TRANSMITTED BY: EMAIL

March 19, 2020

REA Project No. 16769 ***Please quote our file number in any communiques***

Ms. Val Avery
President
Health Sciences Association of British Columbia
180 East Columbia Street
New Westminster, BC V3L 0G7

Dear Ms. Avery,

Subject: Respiratory Protection for Health Workers Caring for COVID-19 Patients

---

This letter is provided in response to your e-mail to me on March 10 2020, in which you asked that I undertake the following work for HSABC and NUPGE:

- Review the report that I authored for HSABC and NUPGE, dated September 9 2009, entitled *Advisory Report for the Health Sciences Association of British Columbia and the National Union of Public and General Employees on Respiratory Protection During Care of Influenza Patients*, and update any relevant science contained in the report.

- Provide recommendations regarding the appropriate use of personal protective equipment (PPE) specific to COVID-19.

- Comment on best practices in scenarios given worldwide shortages of supply. Specifically, if N95 respirators are the protection of choice at a minimum, but are in short supply globally, what is the best recommended protection for healthcare workers.

You indicated that this information was requested in view of the range of recommendations of public health agencies in Canada and internationally with respect specifically to respiratory protection, and the position statement on that subject published February 19 2020 by the Canadian Federation of Nurses Unions.

Review of the Relevant Literature

I reviewed the current published on-line advice for health care workers provided by the British Columbia Provincial Health Services Authority[1], Health Canada[2], Public Health Ontario[3], and United States Centers for Disease Control[4] with respect to respiratory protection recommendations for health workers providing care to persons diagnosed with COVID-19 infection. Using www.archive.org, I also reviewed the advice these organizations provided prior to their latest posted editions on the internet.

To update the state of science since 2009 with respect to aerosol transmission for influenza and coronaviruses, and the utility of respiratory protection, I conducted a literature search using the University of Toronto on-line library system, and the public internet. My search focused on studies published from 2009 to date pertaining to aerosol transmission, and the effectiveness of N95 respirators (hereafter simply N95s) versus surgical masks (hereafter SMs), specifically in a clinical care context.

I retrieved approximately 150 documnets and upon review considered 84 to be relevant to the questions of interest to HSABC and NUPGE. I limited my focus to papers that were concerned with either influenza, or coronaviruses, as opposed to other respiratory viruses or non-virus microbials.

Appended hereto is an indexed and alphabetically coded list of those papers[5]. The reasons for the alphabetical coding will be explained below.

---

[1] http://www.bccdc.ca/health-info/diseases-conditions/covid-19/common-questions, accessed March 16 2020.

[2] https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/health-professionals.html, accessed March 16 2020.

[3] https://www.publichealthontario.ca/-/media/documents/ncov/updated-ipac-measures-covid-19.pdf?la=en, accessed March 16 2020.

[4] https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fcoronavirus%2F2019-ncov%2Fhcp%2Finfection-control.html, accessed March 16 2020.

[5] Time did not permit and this letter should not be misconstrued as an attempted meta-analysis or systematic review of the literature. My use of the selected studies is to describe, in an advisory context, the evidentiary basis supporting aerosol transmission as a mode for viruses causing serious deep lung infection.

Relevance of the 2009 Report Entitled *Advisory Report for the Health Sciences Association of British Columbia and the National Union of Public and General Employees on Respiratory Protection During Care of Influenza Patients* to the Current COVID-19 Situation

All of the content of the 2009 report continues to be accurate and consistent with the literature that has been produced from 2009 to date on the subjects of interest. A large amount of research has been conducted in the past decade, which has largely strengthened the analysis and conclusions contained ithe 2009 report. The discussion below elaborates on the reasons for this being the case.

The "Controversy" Over Aerosol Transmission

As you will appreciate, arguments over the need for and benefit of using N95 or better respiratory protection over SMs are based on views with respect to the relative contribution of aerosol person-to-person transmission in relation to droplet and contact transmission, and the relative effectiveness of both types of airway protection. Aerosol transmission of influenza and coronaviruses is often said to be "controversial". This seems an odd characterization, as there is a substantial quantity of high-quality research literature that indicates it is plausible and probable. In fact, many authors have gone as far as suggesting that it is likely to be a dominant mode for person-to-person transmission of influenzas[6]. Juxtaposed against this is a comparatively sparse knowledge base in support of droplet and contact transmission for these particular types of viral infections.

My consideration of the literature referenced herein makes it difficult for me to comprehend the basis for any scientific "controversy". The science strongly points to the likelihood of aerosol transmission of influenza and coronaviruses[7] as a significant mode of person-to-person infection. At the same time, many public health authorities persist in discounting aerosol transmission while ascribing to theories of droplet and contact as dominant modes of transmission, despite the existence of comparatively little scientific support. Indeed, the British Columbia Provincial Health Services Authority web site asserts with respect to COVID-19 that "the virus is not known to be airborne (e.g. transmitted through the particles floating in the air)…". The latter statement is true in that COVID-19 ***is not known*** to be transmitted by aerosols, but the missing qualification is ***that this is only because it has not yet been studied***. However, studies carried out on many varieties of influenza and coronaviruses have demonstrated conditions necessary for aerosol transmission, and thus far, COVID-19 *is not known* to be expelled from patients, nor transmitted in the atmosphere, nor to induce respiratory infection *in ways*

[6] References 3, 18, 36, 37, 51, 66, 68, 75.

[7] For convenience in this paper I use the terms "influenza" and "coronaviruses" to encompass evidence that has been developed in relation to a variety of different types and strains of both classes of viruses, and the similarities in behavior and characteristics should not be overly generalized.

that markedly differ from seasonal influenza or coronaviruses. In other words, for COVID-19, we have neither specific positive nor negative evidence with respect to modes of transmission, but we have substantial evidence in respect of the influenza and coronaviruses responsible for several global and regional outbreaks over the past twenty years.

Conditions Necessary for Aerosol Transmission, and Research Demonstrating Same

Figure 1 is provided to illustrate the set of conditions necessary for aerosol transmission of a viral infection, and to help organize findings from the research literature and expert opinion on the subject. The discussion below summarizes the now a considerable body of research showing that these conditions are present and operate in practice.

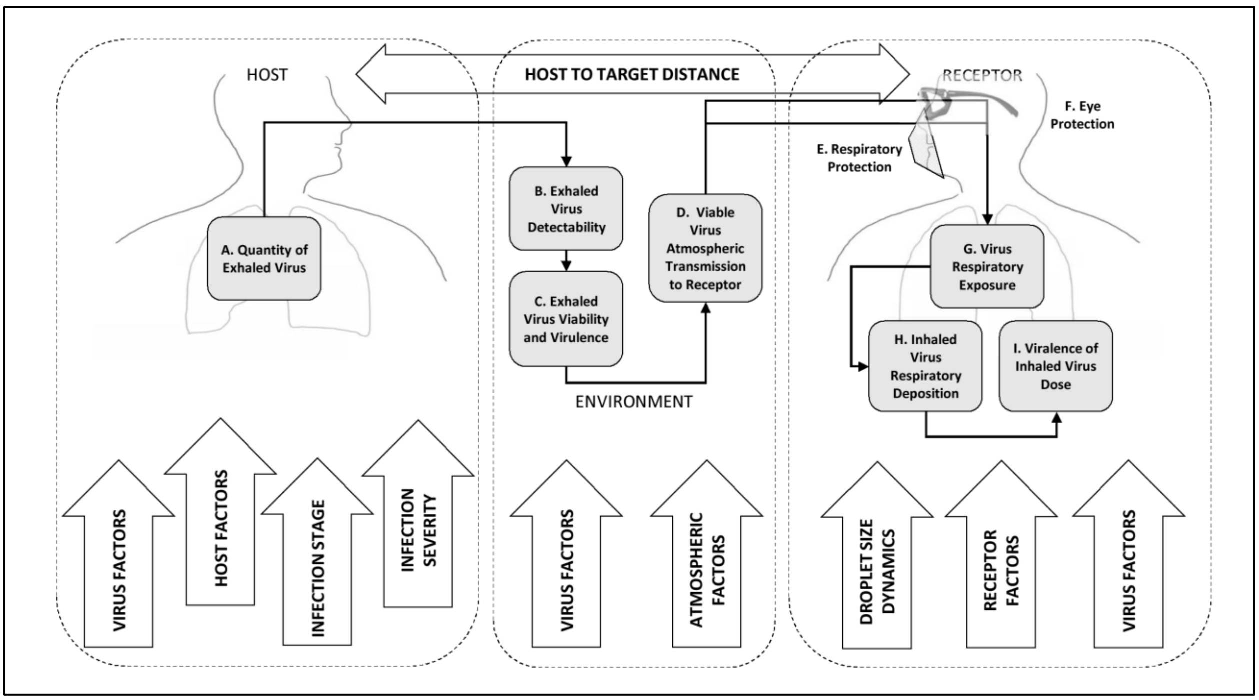

Figure 1 - Conditions Necessary for Aerosol Transmission of Deep Lung Viral Infection

First, the infected host must expel viruses from the respiratory tract (A). Many studies (indicated by the letter "A" in the reference list) have consistently demonstrated that humans constantly expel very small (mostly <4 um) aerosol droplets simply by breathing. These are believed to be generated in the alveoli during inhalation[8]. The volume of these fine droplets expelled also increases substantially by talking, but

[8] Reference 25.

the source and mechanism for formation of speech-related droplets is not understood, but hypothesized to involve the pharyngeal region. The extent of discharge during breathing is influenced by a variety of factors specific to the virus, host, infection stage and severity.

Second, if aerosol transmission is to occur, it is necessary for exhaled viruses to be detectable in the air proximate to and distant from the host (B). Many studies (indicated by the letter "B" in the reference list) have demonstrated through polymerase chain reaction (PCR) analysis of collected air samples that this is the case in the atmosphere near persons infected with influenza viruses. Viruses are initially encased in the liquid droplets expelled by ordinary breathing, and dry to droplet nuclei within seconds of contact with the atmosphere. The concentrations of exhaled viruses vary considerably between individuals and as a function of the stage of infection. They also diminish with distance between the host and receptor in ventilated spaces. There is also limited case study evidence that some individuals shed viruses when asymptomic or presymptomatic[9]. Concentrations in the air depend on the distance from the host, atmospheric temperature and humidity, and factors specific to the virus. Contrary to common assumptions (and information posted on the BC Provincial Health Services Authority web site), it does not appear to be that case that persons with deep lung viral infections expel more viruses by coughing[10] than by simply breathing. Evidence suggests that larger droplets expelled by coughing originate in the upper respiratory tract and mouth, which are not sites of infection for influenza or coronavirus and are not generally virus laden in persons with deep lung infections. It appears that breathing accounts for a very high percentage of the total viral shedding by infected persons.

The earliest studies showing expelled airborne viruses employed PRC analysis to detect viral RNA, but this analytical method does not confirm the existence of viable viruses. To address this uncertainty, it was necessary to verify that viruses collected from the atmosphere could reproduce, and presumably cause infection (C). Many subsequent studies (indicated by the letter "C" in the reference list) demonstrated that host expelled viruses collected in the air produce plaques, and therefore are presumed to be infectious.

Fourth, it is necessary for airborne viruses to remain viable for a long enough period to travel through the atmosphere to a receptor (D). Not surprisingly, there have been no reported studies evaluating atmospheric survival for COVID-19. However, there have been studies conducted on influenza and other coronaviruses that indicate airborne viability for an hour or longer in the atmosphere, and

---

[9] Reference 67.

[10] References 22, 24, 39, 56.

airborne translocation from hosts to receptors. These studies are indicated by the letter "D" in the reference list.

The subject of airway and eye protection (items E and F in Figure 1) will be discussed below under a separate heading.

With respect to inhalation exposure (G in Figure 1), viable droplet nuclei viruses are in the respirable size range, readily inhalable via the nose and mouth, and not filtered out by aerodynamic or mechanical processes during travel between the upper airway and deep lungs. With respect to the locus of deposition in the lungs (H in Figure 1), a particle of 1 um or smaller behaves aerodynamically in the respiratory tract more like a gas than a solid. This means that a during the inhalation and exhalation cycle a fraction of inhaled viral material would be deposited by contact with the mucous lining of the tissue, and a fraction would remain suspended in the air space of the lungs and then exhaled without deposition. However, 1 um inhaled particles will grow in size during passage down the airway due to coalescence with water vapour, causing the resulting larger particle population to more efficiently deposit in the lower bronchi and alveoli[11]. Studies addressing exposure and deposition are indicated by the letters "G" and "H" in the reference list.

Critics of the science summarized to this point might say that evidence demonstrating the potential for a receptor to inhale host-expelled viable viruses does not *prove* that those viruses, once inhaled by a receptor, cause infection (although that is, in essence, the basic assertion of the widely held droplet theory of transmission). The differences between droplet and aerosol exposure, skeptics might say, is that the dose of viable viruses experienced by close proximity exposure to a shower of droplets is enormous, while the atmospheric virus concentration produced by aerosol respiratory emissions is too low to cause infection; or alternatively that most of the aerosolized viruses would be rendered non-viable by aging, whereas the cough droplets are "fresh" when showered onto the receptor. On those points, it is worth noting that the evidence simply does not support the contention that in deep lung infections coughing produces higher concentrations and total quantities of virus emissions as compared to aerosol emissions from breathing – the evidence indicates that the opposite is the case. But more importantly, in terms of positively demonstrating infection of inhaled virus aerosols (I in Figure 1), studies using inactivated influenza viruses and human volunteers have shown that exposure to aerosolized viruses initiate measurable cellular and biochemical immune responses. There is also evidence suggesting the infectious dose by inhalation of aerosolized viruses is considerably lower than the infectious dose for exposure by droplets or contact. Studies supporting the capacity of low doses of aerosols to cause infection are indicated by "I" in the reference list.

[11] Reference 25.

To summarize, a large body of research using a variety of methods demonstrates that aerosol transmission up to the point of human inhalation can and does occur, via the stepwise mechanism illustrated in Figure 1. Many observational studies and animal experiments also support the conclusion that aerosol exposures lead to lower airway infection. Mathematical modelling of transmission routes in outbreaks has also advanced in the past decade, and computational analyses have led some researchers to conclude that aerosol transmission is likely to be the dominant mode of transmission, while others consider the relative contributions of different transmission modes to be influenced by a variety of variables. The research outcomes have significant implications for the choice of respiratory protection in patient care work settings.

Evidence on Respiratory and Eye Protection Against Infection in Health Care Workers

Figure 1 shows respiratory protection as item E, and eye protection as item F. Several experimental and simulated exposure studies have been undertaken to compare the degree of virus penetration through N95s versus SMs, retrospective studies have surveyed health care worker infection rates in relation to reported respiratory protection use (generally N95 or SMs versus none), and there have been at two prospective clinical trials that compared infection rates between health care workers issued N95s versus SMs. The results from these four types of studies have been inconsistent. Relevant papers are marked "E" in the reference list.

The experimental and simulated exposure studies consistently show quantitatively that N95s provide superior aerosol and droplet protection over SMs. SMs when worn by receptors provide no aerosol size fraction protection but can provide some large droplet attenuation subject to the style and manner of use affording a tight facial seal. SMs worn by patients are also beneficial in constraining the expulsion of large droplets during coughing but do not supress emissions of respiratory aerosols during breathing.

Retrospective studies comparing the use of either N95s or SMs find that the odds of infection drop markedly for N95 users, and less so for SM users, but both devices reduce infection risk when compared to no use of either type. One problem with these studies is that the filtration performance characteristics of the SMs are generally not reported, and patterns of protective device use and patient care task performance are not well tracked or reported.

The two commonly cited clinical trials[12] of health care workers who were issued either N95s or SMs found no statistically significant difference in flu infection rates between users of the two types of protection over a flu season. However, those studies did not consistently report on subjects' eye

[12] References 43, 58.

protection practices[13] (which have been shown to have a large influence on influenza infection[14]), immunization status, respirator use practices, task performance frequencies and durations, performance characteristics of the SMs, hygiene practices, nor were the studies controlled for community exposures outside the care setting. Also, given the evidence developed in the last decade regarding ongoing exhalation of viruses in aerosols by infected persons, it is reasonable to assume the health care workers in those studies were regularly exposed at times when they likely deemed it unnecessary to use either type of respiratory protection. These design limitations make it impossible to draw conclusions regarding the relative protective benefits of N95s versus SMs. At best, the clinical trial findings lead to the conclusion that respiratory protection was unlikely to have been properly used in a consistent manner by the participants.

A serious limitation associated with this entire line of respiratory protection research in health care settings is a complete lack of information regarding the actual or potential extent of the subjects' individual exposures to viruses over the duration of the study.

It is important to recognize that SMs are not intended to provide user protection against aerosol inhalation. Research on SMs has shown they vary considerably in filtration performance for various particle size fractions. Since there is no standard for performance of SMs, it raises the question as to the basis for recommendations on SM use by health care workers for viral protection.

Commentary on the Latest Advisory Positions of the Public Health Authorities for Respiratory Protection of Health Care Workers

BC Provincial Health Services Authority and Health Canada

From my review of www.archive.org, it appears that the BC Provincial Health Services Authority and Health Canada have maintained a consistent position over the past month on the circumstances where N95s versus SMs provide appropriate protection. Specifically, both agencies indicate use of SMs for routine patient interactions, and N95s only for aerosol generating medical procedures (AGMPs).

[13] In none of the studies were personnel required to wear protective eyewear. This is a significant concern with the studies as meta analyses of protective practices have found that the use of vapour protective goggles in influenza patient care is almost as protective as using an N95, and that the lowest incidences of HCW infection occur (observationally) when there is consistent use of both proper eye protection and fitted N95s. Biological studies have also determined that influenza and coronaviruses can utilize ocular epithelial tissues for reproduction, and the lacrimal duct is an efficient pathway for virus migration to the respiratory tract.

[14] References 7, 11, 15, 46

The BC Provincial Health Services Authority web site provides no information with respect to the evidentiary basis for the advice provided, other than indicating as follows:

> Currently, health experts believe that coronavirus cannot be transmitted through airborne transmission.

BC Provincial Health Services Authority made available senior medical and administrative officials for teleconferences on March 17 and 18 2020, but those conversations failed to clarify the basis for the above assertion, or what they meant by "airborne" transmission.

The basis for Health Canada's advice is similarly not reported on their web site. The closest the site gets to describing the rational is as follows:

> Current epidemiologic information suggests that limited human-to-human transmission of COVID-19 may have occurred in some reported instances where individuals were in close contact with symptomatic cases. Until more definitive information becomes available, appropriate infection prevention and control measures (contact and droplet precautions) should be implemented to prevent onward transmission of the virus.

The imprecise language seems to say that there has been limited close contact human-to-human transmission, which raises the question of how current that epidemiological information is[15].

Public Health Ontario

Ontario's position on the need for N95s has shifted during the past month from what it was for the past 7 years.

In 2013, a few years after the 2009-2010 H1N1 outbreak, the Ontario Ministry of Health published its *Ontario Health Plan for an Influenza Pandemic, dated March 2013*. In *Chapter 5: Occupational Health & Safety and Infection Prevention & Control*, the document states,

> OCCUPATIONAL HEALTH AND SAFETY & INFECTION PREVENTION AND CONTROL ACTIVITIES BEFORE SEVERITY IS KNOWN
>
> …The MOHLTC recommends Pandemic Precautions (OHS & IPAC precautions specific to an influenza pandemic) based on evidence, legislative requirements, the precautionary principle,

[15] This content on the Health Canada site was posted in late January and has not been updated as of March 16 2020.

> Ontario Public Service (OPS) values and health equity (***such as the use of fit-tested N95 respirators for workers at risk of exposure to a C/P/R[16] with influenza-like illness (ILI) or that C/P/R's environment***) (italics and bold added).

More recently, in February 2020, the Ontario Provincial Infectious Diseases Advisory Committee (PIDAC) released *Best Practices for Prevention, Surveillance and Infection Control Management of Novel Respiratory Infections in All Health Care Settings, 1st revision: February 2020*, which states the following:

> Airborne Precautions and Droplet/Contact Precautions include[17]:
> - ***A fit-tested, seal-checked N95 respirator covering the nose and mouth:***
>   - ***when entering the client/patient/resident's room***
>   - ***when within two metres of the client/patient/resident.*** (italics and bold added)
> - Eye protection when within two metres of the client/patient/resident.
> - Gloves and gown to enter the client/patient/resident's room.
> - A mask worn by the client/patient/resident when outside his or her room or the care area and hand hygiene performed on exiting the room.

The PIDAC document also emphasizes a need for the use of N95 respirators when encountering initially non-infected patients who may have been exposed to an infected patient.

With respect to non-elective AGMPs, PIDAC states[18],

> Non-elective AGMPs should be performed using processes and practices designed to avoid generating aerosols, including:
> - Perform the procedure in an AIIR[19] with the door closed, whenever possible.
> - Keep the number of people in the room during the procedure to a minimum. Have only highly experienced staff perform the procedure.
> - ***Ensure everyone wears appropriate PPE and is instructed in its use. PPE includes a fit-tested, seal-checked N95 respirator, face/eye protection, gloves, gown, and hand hygiene.*** (italics and bold added). The use of PPE extends to family members who are there on compassionate grounds.

[16] Case / Patient / Resident

[17] Page 18 of the referenced document.

[18] Page 20 of the referenced document.

[19] Air Isolated Infection Room

- Use equipment and techniques that minimize exposure to respiratory pathogens. Refer to PIDAC's *Annex B: Best Practices for Prevention of Transmission of Acute Respiratory Infection in All Health Care Settings.*

More recently in the publication entitled *Novel Coronavirus (COVID-19) Guidance for Acute Care, Version 2 – February 11, 2020*, and keeping with advice in the 2013 pandemic plan, the Ontario Ministry of Health emphasized the need for N95s for *both* health care workers *and* other workers who come into contact with patients screened positive, as shown in the excerpt below:

3. What to do if a patient screens positive at triage?

- Patients should be given a procedure mask and placed in a room with the possible, to avoid contact with other patients in door closed on arrival, where to perform hand common area of the practice (e.g., waiting rooms). Patient hygiene at point of entry.
- Staff must safely use all appropriate PPE including gloves, gown, goggles or eye protection and ***fit tested N95 respirators for clinical assessment, examination and testing***. ***Other workers in the hospital who come within the patient's environment must also use appropriate PPE as indicated above.*** (italics and bold added).

It is not clear when the Ministry of Health de-prioritized "health equity" as an organization value, but as of March 12 2020, the Public Health Ontario web site presented a changed position on the need for N95 respiratory protection, as shown in the image on the following page. Note that in the image, Public Health Ontario draws the seemingly contradictory conclusion that while "the majority of cases are linked to person-to-person transmission through close direct contact with someone who is positive for COVID-19… There is no evidence that COVID-19 is transmitted through the airborne route".

Public Health Ontario | Santé publique Ontario

TECHNICAL BRIEF

Updated IPAC Recommendations for Use of Personal Protective Equipment for Care of Individuals with Suspect or Confirmed COVID-19

March 12, 2020

Key Findings

- Given updated information on COVID-19, Droplet and Contact precautions are recommended for the routine care of patients with suspected or confirmed COVID-19.
- Airborne precautions should be used when aerosol generating medical procedures (AGMPs) are planned or anticipated to be performed on patients with suspected or confirmed COVID-19.

Background

In January 2020, when the Ministry of Health developed its first guidance for Infection Prevention and Control (IPAC) and Occupational Health and Safety (OHS) for COVID-19, there was limited information about how the novel coronavirus was transmitted and the spectrum of illness associated with infection.

Because the epidemiologic data was evolving and little was known about COVID-19, the Ministry applied the precautionary principle and initially recommended the use of N95 respirators for patient care and specimen collection/testing, as well as patient placement in an airborne infection isolation room (AIIR), where possible. This was to be reviewed as new information became available.

After two and a half months of global clinical experience and updated scientific and epidemiological evidence, routes of transmission for COVID-19 reveal the following:

- COVID-19 cases and clusters demonstrate that Droplet/Contact transmission are the routes of transmission.
- The majority of cases are linked to person-to-person transmission through close direct contact with someone who is positive for COVID-19.
- There is no evidence that COVID-19 is transmitted through the airborne route.

United States Centers for Disease Control

The CDC's advice is more detailed and specific than that of the Canadian agencies discussed above, but the CDC advice on N95 usage has shifted recently in recognition of supply constraints.

In their website updated to February 21 2020, CDC recommended fitted N95 respiratory protection and appropriate eye protection for routine care of infected patients:

- **Respiratory Protection**
  - Use respiratory protection (i.e., a respirator) that is at least as protective as a fit-tested NIOSH-certified disposable N95 filtering facepiece respirator before entry into the patient room or care area. See appendix for respirator definition.
  - Disposable respirators should be removed and discarded after exiting the patient's room or care area and closing the door. Perform hand hygiene after discarding the respirator.
  - If reusable respirators (e.g., powered air purifying respirator/PAPR) are used, they must be cleaned and disinfected according to manufacturer's reprocessing instructions prior to re-use.
  - Respirator use must be in the context of a complete respiratory protection program in accordance with Occupational Safety and Health Administration (OSHA) Respiratory Protection standard (29 CFR 1910.134). Staff should be medically cleared and fit-tested if using respirators with tight-fitting facepieces (e.g., a NIOSH-certified disposable N95) and trained in the proper use of respirators, safe removal and disposal, and medical contraindications to respirator use.
- **Eye Protection**
  - Put on eye protection (e.g., goggles, a disposable face shield that covers the front and sides of the face) upon entry to the patient room or care area. Remove eye protection before leaving the patient room or care area. Reusable eye protection (e.g., goggles) must be cleaned and disinfected according to manufacturer's reprocessing instructions prior to re-use. Disposable eye protection should be discarded after use.

The same level of respiratory protection was recommended for AGMPs:

- **Use Caution When Performing Aerosol-Generating Procedures**
  - Some procedures performed on COVID-19 patients could generate infectious aerosols. In particular, procedures that are likely to induce coughing (e.g., sputum induction, open suctioning of airways) should be performed cautiously and avoided if possible.
  - If performed, these procedures should take place in an AIIR and personnel should use respiratory protection as described above. In addition:
    - Limit the number of HCP present during the procedure to only those essential for patient care and procedural support.
    - Clean and disinfect procedure room surfaces promptly as described in the section on environmental infection control below.

On March 10 2020, CDC updated their procedural advice, as described below:

Interim Infection Prevention and Control Recommendations for Patients with Suspected or Confirmed Coronavirus Disease 2019 (COVID-19) in Healthcare Settings

Summary of Changes to the Guidance:

- Updated PPE recommendations for the care of patients with known or suspected COVID-19:

- ***Based on local and regional situational analysis of PPE supplies*** (italics and bold added), facemasks are an acceptable alternative ***when the supply chain of respirators cannot meet the demand.*** During this time, available respirators should be prioritized for procedures that are likely to generate respiratory aerosols, which would pose the highest exposure risk to HCP.
    - Facemasks protect the wearer from splashes and sprays.
    - Respirators, which filter inspired air, offer respiratory protection.
- When the supply chain is restored, facilities with a respiratory protection program should return to use of respirators for patients with known or suspected COVID-19. Facilities that do not currently have a respiratory protection program, but care for patients infected with pathogens for which a respirator is recommended, should implement a respiratory protection program.
- Eye protection, gown, and gloves continue to be recommended.
    - If there are shortages of gowns, they should be prioritized for aerosol-generating procedures, care activities where splashes and sprays are anticipated, and high-contact patient care activities that provide opportunities for transfer of pathogens to the hands and clothing of HCP.

CDC makes it clear that the advisory is a response to supply constraints, and N95s use is to continue so long as they are available. CDC does not state that the respiratory protective practice changes are based on developments in the understanding of COVID-19 disease or its transmission, in contrast to Public Health Ontario.

It is worth noting that a large number of the studies in the reference list were conducted by teams at, or with participation of research scientists from the US National Center of Occupational Safety and Health, which is part of the CDC. Given the findings of those studies as described above, it is not surprising that CDC has recommended the need for N95 in preference to SMs.

Public Health Commentaries on the State of Science on Modes of Transmission, and Basis for Policy Decisions Regarding Respiratory Protection

To date, none of the Canadian agencies discussed above have published commentaries regarding the state of science on modes of transmission for deep lung viral infections, nor how such information influences their policy decisions regarding health care worker respiratory protection. This is not only the case in respect of COVID-19, but also H1N1, MERS and SARS. CDC, by comparison, has generated an extensive body of research on the subject spanning the past decade.

It is likely the decisions of public health agencies regarding respiratory protective measures for health care workers against infectious diseases in clinical settings involve many considerations. These may include the state of knowledge with respect to effectiveness of protective measures, the conclusions they draw based on the science they consume; the apparent virulence (which seems still to be low with COVID-19); the severity of illness (which for COVID-19 similarly seems to be demographically similar to seasonal flu); the relative importance of the modes of transmission (which remain uncertain for COVID-19); the consequences to the health care system and community of health care worker illness; the costs, availability, practicality and effectiveness of use of different protective measures; anticipated impacts on public perceptions; and political considerations.

Ultimately, if or how the agencies canvassed and weighed these various factors in formulating their advice on COVID-19 respiratory protection is unknown.

Respiratory Protection for Aerosol Generating Medical Procedures

Several studies identified by the "A" and "E" labels in the reference list measured aerosol droplet output and virus output associated with AGMPs. The overall pattern of findings is that most types of AGMPs do not generate markedly higher levels of aerosols or airborne viruses in comparison to the amounts released by ordinary breathing of the patient[20]. Despite this there is considerable evidence of increased rates of health care worker infection associated with performance of variety of respiratory microbes associated with performing AGMPs[21]. However, the infection rate observational studies provide no insight into the extent of virus exposure, modes of transmission, or the relationship to personnel protection practices.

In the performance of AGMPs for SARS patients, many hospitals implemented respiratory protocols involving higher degrees of protection, such as N95s plus non-pressurized or positively pressurized hoods. The rationale for this was the observed high rate of transmission between patients and health care workers. Thus far with COVID-19 there have not been reports released by any of the public health agencies discussed above, nor in the public media, that have indicated elevated rates of patient to health care worker transmittal. Also, the COVID-19 morbidity for persons under the age of 60 has been quite low[22].

---

[20] References 21, 34, 53, 65, 73. Intubation and mechanical ventilation are reported to be procedures that have been observed to increase aerosol expulsion.

[21] References 33, 44

[22] https://www.cdc.gov/media/releases/2020/t0309-covid-19-update.html

COVID-19 Infection Risks for Health Care Workers

As discussed above, there is abundant evidence for exhalation of influenza and coronaviruses by patients with deep lung infection. Early published evidence on COVID-19 suggests that severe cases that necessitate hospitalization are due to pneumonia (a deep lung infection), and that COVID-19 also infects tissues in the mid-airway. It is therefore reasonable to conclude that patients with pneumonia are likely to exhale respirable droplets (i.e. those under 10 microns in aerodynamic diameter) containing viruses during ordinary and assisted breathing, and that productive coughing may also expel larger visible droplets (i.e. 50 microns and larger) containing viruses. In view of this, the principal concern for health care workers is the potential for exposure to respirable airborne liquid droplets that are not attenuated by SMs, during close proximity (say within 2 meters) contact with infected patients.

In terms of quantifying the potential risk to health care workers, the experience to late February 2020 in China[23] was that health care workers constituted approximately 3.8% of the identified cases[24]. A news media report from March 18 2020 in Italy indicates that health care workers constituted approximately 8% of the identified cases in that country[25]. Unfortunately, no published information is available from China or Italy with respect to infection prevention and control practices associated with the occurrence of health care worker infections, and the contribution of community exposure is similarly unknown. As such the rates from China and Italy are not necessarily indicative of what might be expected in Canada. However, it does present reason to adopt a protective stance.

It is likely that limitations in the supply of N95 or better respiratory protection will necessitate the adoption of risk-based approaches to allocation. This in turn raises the question of how to gauge the level of risk in caring for infected patients. As a starting point in answering the question, it is important to recognize that experimental and observational evidence with respect to the transmission of deep

---

[23] Reference 85.

[24] Inclusion in the case pool in China was based not only on positive test results - cases were also deemed to be COVID-19 on the basis of symptomology, and case classification criteria changed over the course of the outbreak.

[25] https://www.repubblica.it/cronaca/2020/03/18/news/coronavirus_in_vigore_il_decreto_cura-italia_aumentano_i_contagi-251584599/?refresh_ce. From the referenced URL: "The percentage of health workers infected by the coronavirus in Italy is almost double the number found in the Chinese emergency. This was reported by the Gimbe Foundation, a non-profit institution governed by private law established by the Italian group association for evidence-based medicine. Gimbe has reworked the data provided by the Higher Institute of Health and calculated that health workers infected with the new coronavirus have risen to 2,629, or 8.3 percent of the total cases. The data are up to date yesterday and the president of Gimbe, Nino Cartabellotta, notes that "the number of infected health workers is enormous. 8.3% of the total cases is more than double the percentage compared to the Chinese cohort".

lung viral infections supports the notion of there being an inhalation dose-response relationship – in other words, risk of infection increases with quantity of viral material inhaled. The factors affecting virus exposure and inhaled dose by a health care worker when caring for an infected person will include the following:

a. Quantity of virus shedding by the patient, which appears to increase with the severity of infection, and in the case of COVID-19 probably with the extent of coughing (increases exposure).
b. Performance of procedures that increase the patient's ventilation rate and explusion of both non-visible and visible droplets from the patient's airway (increases exposure).
c. Proximity of the health care worker to the breathing zone of the patient (increases exposure).
d. Frequency and duration of time in close proximity to the patient (increases exposure).
e. Number and frequency of close proximity interactions with the patient (increases exposure).
f. Extent of attenuation of large expelled droplets from the patient by having the patient wear a surgical mask (decreases exposure).
g. Extent of dilution and removal of airborne viral material by the general ventilation system of the patient room (decreases exposure)

These factors can be considered in setting priorities for allocation of respiratory protection, with the basic principle being that personnel having higher potential inhalation exposures (and hence doses) are presumed to face higher risks, and accorded higher levels of protection. For example, quick infrequent tasks in a patient room performed 2 meters away from a patient's breathing zone would contribute very little to a worker's overall potential exposure, while frequently performed longer duration tasks carried out very close to the patient would make a large contribution to the worker's overall potential exposure.

Recommendations

1. With respect to the overall suite of infection prevention and control measures for COVID-19 in health care settings, the current guidance provided by the US CDC[26] is superior to that of the other agencies discussed herein. The US CDC guidance is by far the most comprehensive, protective, and consistent with the evidence I have reviewed and described above. Several key recommendations of US CDC source cited herein merit emphasis, with further qualification based on the dose-response considerations described above:
    a. Where possible health care workers should use N95 respiratory protection when providing care for COVID-19 patients.

[26] https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html

   b. Where it is anticipated that logistical constraints may cause supplies of N95 disposable respirators to run out, prioritize allocation based on assessment of the extent of potential exposure and risk.
   c. Use SMs if N95s become unavailable due to supply constraints but resume use of N95s if and when possible.
   d. When performing AGMPs, ensure that room general ventilation operation is optimized to maximize air change rates, and that the full suite of protective equipment listed by US CDC is utilized.
   e. Eye protection that provides protection from both visible and non-visible droplets (i.e. vapour and splash protection goggles) should be used in conjunction with whatever manner of respiratory protection is utilized.

2. While not explicitly addressed in the US CDC guidance, an additional measure to reduce shedding by patients is to require wearing of SMs by patients to the extent practical. If extended wearing by patients is not practical, having patients don SMs prior to and during close proximity interactions with health care workers would confer theoretical protection against large droplets that the patient could expel by coughing. Delaying entry into ventilated patient rooms for sufficient time to allow several theoretical air changes would also afford further aerosol exposure risk reduction.

3. Health care institutions should perform qualitative aerosol exposure risk assessments, considering the aforementioned risk factors, and make decisions with respect to respiratory protective equipment allocations based on the outcomes of the analysis.

4. With respect to the potential constraints on supply of disposable N95 respiratory protection, the United States National Academies of Science, Engineering and Medicine[27] have recommended the implementation of programs in health care workplaces for safe utilization of re-usable style respirators, similar to practices in other workplace sectors. This may present acceptance challenges common to the adoption of any innovation in organizations, but in the short term would mitigate supply chain limitations if re-usable N95 (or better) respirators are more readily available than N95 disposables. In the long run this might be the best and most sustainable solution for outbreak scenarios.

5. As part of the risk assessment described in recommendation 2., consideration should be given to identifying occupations in health care settings where persons could be issued re-usable N95

[27] References 27, 50.

masks in preference to disposable N95s. For example, personnel working in housekeeping, environmental services, SPD, physical plant, etc. who periodically perform tasks in patient rooms might be good candidates for issuance of re-usable N95s, as it is likely to be more practical for those occupational groups to clean and maintain re-usable masks as compared to front line treatment and care personnel. This would extend the supply of N95 disposables.

Let me know if I can be of further assistance in respect of the matters discussed herein.

Yours truly,

Dr. John H Murphy MHSc MBA PhD ROH CIH MACE
President – Resource Environmental Associates Limited
Adjunct Professor – Dalla Lana School of Public Health, University of Toronto

References

1	Ai ZT, Melikov AK. Airborne spread of expiratory droplet nuclei between the occupants of indoor environments: A review. Indoor Air, 2018; 28:500–524									
2	Asadi S, Wexler AS, Cappa CD, Barreda S, Bouvier NM, Ristenpart WD. Aerosol emission and superemission during human speech increase with voice loudness. Nature Scientific Reports, 2019; 9:2348. https://doi.org/10.1038/s41598-019-38808-z.	A								
3	Atkinson MP, Wein LM. Quantifying the Routes of Transmission for Pandemic Influenza. Bulletin of Mathematical Biology. 2008; 70: 820–867	A								
4	Balazy A, Toivola T, Adhikari A, Sivasubramani SK, Reponen T, Grinshpun GA. Do N95 respirators provide 95% protection level against airborne viruses, and how adequate are surgical masks? American Journal of Infection Control. 2006; 34(2): 51-57.					E				
5	Beckman S, Materna B, Goldmacher S, Zipprich J, D'Alessandro M, Novak D, Harrison R. Evaluation of respiratory protection programs and practices in California hospitals during the 2009-2010 H1N1 influenza pandemic. American Journal of Infection Control. November 2013; 41(11): 1024–1031.									
6	Bischoff WE, Katrina Swett K, Leng I, Peters TR. Exposure to Influenza Virus Aerosols During Routine Patient Care. The Journal of Infectious Diseases. 2013;207:1037–46	A	B		D			G		
7	Bischoff WE, Reid T, Russell GB, Peters TR. Transocular Entry of Seasonal Influenza—Attenuated Virus Aerosols and the Efficacy of N95 Respirators, Surgical Masks, and Eye Protection in Humans. The Journal of Infectious Diseases. 2011; 204(2):193-199					E	F			
8	Blachere FM, Cao G, Lindsley WG, Noti JD, Beezhold DJ. Enhanced detection of infectious influenza virus. Journal of Virological Methods. 2011; 176:120-124.									
9	Blachere FM, Lindsley WG, McMillen CM, Beezhold DH, Shaffer RE, Noti JD, Fisher EM. Assessment of influenza virus exposure and recovery from contaminated surgical masks and N95 respirators. Journal of Virological Methods. 2018; 260: 98-106.					E				
10	Blachere FM, Lindsley WG, Pearce TA, Anderson SE, Fisher M, Khakoo R, Meade BJ, Lander O, Davis S, Thewlis RE, Celik I, Chen BT, Beezhold DH. Measurement of Airborne Influenza Virus in a Hospital Emergency Department. Clinical Infectious Diseases 2009;48:438–40	A	B		D					
11	Brosseau LM, Jones R. Commentary: Protecting health workers from airborne MERS-CoV—learning from SARS				D	E		G	H	I

12	Brown JR, Tang JW, Pankhurst L, Klein N, Gant V, Lai KM, McCauley, J Breuer J. Influenza virus survival in aerosols and estimates of viable virus loss resulting from aerosolization and air-sampling. Journal of Hospital Infection. November 2015; 91(3): 278–281.		B	C				
13	Canadian Standards Association. CAN/CSA-Z94.4-18. Selection, Use and Care of Respirators.					E		
14	Characterization of Exhaled Particles from the Healthy Human Lung - A Systematic Analysis in Relation to Pulmonary Function Variables. Schwarz K, Biller H, Windt H, Koch W, Hohlfeld JM. Journal of Aerosol Medicine and Pulmonary Drug Delivery. 2010; 23(6): 371–379. DOI: 10.1089=jamp.2009.0809	A						
15	Coia JE, Ritchie L, Adisesh A, Makison Booth C, Bradley C, Bunyan D, Carson G, Fry C, Hoffman P, Jenkins D, Phin N, Taylor B, Nguyen-Van-Tam JS, Zuckerman M. Guidance on the use of respiratory and facial protection equipment. Journal of Hospital Infection. November 2013; 85(3): 170–182.					E		
16	Coleman KK, Sigler WV. Airborne Influenza Virus Exposure in an Elementary School. Nature Scientific Reports. 2020; 10:1859. https://doi.org/10.1038/s41598-020-58588-1	A	B		D			G
17	Concentrations and size distributions of airborne influenza A viruses measured indoors at a health centre, a day-care centre and on aeroplanes. Journal of the Royal Society Interface. 2011; 8:1176–1184. doi:10.1098/rsif.2010.0686	A	B		D			G
18	Cowling BJ, Ip DKM, Fan VJ, Suntarattiwong P, Olsen SJ, Levy J, Uyeki TM, Leung GM, Peiris JSM, Chotpitayasunondh T, Nishiura H, Simmerman JM. Aerosol transmission is an important mode of influenza A virus spread. Nature Communications. 2013; 4:1935.							
19	Cowling BJ, Zhou Y, Ip DKM, Leung GM, Aiello AE. Face masks to prevent transmission of influenza virus: a systematic review. Epidemiol. Infect. 2010; 138: 449–456							
20	Cowling BJ. Airborne Transmission of Influenza: Implications for Control in Healthcare and Community Settings. Clinical Infectious Diseases. 2012; 54(11): 1578-1580							
21	Davies A, Thomson G, Walker J, Bennett A. A review of the risks and disease transmission associated with aerosol generating medical procedures. Journal of Infection Prevention. 2009; 10(4): 122-126. 10.1177/1757177409106456							
22	Fisher EM, Noti JD, Lindsley WG, Blachere FM, Shaffer RE. Validation and Application of Models to Predict Facemask Influenza Contamination in Healthcare Settings. Risk Analysis. 2014; 34(8).					E		

23	Fowler RA, Guest CB, Lapinsky SE, Sibbald WJ, Louie M, Tang P, Simor AE, Stewart TE. Transmission of Severe Acute Respiratory Syndrome during Intubation and Mechanical Ventilation. American Journal of Respiratory Critical Care Medicine. 2004; 169: 1198–1202.									
24	Gralton J, Tovey E, McLaws M-L, Rawlinson WD. The role of particle size in aerosolised pathogen transmission: A review. The Journal of Infection, 2011; 62: 1-13.	A			D			G	H	
25	Grasmeijer N, Frijlink HW, Hinrichs WLJ. An adaptable model for growth and/or shrinkage of droplets in the respiratory tract during inhalation of aqueous particles. Journal of Aerosol Science. 2016; 93:21-34.								H	
26	Haghnegahdar A, Jianan Zhao J, Feng Y. Lung aerosol dynamics of airborne influenza A virus-laden droplets and the resultant immune system responses: An in-silico study. Journal of Aerosol Science, Volume 134, August 2019, Pages 34-55.							G	H	I
27	Institute of Medicine. Respiratory protection for healthcare workers in the workplace against novel H1N1 influenza A: A letter report. 2009. Washington, DC: The National Academies Press.					E	F			
28	Jaeger JL, Patel M, Dharan N, Hancock K, Meites E, Mattson C, Gladden M, Sugerman D et al. Transmission of 2009 Pandemic Influenza A (H1N1) Virus among Healthcare Personnel—Southern California, 2009. Infection Control and Hospital Epidemiology. 2011; 32(12):1149-1157					E				
29	Jefferson T, Del Mar CB, Dooley L, Ferroni E, Al-Ansary LA, Bawazeer GA, van Driel ML, Nair S, Jones MA, Thorning S, Conly JM. Physical interventions to interrupt or reduce the spread of respiratory viruses. Cochrane Database of Systematic Reviews 2011, Issue 7. Art. No.: CD006207. DOI: 10.1002/ 14651858.CD006207.pub4.					E	F			
30	Johnson DF, Druce JD, Birch C, Grayson ML. A Quantitative Assessment of the Efficacy of Surgical and N95 Masks to Filter Influenza Virus in Patients with Acute Influenza Infection. Clinical Infectious Diseases. 2009; 49(2): 275-277.									
31	Johnson GR, Morawska L. The Mechanism of breath aerosol formation. Journal of Aerosol Medicine and Pulmonary Drug Delivery, 2009; 22(3):229-237.	A								
32	Jones RM, Brosseau LM. Aerosol Transmission of Infectious Disease. Journal of Occupational and Environmental Medicine. Volume 57, Number 5, May 2015.	A	B	C	D	E	F	G	H	I

33	Judson SD, Munster VJ. Nosocomial Transmission of Emerging Viruses via Aerosol-Generating Medical Procedures. Viruses. 2019; 11, 940; doi:10.3390/v11100940								
34	Katy-Anne Thompson K-A, Pappachan JV, Bennett AM, Mittal H, Macken S, Nguyen-Van-Tam JS, Copley VR, O'Brien S, Hoffman P, Dove BK, Bentley A, Isalska B, Thomson G, Parks S. Influenza Aerosols in UK Hospitals during the H1N1 (2009) Pandemic – The Risk of Aerosol Generation during Medical Procedures. PLOS ONE, www.plosone.org 1 February 2013, Volume 8, Issue 2, e56278.	A	B		D			G	H
35	Killingley B, Nguyen-Van-Tam J. Routes of influenza transmission. Influenza and Other Respiratory Viruses. 2013l;(Suppl. 2), 42–51.								
36	Leung NHL, Zhou J, Chu DKW, Yu H, Lindsley WG, Beezhold DH, Yen H-L, Li Y, Seto W-H, Peiris JSM, Cowling BJ. Quantification of Influenza Virus RNA in Aerosols in Patient Rooms. PLoS ONE. 2016; 11(2): e0148669. doi:10.1371/journal.pone.0148669	A	B		D			G	
37	Li S, Eisenberg JNS, Spicknall IH, Koopman JS. Dynamics and Control of Infections Transmitted From Person to Person Through the Environment. American Journal of Epidemiology. 2009;170:257–265	A		C	D	E			
38	Lietz J, Westermann C, Nienhaus A, Schablon A. The Occupational Risk of Influenza A (H1N1) Infection among Healthcare Personnel during the 2009 Pandemic: A Systematic Review and Meta-Analysis of Observational Studies. PLOS ONE, DOI:10.1371/journal.pone.0162061 August 31, 2016.								
39	Lindsley WG, Blachere FM, Beezhold DM, Thewlis RE, Noorbakhsh B, Othumpangat S, Goldsmith WT, McMillen CM, Andrew ME, Burrell CN, Notia JD. Viable influenza A virus in airborne particles expelled during coughs versus exhalations. Influenza Other Respir Viruses. 2016 Sep; 10(5): 404–413. DOI:10.1111/irv.12390	A	B						
40	Lindsley WG, Blachere FM, Thewlis RE, Vishnu A, Davis KA, et al. Measurements of Airborne Influenza Virus in Aerosol Particles from Human Coughs. PLoS ONE 5(11): e15100. doi:10.1371/journal.pone.0015100	A	B	C	D			G	
41	Lindsley WG, Noti JD, Blachere FM, Thewlis RE, Martin SB, Othumpangat S, Noorbakhsh B, Goldsmith WT, Vishnu A, Palmer JE, Clark KE, Beezhold DH. Viable Influenza A Virus in Airborne Particles from Human Coughs. Journal of Occupational and Environmental Hygiene. 2015; 12: 107–113.	A	B	C	D			G	

42	Liu L, Li Y, Nielsen PV, Wei J, Jensen RL. Short range airborne transmission of expiratory droplets between two people. Indoor Air. 2017; 27: 452–462				D			G		
43	Loeb M, Defoe N, Mahoney J, John M, et al. Surgical Mask vs N95 Respirator for Preventing Influenza Among Health Care Workers A Randomized Trial. JAMA. November 4, 2009; 302(17):1865-1871.					E	F			
44	MacIntyre CR, Seale H, Yang P, Zhang Y, Shi W, Almatroudi A, Moa A, Wang X, Pang X, Wang Q. Quantifying the risk of respiratory infection in healthcare workers performing high-risk procedures. Epidemiol. Infect. 2014; 142: 1802–1808	A	D					G	H	I
45	Martin Linster M, van Boheemen S, de Graaf M, Schrauwen EJA, Lexmond P, Manz B, Bestebroer TM, Bauman J, van Riel D, Rimmelzwaan GF, Osterhaus ADME, Matrosovich M, Fouchier RAM, Herfst S. Identification, Characterization, and Natural Selection of Mutations Driving Airborne Transmission of A/H5N1 Virus. Cell, April 10 2014; 157: 329–339.				D					
46	Mermel LA. Eye protection for preventing transmission of respiratory viral infections to healthcare workers. Infection Control & Hospital Epidemiology. 2018; 39:1387–1397					E	F			
47	Milton DK, Fabian MP, Cowling BJ, Grantham ML, McDevitt JJ. Influenza Virus Aerosols in Human Exhaled Breath: Particle Size, Culturability, and Effect of Surgical Masks. 2013, PLoS Pathog 9(3): e1003205. doi:10.1371/journal.ppat.1003205.	A	B	C	D	E				
48	Morawska, L. Droplet Fate in Indoor Environments, or can we Prevent the Spread of Infection? Indoor Air. 2006; (5): 335-347.									
49	National Academies of Sciences, Engineering and Medicine. Reusable Elastomeric Respirators in Health Care: Considerations for Routine and Surge Use (2019). http://nap.edu/25275					E				
50	National Academy of Sciences. Preventing Transmission of Pandemic Influenza and Other Viral Respiratory Diseases: Personal Protective Equipment for Healthcare Workers: Update 2010.									
51	Nicas M, Jones RM. Relative Contributions of Four Exposure Pathways to Influenza Infection Risk. Risk Analysis. 2009; 29(9):1292.									
52	Noti JD, Lindsley WG, Blachere FM,1 Cao G, Kashon ML, Thewlis RE, McMillen CM, King WP, Szalajda JV, Beezhold DH. Detection of Infectious Influenza Virus in Cough Aerosols Generated in a Simulated Patient Examination Room. Clinical Infectious Diseases. 2012: 54(11): 1569-1577		B	C	D			G		

53	O'Neil CA, Li J, Leavey A, Wang Y, Hink M, Wallace M, Biswas P, Burnham CAD, Babcock HM. Characterization of Aerosols Generated During Patient Care Activities. Clinical Infectious Diseases. 2017;65(8):1342–8	A			D			G
54	Oberg T, Brosseau LM. Surgical mask filter and fit performance. American Journal of Infection Control. 2008; 36: 276-282.					E		
55	Pan M, Lednicky LA, Wu C-Y. Collection, particle sizing and detection of airborne viruses. Journal of Applied Microbiology. 2019; 127:1596-1611							
56	Papineni RS, Rosenthal FS. The size distribution of droplets in the exhaled breath of healthy human subjects. Journal of Aerosol Medicine. 1997;10:105-116.	A						G
57	Pyankov OV, Bodnev SA, Pyankova OG, Agranovs IE. Survival of aerosolized coronavirus in the ambient air. Journal of Aerosol Science, Volume 115, January 2018, Pages 158-163.		B		D			G
58	Radonovich LI, Simberkoff MS, Bessesen MT, Brown AC, et al. N95 Respirators vs Medical Masks for Preventing Influenza Among Health Care Personnel A Randomized Clinical Trial. JAMA. September 3, 2019; 322, Number 9: 824-833.					E	F	
59	Radonovich LJ, Bessesen MT, Cummings DA, Eagan A, et al. The Respiratory Protection Effectiveness Clinical Trial (ResPECT): A cluster-randomized comparison of respirator and medical mask effectiveness against respiratory infections in healthcare personnel. BMC Infectious Diseases, ISSN 1471-2334, 06/2016, Volume 16, Issue 1, p. 243					E	F	
60	Richard M, Fouchier RAM. Influenza A virus transmission via respiratory aerosols or droplets as it relates to pandemic potential. FEMS Microbiology Reviews. 2016; fuv039, 40: 68–85.							
61	Roberge, RJ. Evaluation of the rationale for concurrent use of N95 filtering facepiece respirators with loose-fitting powered air-purifying respirators during aerosol-generating medical procedures. American Journal of Infection Control. 2008;36:135-141.							
62	Seto WH. Airborne transmission and precautions: facts and myths. April 2015; 89(4): 225–228.							
63	Shine KI, Rogers B, Goldfrank LR. Novel H1N1 Influenza and Respiratory Protection for Health Care Workers. New England Journal of Medicine. November 5 2009; 361(19): 1823-1825.							
64	Shiu EYC, Leung NHL, Cowling BJ. Controversy around airborne versus droplet transmission of respiratory viruses: implication							

	for infection prevention. Current Opinion on Infectious Diseases. 2019; 32:372–379.									
65	Simonds AK, Hanak A, Chatwin M, Hall A, Parker KH, Siggers JH. Morrell MJ, Dickinson RJ. Evaluation of droplet dispersion during non-invasive ventilation, oxygen therapy, nebuliser treatment and chest physiotherapy in clinical practice: implications for management of pandemic influenza and other airborne infections. Health Technol Assess 2010; 14(46):131–172.	A			D					
66	Spicknall IH, Koopman JS, Nicas M, Pujol JM, Li S, et al. Informing Optimal Environmental Influenza Interventions: How the Host, Agent, and Environment Alter Dominant Routes of Transmission. PLoS Computational Biology. 2010; 6(10): e1000969. doi:10.1371/journal.pcbi.1000969									
67	Stelzer-Braid S, Oliver BG, Blazey AJ, Argent E, Newsome TP, Rawlinson WD, Tovey ER. Exhalation of Respiratory Viruses by Breathing, Coughing, and Talking. Journal of Medical Virology. 2009; 81:1674–1679.	A	B							
68	Stilianakis NI, Drossinos Y. Dynamics of infectious disease transmission by inhalable respiratory droplets. Journal of the Royal Society Interface. 2010;7:1355–1366.				D					
69	Sung-Han Kim S-H, Chang SY, Sung M, Park JH, Kim HB, Lee H, Choi J-P, Choi WS, Min J-Y. Extensive Viable Middle East Respiratory Syndrome (MERS) Coronavirus Contamination in Air and Surrounding Environment in MERS Isolation Wards. Clinical Infectious Diseases. 2016;63(3):363–9		B	C						
70	Tellier R, Li Y, Cowling BJ, Tang JW. Recognition of aerosol transmission of infectious agents: a commentary. British Medical Journal Infectious Diseases. 2019; 19:101.	A	B	C	D	E	F	G	H	I
71	Tellier R. Aerosol transmission of influenza A virus: a review of new studies. Journal of the Royal Society Interface. 2009; 6: S783–S790									
72	Thomas RJ. Particle size and pathogenicity in the respiratory tract. Virulence 2013; November, 4(8):847–858.									I
73	Tran K, Cimon K, Severn M, Pessoa-Silva CL, Conly J. Aerosol Generating Procedures and Risk of Transmission of Acute Respiratory Infections to Healthcare Workers: A Systematic Review. PLoS ONE, www.plosone.org 1 April 2012, Volume 7, Issue 4, e35797.	A			D			G	H	I
74	Wan G-H, Wu C-L, Chen Y-F, Huang S-H, Wang Y-L, Chen C-W. Particle Size Concentration Distribution and Influences on Exhaled Breath Particles in Mechanically Ventilated Patients. PLOS ONE, www.plosone.org, 1 January 2014; 9(1):e87088	A						G		

75	Weber TP, Stilianakis NI. Inactivation of influenza A viruses in the environment and modes of transmission: A critical review. Journal of Infection. 2008; 57:361-373				D					
76	WG, Blachere FM, Davis KA, Pearce TA, Fisher MA, Khakoo R, Davis SM, Rogers ME, Thewlis RE, Posada JA, Redrow JB, Celik IB, Chen BT, Beezhold DH. Distribution of Airborne Influenza Virus and Respiratory Syncytial Virus in an Urgent Care Medical Clinic. Clinical Infectious Diseases. 2010; 50(5): 693-698.	A	B		D			G		
77	Wise ME, De Perio M, Halpin J, Jhung M, Magill S, et al. Transmission of Pandemic (H1N1) 2009 Influenza to Healthcare Personnel in the United States. Clinical Infectious Diseases. 2011; 52(S1): The 2009 H1N1 Influenza Pandemic: Field and Epidemiologic Investigations: S198-S204					E				
78	Wong BCK, Lee N, Li Y, Chan PKS, Qiu H, Luo Z, Lai RWM, Ngai K, Hui DSC, Choi KW, Yu ITS. Possible Role of Aerosol Transmission in a Hospital Outbreak of Influenza. Clinical Infectious Diseases. 2010; 51(10):1176–1183	A			D			G	H	I
79	Wurie F, Le Polain de Waroux O, Brande M, DeHaan W, Holdgate K, Mannan R, Milton D, Swerdlow D, Hayward A. Characteristics of exhaled particle production in healthy volunteers: possible implications for infectious disease transmission. F1000Research 2013, 2:14 Last updated: 23 JUL 2019	A						G		
80	Xiao S, Tang JW, Hui DS, Lei H, Yu H, Li Y. Probable transmission routes of the influenza virus in a nosocomial outbreak. Epidemiology and Infection 146, 1114–1122. https://doi.org/10.1017/S0950268818001012			C	D			G	H	I
81	Xie X, Ki Y, Chwaung ATY, Ho PL, Seto WH. How far droplets can move in indoor environments – revisiting the Wells evaporation–falling curve. Indoor Air. 2007; 17: 211–225				D					
82	Yan J, Grantham M, Pantelic J, Bueno de Mesquita PJ, Albert B, Liu F, Ehrman S, Milton DK, EMIT Consortium. Infectious virus in exhaled breath of symptomatic seasonal influenza cases from a college community. PNAS January 30, 2018 vol. 115 no. 5 1081–1086.	A	B		D			G		
83	Zietsman M, Phan LT, Jones RM. Potential for occupational exposures to pathogens during bronchoscopy procedures. Journal of Occupational and Environmental Hygiene. 2016;16(10): 707-716, DOI: 10.1080/15459624.2019.1649414	A			D			G		
84	Zuo Z, Kuehn TH, Verma H, Kumar S, Sagar M, Goyal SM, Appert J, Raynor PC, Ge S, Pui DYH. Association of Airborne Virus Infectivity and Survivability with its Carrier Particle Size. Aerosol Science and Technology. 2012; 47:4, 373-382, DOI: 10.1080/02786826.2012.754841				D					

85	Zunyou W, McCoogan JM. Characteristics of and Important Lessons From the Coronavirus Disease 2019 (COVID-19) Outbreak in China – Summary of a Report of 72 314 Cases From the Chinese Center for Disease Control and Prevention. Journal of the American Medical Association JPublished online February 24, 2020.