-2 estimates were extracted from 15 studies. There was substantial variation in the estimates reported. Estimates derived from mathematical models fell within a wider range of 1.94-6.94 than statistical models which fell between the range of 2.2 to 4.4." [57]

Interestingly the upper range of these estimates for COVID-19 (i.e. an R_0 of 6.94) overlaps with the lower range of the measles estimates (an R_0 of 6.1). In an investigation of the Diamond Princess cruise ship outbreak, Rocklöv et al.[58] noted: "The R_0 was 14.8 initially and then R_0 declined to a stable 1.78 after the quarantine and removal interventions were initiated."[58]

Commentaries: The PHO document also cites two commentaries, one signed by 239 experts which stated[59]:

> "The evidence is admittedly incomplete for all the steps in COVID-19 microdroplet transmission, but it is similarly incomplete for the large droplet and fomite modes of transmission. The airborne transmission mechanism operates in parallel with the large droplet and fomite routes, e.g. [16] that are now the basis of guidance. Following the precautionary principle, we must address every potentially important pathway to slow the spread of COVID-19."[59]

The second commentary[60] is seemingly cited to provide a counter to the 239 experts' recommendation:

> "The balance of evidence, however, seems inconsistent with aerosol-based transmission of SARS-CoV-2 particularly in well-ventilated spaces." … "It is impossible to conclude that aerosol-based transmission never occurs and it is perfectly understandable that many prefer to err on the side of caution, particularly in health care settings when caring for patients with suspected or confirmed COVID-19. However, the balance of currently available evidence suggests that long-range aerosol-based transmission is not the dominant mode of SARS-CoV-2 transmission." [60]

It is telling to see the similarities and differences in the two arguments. They both agree that the evidence is not sufficient to conclude airborne transmission. The 239 experts also stress that the state of evidence for droplet and fomite transmission is also incomplete, a point which the opposing commentary ignores.

They both mention the precautionary principle. However, the 239 experts recommend following it, while the opposing commentary view the option as an "understandable" preference, but then imply that such a preference is not justifiable on a scientific basis. However, they couch the argument against in such language that they create a "straw man" argument by specifying "long-range" aerosol-based transmission. As per Chen et al.[34] (cited in the PHO document and quoted above): "Short-range airborne transmission is dominant beyond 0.2 m for talking and 0.5 m for coughing."[34], implying that droplet transmission extends 0.5 m or less away from the source and beyond that "short-range" airborne transmission predominates[34]. The fact that Klompas et al.[60] qualify their conclusion as applying particularly to "well-ventilated spaces"[60], again implies the possibility of short-range airborne in poorly ventilated spaces.

The Bottom-Line: Preventing any HCW Infections: Finally, when the IPC do address the infection rate of HCWs it is often done in comparison to community rates, implying that the infections came from the community and the HCWs brought them into the workplace. With respect to LTC outbreaks, Fisman et al.[61] suggest that "The greater mobility and connectedness of staff, compared with residents, lends biological plausibility to this association."[61], meaning because staff are out in the community and residents are stationary within the home it suggests staff are the source of the residents' infections. However, what they fail to consider is that residents have family and friends who were still visiting in the early days of the pandemic. Also, the demographic of the family members visiting elderly parents would suggest the around retirement age "Baby Boomer" generation – a demographic with a lot of travel experience. Fisman et al.[61] seem to have completely missed this aspect of the possible transmission. In the early days of the pandemic, travel outside the country was the major risk factor for infection –

HCWs, (particularly PSWs with minimum wage and part-time work), are not as likely to travel as the children of elderly parents.

Similarly, one particular hospital in Toronto was quite proud of the performance of their infection control program and boasted that 2.8% of frontline COVID staff had been infected while 4% of other frontline staff and 4.3% of non-clinical staff were infected. Assuming an overall average of 4% of staff infected and assuming 10,000 total staff members, this would mean about 400 workers were infected! The suggestion was that non-clinical staff rates of infection were comparable to the general population, however at that time (May 22) in Toronto the rate of infection was 0.28% - more than 10 times lower. One must, however, take into consideration that all healthcare workers in Ontario were being tested at the time, while not everyone in the general population was being tested, so one would expect a higher rate among the more fully tested population. However, given that the seroprevalence in Toronto as measured in June was 1.5% (95% CI 0.9-2.1%), this would mean that working at this particular hospital implied a 2 to 3 times higher risk of infection than in the general Toronto population. If we compare this to the 46,200 Chinese COVID HCW cohort who did not record a single infection[12-14], we can contrast the difference in performance between the IPC programs. It is possible to prevent SARS-CoV-2 infections but we haven't been able to do that in Ontario.

Worldwide, it was reported mid-July that 1.4 million HCWs had been infected so far. The WHO tweeted:

> "So far, about 10% of all #COVID19 cases globally are among #healthworkers. Many health workers are also suffering physical and psychological exhaustion after months of working in extremely stressful environments"-@DrTedros 11:29 AM · Jul 17, 2020 https://twitter.com/WHO/status/1284148139797209093

It is somewhat conflicting to see the empathy expressed in the Tweet while knowing that, if the Chinese experience had been shared through WHO guidelines, this number would have been much smaller. Yet, the WHO seems to be very resistant to improving protection for HCWs – stating it requires more studies to determine the paths of transmission and more time to review the results. In contrast, on January 20th, the Chinese government, when they were finally willing to accept human-to-human transmission based on the number of HCWs being infected, immediately increased protections, and were ultimately able to prevent HCW infections. But, unfortunately, the nature of this heightened response was not described in the Joint WHO-China report.

Yesterday (Aug 12, 2020) the PHO reported[62] 6,578 confirmed HCW cases (16.3% of all confirmed cases), which is much higher than the 10% the WHO reports worldwide, and much higher than the 3% reported among Chinese HCW (most occurring at the beginning of the pandemic prior to the increased preventive measures). It is obvious that HCW infections can be prevented – we may not understand all the details of the paths of transmission, but the Chinese have shown that such detailed, scientific information is not required to prevent infections. Using the precautionary principle one can protect oneself from incompletely understood hazards. Tobacco companies also objected to being held responsible for deaths and disease caused by their products by claiming there wasn't sufficient scientific evidence to make the connection[63]. There is no need to wait for "the perfect RCT" in order to justify providing more protection for HCWs today.

John Oudyk
August 13, 2020

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Appendix

The following tables were constructed to compare the PHO's interpretation of particular studies with the original authors' interpretations of their findings

Source cited *(items in italics not cited)*	**PHO interpretation**	**Original authors' interpretation** *(my summary/commentary in italics)*
Stadnyskyi et al (May 4 2020) - The airborne lifetime of small speech droplets and their potential importance in SARS-CoV-2 transmission	"While aerosols are produced during activities such as speaking, breathing and coughing (Stadnytskyi et al.), it is not clear what role in transmission these have for distances greater than 2 m as viable SARS-CoV-2 has not been detected during air sampling." *[link to Zhou et al., 2020]*	"Speech droplets generated by asymptomatic carriers of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) are increasingly considered to be a likely mode of disease transmission. " "These observations confirm that there is a substantial probability that normal speaking causes airborne virus transmission in confined environments."
Zhou et al (May 26 2020) "Investigating SARS-CoV-2 surface and air contamination in an acute healthcare setting during the peak of the COVID-19 pandemic in London"		"Bearing in mind that the viral RNA detected in the hospital setting might have been deposited more than two hours previously, we cannot differentiate whether our inability to culture virus from the samples is explained by the low RNA levels or the length of time since deposition which may reflect non-viable viral RNA. It is also possible that virus was infectious but not culturable in the laboratory. " "Whilst we did not measure particle sizes during our air sampling, our findings highlight a potential role for contaminated air in the spread of COVID-19. Our finding of air contamination outside of clinical areas should be considered when making respiratory PPE recommendations in healthcare settings"
Morwaska & Milton () "Commentary – It is Time to Address Airborne Transmission of COVID-19"	"A recent commentary in Clinical Infectious Diseases appealed to the medical community to recognize the potential of airborne transmission based on experimental evidence that small respiratory droplets (or aerosols) could be inhaled."	"The evidence is admittedly incomplete for all the steps in COVID-19 microdroplet transmission, but it is similarly incomplete for the large droplet and fomite modes of transmission. The airborne transmission mechanism operates in parallel with the large droplet and fomite routes, e.g. [16] that are now the basis of guidance. Following the precautionary principle, we must address every potentially important pathway to slow the spread of COVID-19."
Klompas et al. (Jul 16 2020) "Viewpoint - Airborne Transmission of SARS-CoV-2 Theoretical Considerations and Available Evidence"	"Another commentary in the Journal of the American Medical Association discusses how the balance of currently available evidence does not support long-range aerosol	"All told, current understanding about SARS-CoV-2 transmission is still limited. There are no perfect experimental data proving or disproving droplet vs aerosol-based transmission of SARS-CoV-2. The balance of evidence, however, seems inconsistent with aerosol-based transmission of SARS-CoV-2 particularly in well-ventilated spaces."

	transmission as the dominant mode of COVID-19 transmission."	"It is impossible to conclude that aerosol-based transmission never occurs and it is perfectly understandable that many prefer to err on the side of caution, particularly in health care settings when caring for patients with suspected or confirmed COVID-19. However, the balance of currently available evidence suggests that long-range aerosol-based transmission is not the dominant mode of SARS-CoV-2 transmission."
Chen et al (Mar 23 2020) "Short-range airborne route dominates exposure of respiratory infection during close contact"	"The role of these aerosols has been suggested in a modelling study to be most important for transmission in close proximity (within 2 m) (Chen W et al.)."	"Close contact in itself is not a transmission route, but a facilitating event for droplet transmission. Note that the use of "droplets" in the remaining text refers to all sizes, down to and including all fine droplets, such as the sub-micron ones. Two major sub-routes are possible in close contact transmission. The large droplet sub-route refers to the deposition of large droplets on the lip/eye/nostril mucosa of another person at close proximity, resulting in his or her self-inoculation. Dry surroundings enable the exhaled droplets to evaporate, and some rapidly shrink to droplet nuclei. The fine droplets and droplet nuclei can also be directly inhaled, which is the short-range airborne sub-route." "The maximum distance studied is 2 m." "Short-range airborne transmission is dominant beyond 0.2 m for talking and 0.5 m for coughing. … The work presented here poses a challenge to the traditional belief that large droplet infection is dominant." *Note: Chen et al., deliberately only studied the range of 0-2 m; to suggest that this means this range is most important for transmission is a misinterpretation of the study*
Experimental evidence of aerosol generation:		
van Doremalen et al. (Mar 17 2020) "Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1"	"In a study comparing SARS- CoV-2 and SARS-CoV-1, van Doremalen et al. reported that SARS-CoV-2 could be artificially aerosolized with a jet nebulizer and detectable for up to three hours in a rotating metal drum. … While the van Doremalen et al. study concluded that aerosol transmission is possible, they did not demonstrate that it occurs"	"Our results indicate that aerosol and fomite transmission of SARS-CoV-2 is plausible, since the virus can remain viable and infectious in aerosols for hours and on surfaces up to days (depending on the inoculum shed). These findings echo those with SARS-CoV-1, in which these forms of transmission were associated with nosocomial spread and super-spreading events,[5] and they provide information for pandemic mitigation efforts."

Fears et al. (Apr 18 2020) "Comparative dynamic aerosol efficiencies of three emergent coronaviruses and the unusual persistence of SARS-CoV-2 in aerosol suspensions"	"Similar conclusions were drawn from a study conducting a similar experiment (Fears et al.)."	"Collectively, these preliminary data suggest that SARS-CoV-2 is resilient in aerosol form and agree with conclusions reached in earlier studies of aerosol fitness (6). A clear limitation of the aerosol stability data is that we report only 1 measurement of the 16-h time point; future studies need to repeat these findings before any definitive conclusions are reached. Aerosol transmission of SARS-CoV-2 may be a more important exposure transmission pathway than previously considered (7)." "Accordingly, our study results provide a preliminary basis for broader recognition of the unique aerobiology of SARS-CoV-2, which might lead to tractable solutions and prevention interventions."
Schuit et al. (Jun 11 2020) "Airborne SARS-CoV-2 Is Rapidly Inactivated by Simulated Sunlight"	"Environmental exposures, such as sunlight, may have significant effects on viability of SARS-CoV-2." … "Results indicated 90% inactivation of virus within 20 minutes supporting indoor environments as higher risk for transmission (Schuit et al.)."	"The prolonged persistence of SARS-CoV-2 under conditions representative of indoor environments highlights the need for additional studies to better understand the potential sources of aerosols and viral load present in these settings." "The present study provides the first data on the influence of relative humidity, simulated sunlight, and suspension matrix on the survival of SARS-CoV-2 in aerosols and suggests that sunlight may be an important factor influencing the risk of aerosol transmission of disease. These data, in conjunction with studies on the epidemiology of COVID-19, aerosol sampling studies in clinical settings, and studies on the infectious dose of SARS-CoV-2, may be useful to better understand the potential for this virus to spread via the aerosol route." *Note: since there is little direct sunlight indoors and most people spend 80-90% of their time indoors (before the pandemic), we have some difficulty understanding how this relates the topic at hand? The author quoted seems to take the possibility of aerosol transmission as a given.*
Secondary attack rates and epidemiologic reports are not consistent with airborne spread:		
World Health Organization (WHO). Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19): 16-24 February 2020 [Internet]. Geneva: World Health Organization; 2020	"A report from the WHO China Joint Mission on COVID-19 summarizing 75,465 cases indicates that airborne spread has not been reported (WHO)." "The absence of significant clusters in non-household settings suggests that	"Airborne spread has not been reported for COVID-19 and it is not believed to be a major driver of transmission based on available evidence; however, it can be envisaged if certain aerosol-generating procedures are conducted in health care facilities." "**D. Knowledge Gaps**

	the mode of COVID-19 transmission is not airborne."	Knowledge gaps and key questions to be answered to guide control strategies include: **Modes of Transmission:** o Role of aerosol transmission in non-health care settings"
Burke et al (Feb 26 2020) "Active Monitoring of persons exposed to patients with confirmed COVID-19—United States, January–February 2020"	"active follow-up of 445 close contacts to the first ten cases of COVID-19 in the United States described two cases of secondary transmission only to close household contacts."	"However, despite intensive follow-up, no sustained person-to-person transmission of symptomatic SARS-CoV-2 was observed in the United States among the close contacts of the first 10 persons with diagnosed travel-related COVID-19."
Bi et al., Cheng HY et al., Li W et al., Wang Y et al.	"Epidemiological COVID-19 transmission studies of thousands of secondary household contacts have identified attack rates between 7% and 23%. Non-household close contacts have secondary attack rates <1% (Bi et al., Cheng HY et al., Li W et al., Wang Y et al.). The limited transmission to contacts outside the household setting suggests that the mode of COVID-19 transmission is not airborne."	*It is interesting to note that most of these studies occurred when lock-down and social isolation requirements were in place, thus severely limiting any possibility of non-household contacts, in fact two of the four studies cited studied only family members. A recent review (Madwell et al. Aug 1) of papers up to July 29 reporting household secondary attack rates found 40 papers from various countries thus raising the question as to why these 4 were selected?* *The studies by Li et al & Wang et al, only studied household contacts – not sure how those studies provide evidence for non-household contacts* *Bi et al. found an 11.2% secondary attack rate among household contacts and 0.9% among non-household contacts, however, over 60% of the total contacts were household and if one compares the amount of time spent with non-household contacts (i.e. a minimum of 15 minutes) to the amount of time spent with household contacts, one can easily imagine spending more than 10 times of your contact time (e.g. >150 minutes) with household members as opposed to non-household contacts especially during lock-down conditions.* *In another study not included, Liu et al (May 18) looking at 11,580 contacts of 1361 cases between Jan 10 – Mar 15, calculated secondary attack rates by spouse – 23.3%; non-spouse family members – 10.6%; close relatives – 7.0%; other relatives – 4.1%; social activity contacts – 1.3%. Liu et al. also looked at contacts from different modes of transportation: flight – 0.8%; train – 1.2%; other public transportation – 2.1%; private care – 4.2%; "Dream Cruises" – 9.5%.*

		Cultural factors also play a role, all the contact tracing papers were from China and Taiwan – an Italian paper (Fateh-Moghadam et al (Jul 29)) calculated the following secondary attack rates: cohabitant – 14.1%; non-cohabitant (friend/family) – 12.9%; work colleague – 15.8%; other 9.0%.
Rocklöv et al (Feb 24 2020) "COVID-19 outbreak on the Diamond Princess cruise ship - estimating the epidemic potential and effectiveness of public health countermeasures" *Barber et al (Jul 30 2020) "The basic reproduction number of SARS-CoV-2 - a scoping review of available evidence"*	"The reproductive number (R_0) is less suggestive of airborne spread— airborne infections tend to have a higher R_0. For example, in a systematic review (Guerra et al.) the R_0 for measles in the pre-vaccine era was 6.1-27.0; compared to the range of R_0 (2-3) reported for COVID-19 (Park et al.)."	*"The R_0 was 14.8 initially and then R_0 declined to a stable 1.78 after the quarantine and removal interventions were initiated." Rocklöv et al (Feb 24 2020)* *"A total of 20 R_0 for SARS-CoV-2 estimates were extracted from 15 studies. There was substantial variation in the estimates reported. Estimates derived from mathematical models fell within a wider range of 1.94-6.94 than statistical models which fell between the range of 2.2 to 4.4." Barber et al (Jul 30 2020)* *Interestingly the upper range of these estimates overlaps with the lower range of the measles estimates*
Studies have not consistently detected virus in air samples:		
Zhou et al. (May 26) *see above*	"Studies have not consistently detected virus in air samples"	*Absence of evidence fallacy – Zhou et al. (May 26) see comments above – other studies are missing*
Cheng et al (Feb 17 2020) "Escalating Infection Control Response to the Rapidly Evolving Epidemiology of the Coronavirus Disease 2019 COVID-19 due to SARS-CoV-2 in Hong Kong"	"Studies have not consistently detected virus in air samples" "Cheng V et al. sampled air at a high flow rate 10 cm from the chin of symptomatic and asymptomatic patients (n=6). No viable virus was detected by culture from collected air samples"	*8 air samples were taken in an hour 10 cm from the chin of a patient with a mild case of COVID-19 inside an AIIR room (12 air changes per hour (ACH)) – no virus was detected in the 8 samples with 1000 L of air sampled at a rate of 180 L/min*
Ong et al (Apr 28 2020) "Air, Surface Environmental, and Personal Protective Equipment Contamination by Severe Acute Respiratory Syndrome Coronavirus2 (SARS-CoV-2) From a Symptomatic Patient" Chia et al (Apr 1 2020) "Detection of Air and Surface Contamination by Severe	"Studies have not consistently detected virus in air samples" "Chia et al., an extended study of Ong et al., detected genetic material of SARS-CoV-2 by PCR in the air within 1 m from patients in two of three airborne infection isolation rooms."	*Ong et al. sampled 150-300 L of air in 10 samples that could not detect any virus.* *The follow-up study (Chia et al) found virus in 2 of 3 samples collected in samples of 5000+ L of air in rooms with 12 ACH* "The difficulty in culturing virus from air samples arises from low-virus concentrations, as well as the compromised integrity of the virus due to air sampling stressors." (Chia et al)

Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) in Hospital Rooms of Infected Patients"		
Faridi et al (Mar 31 2020) "A field indoor air measurement of SARS-CoV-2 in the patient rooms of the largest hospital in Iran"	"Studies have not consistently detected virus in air samples"	*Faridi took 10 air samples of 72 L and could not detect any virus – they suggested that perhaps the volume collected was too small to detect any virus. Carbon dioxide measurements taken simultaneously show concentrations between 360-505 ppm suggesting very high air exchange rates*
Wu et al (2020) "Environmental contamination by SARS-CoV-2 in a designated hospital for coronoavirus disease"		*Wu et al. took 44 samples; the authors did not give any details of the methods, but suggested sampling volume may have not been sufficient to detect any virus.*
Santarpia et al (Mar 26 2020) "Transmission Potential of SARS-CoV-2 in Viral Shedding Observed at the University of Nebraska Medical Center" *Santarpia et al (Jul 21 2020) "The Infectious Nature of Patient-Generated SARS-CoV-2 Aerosol"* *Lednicky et al (Aug 4 2020) "Viable SARS-CoV-2 in the air of a hospital room with COVID-19 patients"*	"Santarpia et al. was unable to culture virus from air samples collected outside of patient rooms."	*In their first study this was the case, but since then Santarpia et al have done a second study in which they were able to culture the virus from air samples taken around patients* *Lednicky et al also were able to culture virus collected from air samples*
Guo et al (Apr 12 2020) "Aerosol and Surface Distribution of Severe Acute Respiratory Syndrome Coronavirus 2 in Hospital Wards, Wuhan, China, 2020"	"Another study detected SARS-CoV-2 by PCR in 35% (14/40) air samples in the intensive care unit (ICU) and 12.5% (2/16) air samples on the general ward where patients with COVID-19 were managed. 15/16 PCR positive air samples were from within 2 m of the patients, with 1/8 samples positive at 4 m away (Guo et al.)."	*ICU rooms had 16 air exchanges per hour (12 outdoor ACH) and general ward rooms had 12 air exchanges per hour (8 outdoor ACH) i.e. ventilated at a much higher rate than most North American hospitals*
Liu et al (Jun 2020) "Aerodynamic analysis of SARS-CoV-2 in two Wuhan hospitals"	"Liu Y, Ning Z, Chen Y, Guo M, Liu Y, Gali NK, et al. Aerodynamic analysis of SARS-CoV-2 in two Wuhan hospitals. Nature. 2020;582(7813):557-60"	*– 21 of 30 air samples positive.* "Although we have not established the infectivity of the virus detected in these hospital areas, we propose that SARS-CoV-2 may have the potential

	Listed in bibliography but not referred to in the text ??	to be transmitted through aerosols. Our results indicate that room ventilation, open space, sanitization of protective apparel, and proper use and disinfection of toilet areas can effectively limit the concentration of SARS-CoV-2 RNA in aerosols."
Long distance spread is uncommon:		
Lu et al (Apr 2 2020) "COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020" *Li et al (Apr 23 2020) "Evidence for probable aerosol transmission of SARS-CoV-2 in a poorly ventilated restaurant"*	"While this article is often used to support airborne transmission of COVID-19, there is more evidence to support transmission via respiratory droplets:" *PHO review: "A weakness of this report is that the authors did not conduct any aerodynamic testing to support their hypothesis. In addition, the authors focused on potential droplet transmission at the restaurant and did not explore other possibilities, such as indirect transmission of fomites."*	"We conclude that in this outbreak, droplet transmission was prompted by air-conditioned ventilation. The key factor for infection was the direction of the airflow." … "Our study has limitations. We did not conduct an experimental study simulating the airborne transmission route." *Li et al (Apr 23 2020):* *"We collected epidemiological data, obtained a video record and a patron seating-arrangement from the restaurant, and measured the dispersion of a warm tracer gas as a surrogate for exhaled droplets from the suspected index patient. Computer simulations were performed to simulate the spread of fine exhaled droplets. We compared the in-room location of subsequently infected cases and spread of the simulated virus-laden aerosol tracer. The ventilation rate was measured using the tracer decay method.* *…* *In summary, our epidemiologic analysis, onsite experimental tracer measurements, and airflow simulations support the probability of an extended short-range aerosol spread of the SARS-CoV-2 having occurred in the poorly ventilated and crowded Restaurant X on January 24, 2020. Specifically, although close contact and fomite exposure may play a major role in the transmission of SARS-CoV-2, extended short-range aerosol transmission of the virus is possible in crowded and poorly ventilated enclosures. Our study suggests that it is crucial to prevent overcrowding and provide good ventilation in buildings and transport cabins for preventing the spread of SARS-CoV-2 and the development of COVID-19."*
Schwartz et al (Apr 14 2020) "Lack of COVID-19 transmission on an international flight"	"The minimal transmission to passengers seated nearby cases who have travelled on airplanes does not support an airborne transmission route of COVID-19 (Schwartz et al., Chen et al., Yang N. et al.).	"In our investigation, transmission may have been mitigated by mild symptoms and masking during the flight. However, the lack of secondary cases after prolonged air travel exposure supports droplet transmission, not airborne, as the likely route of spread of the COVID-19."
Chen et al (Mar 25 2020) "Potential transmission of SARS-CoV-2 on a flight		"A total of 16 COVID-19 patients were diagnosed among all passengers; the overall attack rate was 4.8%."

from Singapore to Hangzhou, China - An epidemiological investigation"		"One passenger without an epidemiological history of exposure before boarding developed COVID-19. During the flight, he was seated near four infected passengers from Wuhan for approximately an hour and did not wear his facemask correctly during the flight." "COVID-19 transmission may have occurred during the flight. However, the majority of the cases in the flight-associated outbreak could not be attributed to transmission on the flight but were associated with exposure to the virus in Wuhan or to infected members in a single tour group."
Yang et al (Mar 30 2020) "In-flight Transmission Cluster of COVID-19 - A Retrospective Case Series"		"…we believe that the most plausible index case resulting transmission of SARS-CoV-2 in the other nine passengers was patient 1, the 45-year-old man from Wuhan, who had onset of fever during this flight."
Zhang et al (Jun 1 2020) "Transmission of SARS-CoV-2 on Aircraft"		"*We screened 4492 passengers and crew with suspected COVID-19 infection, verified 161 confirmed cases (mean age 28·6 years), and traced two confirmed cases who may have been infected in the aircraft. The overall attack rate was 0·14‰ (95% CI 0-0·34‰)."* *"We found that the universal use of face masks on the flight, together with the plane's ventilation system, likely prevented all secondary cases of COVID-19*."

Section on AGMPs		
Booth et al (2003) "Clinical Features and Short-term Outcomes of 144 Patients With SARS in the Greater Toronto Area" *McDonald et al (2004) "SARS in Healthcare Facilities, Toronto and Taiwan"* *Booth et al (2005) "Detection of airborne severe acute respiratory syndrome (SARS) coronavirus and environmental contamination in SARS outbreak units"*	"During the SARS outbreak in 2003, infections disproportionately occurred among healthcare workers, with those involved in aerosol-generating procedures and manipulation of the airway (i.e. at the time of intubation) at greatest risk (Booth CM et al.)." "Iinfected healthcare workers were no less likely to contract SARS while wearing an N95 (vs. surgical mask), suggesting that it was most likely doffing (droplet/contact) where transmission occurred (Smith et al.)."	"Seventy-three patients (51%) were health care workers (nurses, respiratory therapists, physicians, radiology and electrocardiogram technicians, housekeepers, clerical staff, security personnel, paramedics, and research assistants)." *The word aerosol is not used in the paper and intubation is mentioned once but not in relation to exposures.* *"Experiences in Toronto (5), Taiwan (4), and globally (9) indicate that the primary mode of SARS transmission is through direct contact and respiratory droplets. However, the cluster of SARS cases in Toronto healthcare workers after the intubation of a patient (10), as well as other reported superspreader events, suggest the possibility of limited airborne transmission under certain circumstances." McDonald et al (2004)*

Ofner et al (2003) "Cluster of Severe Acute Respiratory Syndrome Cases Among Protected Health-Care Workers --- Toronto, Canada, April 2003" *Ofner-Agostini et al (2006) "Cluster of Cases of Severe Acute Respiratory Syndrome Among Toronto Healthcare Workers After Implementation of Infection Control Precautions - A Case Series"* *Seto et al (2003) "Effectiveness of precautions against droplets and contact in prevention of nosocomial transmission of severe acute respiratory syndrome (SARS)"* *Loeb et al (2004) "SARS among critical care nurses, Toronto"*		*"During the Toronto outbreaks of SARS, we investigated environmental contamination in SARS units, by employing novel air sampling and conventional surface swabbing." …* *"These data provide the first experimental confirmation of viral aerosol generation by a patient with SARS, indicating the possibility of airborne droplet transmission, which emphasizes the need for adequate respiratory protection, as well as for strict surface hygiene practices." …* "Confirmation that the SARS virus can be shed into the air of a patient room will guide the response to any future SARS outbreaks." *Booth, Henry, Low, McGeer et al. (2005)* *"The respirators used in hospital A, although compliant with Canadian public health recommendations, were not NIOSH-approved. In addition, at the time these exposures occurred, fit testing was not recommended by Canadian public health authorities; such testing has been mandated in the United States since 1972." Ofner et al (2003)* *"HCWs wore N95 masks or respirators (or their equivalents) approved by the NIOSH, although the equipment was not fit tested until near the end of the outbreak (ie, after the study period)." Ofner-Agostini et al (2006)* *Seto et al (2003)" That use of masks and hand-washing was associated with non-infection, and that no staff became infected when they used all four measures, suggest that precautions against droplets and contact are adequate for prevention of nosocomial SARS, where no aerosolisations are expected."* *The four measures were: masks (N95 or surgical but not paper), gloves, gowns & hand-washing* *Loeb, McGeer, Henry et al (2004) "When we compared use of N95 to use of surgical masks, the relative SARS risk associated with the N95 mask was half that for the surgical mask; however, because of the small sample size, the result was not statistically significant. Our data suggest that the N95 mask offers more protection than a surgical mask."*
OAHPP (PHO). "COVID-19 - What we know so far about…the risks to health care workers." Toronto, ON: Queen's Printer for Ontario; 2020.	"More information on what is currently known about COVID-19 and the risks to healthcare workers can be found in the	*This document is dated Feb 27, 2020, before any Canadian HCWs were known to be infected and hasn't been updated since and so does not discuss the 6500+ HCWs infected in Ontario*

	WWKSF document on the Risks to Health Care Workers."	

Evidence Supporting Droplet Transmission		
World Health Organization (WHO). Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19): 16-24 February 2020 *Diagnosis and treatment plan of Corona Virus Disease 2019 (6th edition)*	"A report from the WHO China Joint Mission on COVID-19 summarizing 75,465 cases indicates that airborne spread has not been reported (WHO). … The absence of significant clusters in non-household settings suggests that the mode of COVID-19 transmission is not airborne."	"**Routes of transmission** COVID-19 is transmitted via droplets and fomites during close unprotected contact between an infector and infectee. Airborne spread has not been reported for COVID-19 and it is not believed to be a major driver of transmission based on available evidence; however, it can be envisaged if certain aerosol-generating procedures are conducted in health care facilities." (page 8, WHO (Feb 28 2020) - Report of the WHO-China Joint Mission) *"**2.2. Route of transmission*** *COVID-19 is mainly transmitted by droplets and contact. Aerosol transmission is possible when people have prolonged exposure to high concentrations of aerosols in relatively closed spaces."* *From the: Diagnosis and treatment plan of Corona Virus Disease 2019 (6th edition), released mid-February two weeks before the Joint Commission's Report was released widely reported in the media (especially in China)* *NOTE: "Absence of evidence" fallacy – they were also in severe lockdown making it hard to have non-household contacts*
European Centre for Disease Prevention and Control (ECDC). "Risk assessment: outbreak of acute respiratory syndrome associated with a novel coronavirus, China: first local transmission in the EU/EEA – third update"	"The majority of COVID-19 cases have been linked to person-to-person transmission through close direct contact with someone with respiratory symptoms"	"WHO's interim guidance recommends placement of suspected and confirmed cases in single rooms, implementation of contact and droplet precautions, and airborne precautions when performing aerosol generating procedures or interventions [43-45]. Although there is no evidence of airborne transmission so far, ECDC recommends a cautious approach for all patient contacts, with placement of patients in airborne isolation rooms with negative pressure and use of FFP2 or FFP3 respirators with appropriate fit testing."
Imai N, Cori A, Dorigatti L, Baguelin M, Donnelly CA, Riley S, et al. "Report 3: Transmissibility of 2019-nCoV"	"Current evidence suggests that the primary mode of transmission of COVID-19 is through direct contact from	*there is no mention of word "droplet" at all in this report ??*

Schneider E, Bermingham A, Pebody R, Watson JM. "SARS, MERS, and other coronavirus infections." In: Heymann DL, editor. Control of communicable diseases manual. 20th ed. (2016)	respiratory droplets that have the potential to be propelled for varying distances"	*Does not mention COVID-19, only SARS and MERS. Experts are still disputing whether SARS and MERS have aerosol transmission*
Wilson et al (Apr 16 2020) – "Airborne transmission of severe acute respiratory syndrome coronavirus-2 to healthcare workers - a narrative review"		"Several studies of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) support aerosol transmission, and 1 study documented virus at a distance of 4 meters (≈13 feet) from the patient. Moreover, evidence suggests that infections cannot neatly be separated into the dichotomy of droplet versus airborne transmission routes. Available studies also show that SARS-CoV-2 can be detected in the air, and remain viable 3 hours after aerosolization. The weight of combined evidence supports airborne precautions for the occupational health and safety of health workers treating patients with COVID-19." *NOTE: the conclusions of this reference are totally opposite of what the PHO is stating when they reference this study ??*
(e.g., Burke et al., Chan et al., ECDC, Pung et al.)	"The majority of COVID-19 cases have been linked to person-to-person transmission through close direct contact with someone with respiratory symptoms"	"Our findings are consistent with person-to-person transmission of this novel coronavirus in hospital and family settings, and the reports of infected travellers in other geographical regions." (Chan et al.) "Therefore, direct transmission could be possible by contact or indirect transmission (eg, via fomites and shared food)." Pung et al. *NOTE: see Chen et al (Mar 23) above – close contact does not exclude short-range airborne transmission*
(Huang R et al., Tong et al., Yu P et al.)	"or close contact with a case in the incubation period who was later confirmed to have COVID-19"	*Not sure why transmission during incubation period exclusively supports droplet transmission?*
(Arons et al., Chau et al., Wei et al.).	"High viral loads have been identified in individuals who were asymptomatic or pre-symptomatic"	*Not sure why high viral loads in exclusively a- or pre-symptomatic persons supports droplet transmission?*
Guo et al. Bahl et al (Apr 16)	"Respiratory droplets have been shown to be propelled up to 2 m (Schneider et al.) and in one study was found on the floor up to 13 ft (or 4 m) away from the patient (Guo et al.). A systematic review	*Not sure why droplets travelling 8 m supports droplet transmission?* "The weight of combined evidence supports airborne precautions for the occupational health and safety of health workers treating patients with COVID-19." Bahl et al (Apr 16)

	of studies assessing the horizontal distance travelled by respiratory droplets found that droplets can travel more than 2 m and up to 8 m (Bahl et al.).”	*NOTE: again, the conclusions of this reference are totally opposite of what the PHO is stating when they reference this study ??*