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October 02, 2020

REA Project No. 16832 ***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: Update on Evidence for Aerosol Transmission of COVID-19 and Implications for Health Care Worker Respiratory Protection

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In response to your September 24th request I have prepared this letter for HSABC and NUPGE, to provide an update on the evidence concerning airborne transmission of COVID-19 that has emerged subsequent to my March 20th letter for HSABC and NUPGE, and to discuss the official opinions of key public health agencies regarding this mode of transmission.

Attached as Appendix 1 is a list of papers I consulted in preparation of this letter, most of which have publication dates post March 2020.

Context for the March 20, 2020 Letter

I believe it helpful to begin by recapping the circumstances leading to my March letter. The March letter was prepared to supplement information provided in an earlier more comprehensive report that I produced for HSABC and NUPGE in September 2009, at that time in the context of concerns over H1N1. The focus of the September 2009 report was evidence for modes of transmission of influenza, and implications for protection of health care workers, those being subjects of interest to HSABC and NUPGE, in order to inform organizational positions regarding the need for N95 respiratory protection for health care workers.

The September 2009 report summarized evidence accumulated to that time, which pointed to the likelihood that influenza was most likely transmitted primarily by inhalation of respiratory aerosols in close proximity to an emitter, and not, contrary to public health and medical nostrum, solely via contact with visible droplet expulsions and fomites. That report also spoke to the implications for environmental infection prevention and control measures, and protective equipment requirements for health care workers flowing from the evidence on modes of transmission.

My March 2020 letter summarized the additional evidence developed in the period between September 2009 and early 2020 with respect to close proximity aerosol transmission of viral respiratory diseases, and in particular those caused by other corona viruses, specifically SARS and MERS. At the time of my research for the March 2020 letter it was the emerging stage of the COVID-19 pandemic, and to that time there was little in the way of quality evidence published specifically with respect to aerosol transmission of COVID-19. There had, however, been a considerable amount of additional relevant evidence on virus aerosol transmission produced between 2009 and 2020, which strengthened understanding of aerosol transmission dynamics, pointed to the likelihood of aerosol transmission in clinical settings for SARS and MERS, and pointed to the likelihood of a similar picture emerging for SARS CoV-2 and COVID-19.

Despite the absence of specific evidence in March 2020 on modes of transmission for COVID-19, public health authorities in Canada and abroad expressed their consensus opinion that transmission was via droplet[1] and contact modes, and not via aerosols. This was a convenient position for governmental public health agencies, given the publicized shortages of N95-type respirators at the time, and the notion that N95 protection wasn't needed for protection against droplet and contact transmission. The commonly cited authority for this position on modes of transmission was the World Health Organization (WHO), which published statements to that effect on several occasions between January and March. WHO's position was ultimately memorialized in a WHO Scientific Brief published on March 29, 2020[2],

[1] Many guidance documents produced by Canadian public health authorities provided no definition of a "droplet", but in cases where a definition was offered it was invariably a liquid phase particle having a diameter of 5 micrometers or larger, which purportedly would fallout onto surfaces under the influence of gravity within 1 to 2 meters of generation, which was contrasted to an "aerosol", which consisted of particles under 5 micrometers in diameter and remained airborne. In this context it is interesting to observe that until 2016, the Public Health Agency of Canada had defined a "droplet" as having a diameter of 50 (fifty) microns and larger (https://www.canada.ca/content/dam/phac-aspc/documents/services/publications/diseases-conditions/routine-practices-precautions-healthcare-associated-infections/routine-practices-precautions-healthcare-associated-infections-2016-FINAL-eng.pdf), and indicated that N95 respiratory protection was needed for "aerosols", which were smaller than 50 microns. The basis for the change of definition is unknown.

[2] https://apps.who.int/iris/handle/10665/331616?show=full. The original Scientific Brief was updated in on July 9, 2020 (https://www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-

which cited seven sources as forming the basis for its conclusion. In fact, the sources cited by WHO in the March 29 Scientific Brief did not demonstrate the absence of aerosol transmission, nor even opine on modes of transmission.[3]

Brief Summary of the Main Conclusions of my March 2020 Letter

As indicated in my March letter, considerable evidence developed over the past two decades informs our understanding of how infectious viral respiratory diseases such as influenza, SARS and MERS can be transmitted by aerosol inhalation between persons in close proximity to one another. The transmission process can be explained as follows:

- A variety of expiratory actions – breathing, talking, singing, laughing, coughing, and sneezing – result in the emission of respiratory aerosols, which are expelled from the airway into the air volume in front of the source individual's face, in a form that can be thought of as a "cloud", comprised of liquid phase particles, and a mix of gases saturated with water vapour.
- Different types of expiratory actions produce populations of respiratory aerosols that differ in six main respects:
    - The total volume of liquid from the sum of all droplets[4]
    - The numbers of droplets of different diameters contained in the initial release
    - The distance travelled by the cloud.
    - The change in cloud shape as it projects outward from the airway.
    - The initial cloud velocity, and its rate of deceleration as it flows through the atmosphere.

infection-prevention-precautions), and described the emerging evidence suggesting aerosol transmission. Yet, despite canvassing the emerging evidence, WHO still concluded, based on the same sources cited on March 29th, that "SARS-CoV-2 transmission appears to mainly be spread via droplets and close contact with infected symptomatic cases".

[3] The attached Appendix 2 provides my critique of the March 29th Scientific Brief, submitted to the editor of the *Bulletin of the World Health Organization*, which they declined to publish notwithstanding peer reviewer concurrence with my conclusions. The letter addresses the absence of evidence for the assertions of the March 29 2020 WHO Scientific Bulletin, and the misrepresentation of evidence presented in the published sources cited.

[4] In this context I am not using "droplet" to only mean a liquid phase particle with a diameter over 5 micrometers. I mean any droplet of any size.

    - The directional trajectory of the cloud.

- The total volumes of liquid expelled by each type of expiratory actions differ considerably. Typical values are on the following orders of magnitude:

    - normal breathing 1 nanolitre (nL) per minute
    - moderate volume talking 10 nL per minute
    - loud talking 50 nL per minute
    - coughing 100 nL per cough
    - sneezing 500,000 nL per sneeze.

  There are variations in these volumes between and within individuals.

- When an individual's airway tissues are infected by a population of viruses, viruses are emitted in the cloud discharged by the various expiratory actions.

- The quantity of virus present in the expiratory cloud is proportionate to the concentration of viruses in the fluids lining the airway at the loci of droplet creation.

- Virus concentrations in airway fluids generally differ along the pathway between between the sinus / mouth and alveoli, as a function of the prevalence of target tissues, and the effects of respiratory mucus and airflows on the redistribution of extracellular viruses and cells shed from the epithelia. Virus concentrations in airway fluids also change over the cycle of infection, which in turn affects the quantities of viruses discharged by expiratory actions over time.

- The droplets released by breathing are mostly under 0.5 microns in diameter and are formed in the alveoli and terminal bronchioles. Talking produces the same droplet constellation as breathing, and overlays a second distribution with an upper size limit of 1 micron that emanates from the larger diameter bronchi, and a third overlaid distribution with an upper size limit of 10 microns that emanates from the tracheal pharyngeal region. Air and aerosols expelled by breathing and talking are emitted at relatively low velocity, and tend to immediately rise upward in indoor atmospheres due to thermal buoyancy and the upward convection flows generated by the exterior temperature of the body. This effectively results in the concentrations of respiratory aerosols being only 5% to 10% of their initial concentrations at a distance of 1.5 meters from the mouth and nose of the emitter.

- Coughing includes all of the droplet size distributions observed in talking, with increased overall contribution by droplets from the tracheal pharyngeal region, and the addition of a small percentage of larger droplets up to 20 microns that originate in the mouth, plus occasional large visible spittle expulsions. The velocity of cough explusions is much higher than the air and aerosol velocities of explusions from breathing or talking. As a result, cough clouds follow an outward trajectory which can deliver relatively constant aerosol concentrations for distances up to 3 meters from the source.

- Sneezing includes all of the droplet size distributions observed in coughing, and overlays two additional size spectra of droplets originating in the sinuses, that are more or less normally distributed, with median droplet diameters centred near 100 microns and 600 microns, with an upper limit of 1000 microns. Sneezes are emitted at very high velocities at trajectories perpendicular to the face. These velocities carry larger ballistic droplets to distances of a few meters before fallout, and carry the cloud and entrained non-visible droplets up to 7 meters or more.

- Almost instantaneously upon discharge, droplets expelled by breathing, talking and coughing lose their water fraction, leaving droplet nuclei, which are solid particles typically 1/5th the diameter of the original droplet, comprised of inorganic and organic solutes. If the original droplet was large enough to harbour one or more virions, those will be adhered to or insinuated in the solutes in the droplet nucleus.

- When indoors in adequately ventilated spaces, the clouds produced by breathing and talking travel approximately 1.5 meters before losing momentum, and coughs clouds can travel 3 meters before losing momentum. By the point in space where the cloud's momentum is lost, the droplet nucleus concentration has dropped within the cloud as a result of cloud volume expansion and removal by the surrounding airflows, resulting in a concentration that is 10 to 20 times lower than at the point of discharge from the nose or mouth. The cloud then dissipates, with the solid droplet nuclei dispersing into the air, and the concentration approaches the background concentration in the space. That point where the cloud concentration drops to the background concentration can be considered the boundary between the "near field" and the "far field". This cloud behaviour for breathing, talking and coughing, and the associated virus concentration attenuation reduces the potential for aerosol infection transmission beyond a near field boundary in indoor spaces, so long as those spaces are not small and confined, or poorly ventilated.

- Indoors in adequately ventilation spaces, the sneezes more commonly project aerosols 3 to 7 meters, meaning that 7 meters should be considered the edge of the near field boundary for a sneeze. The largest visible droplets generated by a sneeze travel ballistically and can fallout onto surfaces before transforming to droplet nuclei. Those which fallout are not available for inhalation, and those with diameters above 100 micrometers that temporarily remain airborne cannot be readily inhaled because of the low entrainment velocities associated with inhalation. In contrast to breathing, talking, and coughing, the smaller droplet fractions generated by a sneeze can travel further and persist for several seconds longer before converting to droplet nuclei, owing to the airflow and humidity conditions in the fast flowing sneeze cloud. This behaviour, and the comparatively larger liquid volumes expelled by a sneeze, can result in elevated airborne virus concentrations several meters from the source, even in large well-ventilated spaces.

- With the exception of the large visible droplets that behave ballistically in a sneeze, all other droplets expelled by a sneeze, and released by the other expiratory actions, rapidly convert to droplet nuclei, remain suspended in air for considerable lengths of time, can be inhaled by persons sharing the same space as an infected emitter, and with sufficient concentrations the dose inhaled can be large enough to initiate infection. The long held notion, frequently cited in the peer reviewed literature and public health agency guidance documents, that droplets 5 microns and larger rapidly falling out onto surfaces within a distance of one to two meters from the emitter is simply incorrect, was demonstrated mathematically to be incorrect in the 1930s, and has been empirically disproven by many studies in the past two decades. In effect, most droplets generated by expiratory actions are in fact inhalable droplet nuclei that remain suspended in ventilated spaces indefinitely until removed by air extraction ventilation, electrostatic deposition onto surfaces, or filtration. Respiratory protection guidance of public health agencies based on the assertion that 5 micron droplets behave ballistically is a longstanding frequently restated misconception based on misunderstandings of fundamental aerosol physics.

- Inhalation by a non-infected person of virus-laden respiratory aerosols creates potential for initiation of an infection. The virus dose and timeframe of delivery necessary to cause infection is unknown, but for influenzas, SARS and MERS it has been variously estimated to be on the order of 100 to 1000 virions.

- In view of the above, whether infection occurs as a result of exposure to expiratory emissions of an infected person depends on many variables, including:

    - the concentrations of the virus in the respiratory fluids that give rise to the expelled liquid;
    - the volume of liquid expelled by the particular combination of expiratory actions;
    - the size distribution of the droplets;
    - the atmospheric transport and dispersal of the droplets;

- the resulting air concentration in the downstream individual's breathing zone;
- the duration of time exposed to that concentration;
- the target individual's breathing rate;
- the target individuals inhaled and deposited dose;
- the infectious dose for the virus; and
- individual susceptibility to initiation of infection.

Current Understanding of Near Field Transmission Risk from Respiratory Virus Aerosol Emission, Transport and Dispersal

A considerable amount of new evidence specifically implicating aerosol transmission of COVID-19 has developed between April and September 2020. This includes,

- demonstration of aerosol transmission in animal test systems in controlled conditions;
- detection of viable SARS CoV-2 viruses in air in health care settings;
- demonstration that air suspended SARS CoV-2 viruses can remain viable for several hours under ideal conditions;
- demonstration that the likely airborne half-life for viable SARS CoV-2 in air is on the order of 1.5 hours;
- outbreak clusters in a wide variety of indoor settings that are either only explained, or best explained, by aerosol transmission;
- evidence that community masking is effective in reducing identified positive cases.

Interest among the medical and scientific community in the potential for significant near field aerosol transmission of COVID-19 started in April, as reflected by several commentary and opinion papers in the peer reviewed literature, culminating in communiques in July to the US CDC and WHO by a group of 239 experts from a variety of disciplines outlining the overwhelming evidence for aerosol transmission of

COVID-19, and urging official acknowledgement of the phenomenon[5]. The subject commentary was published on July 7, 2020.[6]

On August 26 and 27, the National Academies of Medicine Engineering and Science hosted a virtual workshop by academic and government experts covering the evidence for aerosol transmission of COVID-19. Many of those presenters subsequently compiled a web site, just released on September 26, containing an extensive series of questions and answers regarding aerosol transmission, supported by citations to relevant peer reviewed literature[7]. The information provided on their web site is based substantially on the same body of publications contained herein in Appendix 1, and sources cited in my March 2020 report. The following figure from that web site provides an excellent visual summary of the lines of evidence now strongly pointing to aerosol transmission as a significant mode for COVID-19.

Type of Evidence	Droplets	Fomites	Aerosols
Outdoors << Indoors	X	✓	✓✓
Similar viruses demonstrated	X	✓	✓
Animal models	?	✓	✓
Superspreading events	X	X	✓✓
Supersp. Patterns similar to known aerosol diseases	n/a	n/a	✓
Importance of close proximity	✓	X	✓✓
Consistency of close prox. & room-level	X	X	✓
Physical plausibility (talking)	X	✓	✓
Physical plausibility (cough, sneeze)	✓	✓	✓
Impact of reduced ventilation	X	X	✓
SARS-CoV-2 infectivity demonstrated in real world	X	X	✓
SARS-CoV-2 infectivity demonstrated in lab	X	✓	✓
"Droplet" PPE works reasonably well	✓	✓	✓
Transmission by a/pre-symptomatics (no cough)	X	✓	✓
Infection through eyes	✓	✓	✓
Transmission risk models	✓	✓	✓

Key:
✓: evidence
✓✓: very strong ev.
X: no evidence
X: evidence against
n/a: not applicable
(v1.45, 13-Sep-2020)

Figure 1 - Types of Evidence for COVID-19 Modes of Transmission

A few weeks following the publication of the July 7 2020 paper, the United States Centers for Disease Control revised the COVID-19 mode of transmission information on its web site, indicating that aerosol transmission appeared to be significant mode. A week thereafter that information was removed and

[5] https://www.ncbi.nlm.nih.gov/search/research-news/10574/.

[6] https://academic.oup.com/cid/advance-article/doi/10.1093/cid/ciaa939/5867798

[7] https://docs.google.com/document/d/1fB5pysccOHvxphpTmCG_TGdytavMmc1cUumn8m0pwzo/mobilebasic

said to have been posted in error. As of September 30, WHO, US CDC, and PHAC continue to assert that COVID-19 is transmitted principally by droplets and contact. Juxtaposed against this is the fact that Dr. Anthony Fauci, the much heralded Director of the US National Institutes of Health, stated September 9 in an on-line presentation for Harvard Medical School clinical rounds[8], and again on September 25 in an on-line interview with the Journal of the American Medical Association[9] that he is convinced that the aerosol scientists view on COVID-19 aerosol transmission is correct. In the Harvard Medical School clinical rounds presentation he went so far as saying that the medical, public health and infection control communities have "had it all wrong about droplets for a long time" (or words to that effect).

As of March 2020, there were no published estimates for an infectious aerosol dose of SARS CoV-2. Since then, patterns of person-to-person transmission, measured concentrations of SARS CoV-2 RNA copies in endotracheal fluids and saliva, and integration of that information into the knowledge base on respiratory aerosol dynamics, has lead to speculation that the infectious dose for SARS CoV-2 infection is likely on the order of 1000 virions deposited in the airway over a timeframe ranging from perhaps a few minutes to several hours, either via continuous low concentration exposure, or intermittent bursts of elevated exposure, or some combination. This order of magnitude is in line with prior estimates developed for influenzas, SARS and MERS.

The quantity of viruses thought necessary to initiate infection has important implications for aerosol transmission, because it allows us to develop predictions regarding the types of expiratory event exposure scenarios where aerosol transmissions are most likely to occur, and therefore provides a more logical basis for respiratory protection recommendations.

Is Aerosol Transmission Significant Among Health Care Workers in Canada?

On September 3, 2020, the Canadian Institute for Health Information published a tabulation of health care worker cases across Canada, as of July 23 2020, and calculated their representation as a percentage of total cases (see Figure 2)[10].

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8 https://partners.mediasite.com/mediasite/Play/17db07327ba3458cb647cb511c3aa2f71d?fbclid=IwAR2LCxreCth3wweD9HHFgILRP6aUusiTFuvnRIPub_g45MjIFGudZwYxNSI

9 https://www.youtube.com/watch?v=R84Rvcc9mu0. See video at 27:35 to 29:00.

10 https://www.cihi.ca/en/covid-19-cases-and-deaths-among-health-care-workers-in-canada

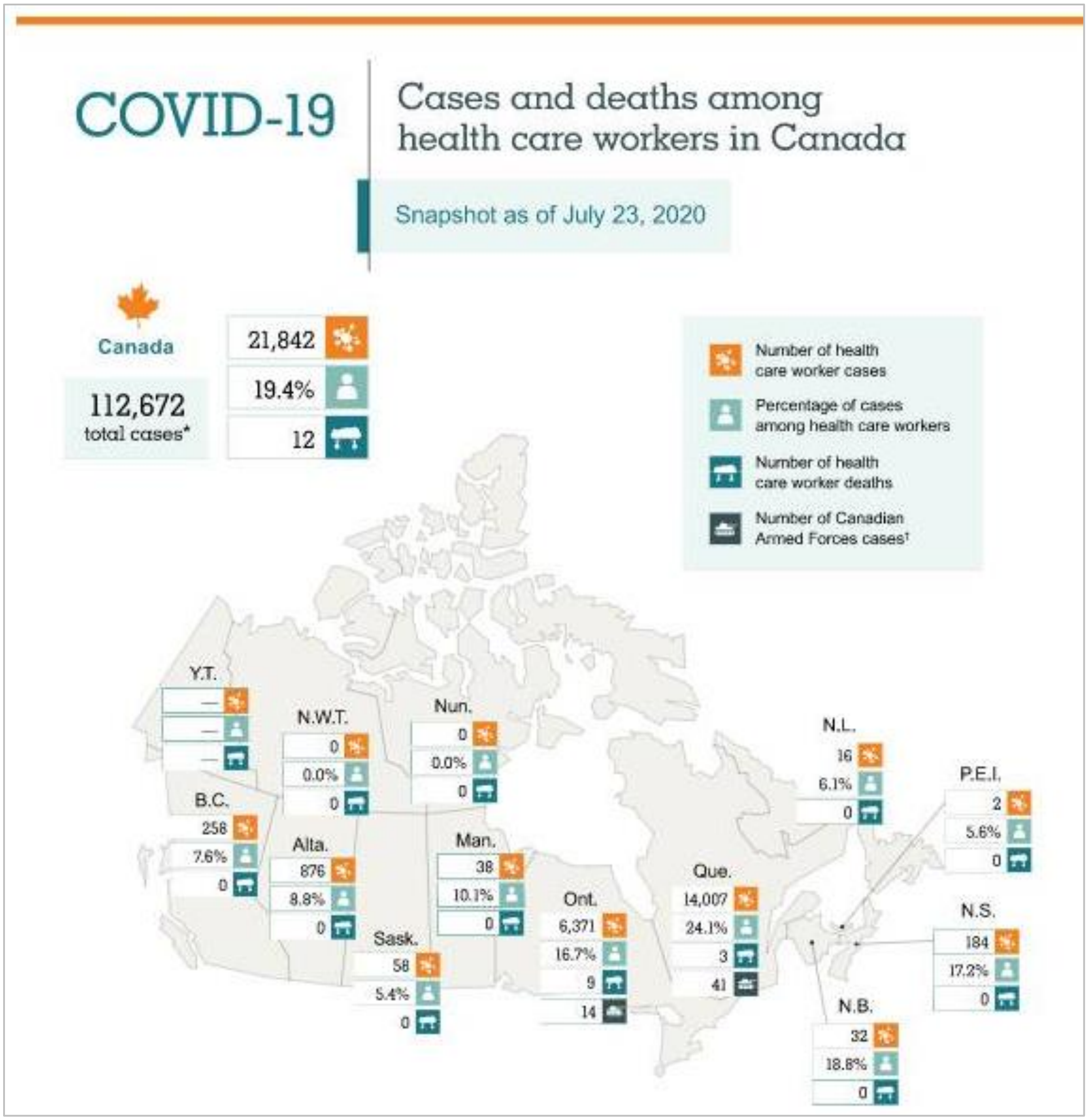

Figure 2 - Health Care Worker COVID-19 Infections in Canada, as of July 23 2020[11]

[11] Figures for Canadian Armed Forces personnel performing care functions in long term care settings are also included in view of their deployments in the spring and summer 2020.

The only province that appears to present daily updates on health care work case statistics is Ontario, where health care workers[12] represented 13.6% (7044 cases) of all identified cases as of September 29 2020.[13] According to the CIHI there were 511,517 health care workers in Ontario as of a 2018. If we assume a comparable number of health care workers in 2020, the case rate for Ontario health care workers would be 7,044 / 511,517 = 0.0138, or approximately 14 cases per 1000 workers. By comparison, the non-health care worker general population rate to September 29 in Ontario is (51,170 total cases – 7,044 health care worker cases) / (14,734,014 total population[14] – 511,517 health care workers) = 0.0031, or approximately 3 cases per 1000 persons. It is reasonable to assume that a portion of the cases identified among health care workers were contracted outside of health care settings in the community, and if that occurred at the same rates as the non-health care general population (3 per 1000), it yields an adjusted case rate for health care workers of 11 cases per 1000 in Ontario. This suggests the occupational attack rate among health care workers in Ontario is 3.7x higher than the non-health care worker general population attack rate. Similar calculations cannot be made for other provinces because the necessary information is not readily available on the internet, or in the on-line collection of the University of Toronto Library System.

An evidence brief published on June 12 2020 by the Emerging Science Secretariat of the Public Health Agency of Canada[15] summarized research reports to that date from various jurisdictions on the representation of health care workers among cases and elevated risk, noting the following findings:

- The risk of testing positive for SARS CoV-2 infection was approximately 7.6 times higher for a cohort of health care workers in the United Kingdom as compared to the community at large.

- A comparative survey of health care workers and community controls in the United States and United Kingdom conducted in March 2020 found that,

[12] Ontario defines this group as health care worker, doctor, nurse, dentist, dental hygienist, midwife, other medical technicians, personal support worker, respiratory therapist, or first responder. https://www.publichealthontario.ca/-/media/documents/ncov/epi/2020/07/covid-19-epi-health-care-workers-ontario.pdf?la=en

[13] https://www.publichealthontario.ca/en/data-and-analysis/infectious-disease/covid-19-data-surveillance/covid-19-data-tool. This is slightly lower than the percentage for Ontario in July, most likely because of the September surge in community cases in the province, which would reduce the contribution of health care workers to the total.

[14] Statistics Canada estimate, 3rd quarter 2020: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000901

[15] Public Health Agency of Canada. *COVID-19 Summary of the Risk of Outbreaks in the Workplace*. June 12 2020.

  - Frontline health care workers were approximately 12 times more likely to test positive for SARS CoV-2 than non-health care workers.

  - Health care workers who considered their personal protective equipment to be inadequate had a 23% higher likelihood of testing positive than health care workers who considered their protective measures adequate.

  - As compared to health care workers not caring for patients with documented COVID-19, those caring for such patients were 4.9 times more likely to test positive if they considered their PPE adequate, and 5.9 times more likely if they considered their PPE inadequate.

- To June 2020 there had been more than six dozen case reports published internationally describing occupational outbreaks among health care workers.

All the above suggests that health care workers may be at increased risk of SARS CoV-2 infection at a magnitude 4 to 12 times higher than the general population.[16]

Based on the emerging picture on the significance and potential dominance of aerosol transmission mode for COVID-19, and the substantial evidence of elevated risk among health care workers, it seems likely that near field aerosol transmission is happening in certain care setting interactions. Given the overall picture of the evidence on airborne transmission, it is likely that is occurring as a result of exposure to non-visible aerosols, and not "droplets" as wrongly conceived by the world's major public health authorities.

Below I describe the scenarios where, based on evidence to date, there is likely to be an elevated risk of health care worker occupational infection by COVID-19 aerosol transmission.

Implications of COVID-19 Aerosol Transmission for Respiratory Protection for Health Care Workers

Evidence to date on SARS CoV-2 virus concentrations in respiratory fluids, changes in virus loads over the cycle of infection, liquid volumes expelled by various types of expiratory actions, and the droplet size

[16] *Are health care workers significant vectors for community transmission?* Given the higher risk faced by health care workers, and the likelihood that there are many unrecognized asymptomatic cases among health care workers, it is reasonable to suspect that health care workers make a disproportionate contribution to COVID-19 spread in the community at large. While there are case reports of care workers being index cases for outbreaks in residential long-term care settings, I found no studies that specifically explored the possible role of health care workers as vectors in the community at large.

distributions and flow dynamics of those expiratory actions, can be used to construct reasonable estimates of virus emission rates associated with ordinary breathing, talking, coughing and sneezing. That information, combined with the reasonable assumption that respiratory deposition of 1000 inhaled viruses is the approximate infectious dose, can be used to mathematically model the scenarios where near field care interactions present high risk of aerosol transmission infection in indoor environments.

I have modelled near field exposures for routine health care worker-to-patient encounters[17], and provide simple descriptions of high-risk scenarios in Appendix 3.

In my opinion, N95 respiratory protection for health care workers is warranted for all scenarios described in Appendix 3.

This concludes my commentary.

Yours truly,

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President – REA Group
Adjunct Professor – Dalla Lana School of Public Health, University of Toronto

[17] Models and calculations available on request. "Routine" encounters excludes aerosol generating medical procedures, surgery, respiratory disease physiotherapy, and similar treatment activities.

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Appendix 2 – Letter to the Editor, Bulletin of the World Health Organization

June 2, 2020

Dear Sir / Madam,

Subject: Expression of Concern - Modes of transmission of virus causing COVID-19: implications for IPC precaution recommendations, Scientific Brief, 29 March 2020

This letter expresses concern over what must be considered misleading statements in the World Health Organization document entitled "Modes of transmission of virus causing COVID-19: implications for IPC precaution recommendations, Scientific Brief, 29 March 2020".[18]

The Scientific Brief states "According to current evidence, COVID-19 virus is primarily transmitted between people through respiratory droplets and contact routes" and cites six papers as authority for the statement[19]. The Scientific Brief further defines "respiratory droplets" as those that are ">5-10 µm in diameter".

A careful review of the six referenced papers (five original research, and a WHO Report) reveals that none provide any "evidence" supporting the mode-of-transmission claim quoted above. In fact, none of the authors discuss, speculate on, nor draw conclusions regarding modes of transmission. Three papers (Liu et al, Burke et al, Huang et al) simply note that transmission between cases and new infectees appeared to be related to "close contact". None actually define "close contact", nor conclude transmission was via the "contact route" or "respiratory droplets >5-10 um in diameter". Two papers (Chan et al, Li et al) simply indicate their findings suggest "person-to-person transmission".

The WHO-China Joint Mission Report, also cited as evidence for modes of transmission, claims that "COVID-19 is transmitted via droplets and fomites during close unprotected contact between an infector and infectee" but the Report presents no evidence in support of that statement, and offers no definition of "droplet". In contrast to the inference of the Scientific Brief that the modes of transmission are known, the WHO-China Joint Mission Report

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[18] https://www.who.int/news-room/commentaries/detail/modes-of-transmission-of-virus-causing-covid-19-implications-for-ipc-precaution-recommendations

[19] (1) Liu J, Liao X, Qian S et al. Community transmission of severe acute respiratory syndrome coronavirus 2, Shenzhen, China, 2020. Emerg Infect Dis 2020 doi.org/10.3201/eid2606.200239; (2) Chan J, Yuan S, Kok K et al. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. Lancet 2020 doi: 10.1016/S0140-6736(20)30154-9; (3) Li Q, Guan X, Wu P, et al. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. N Engl J Med 2020; doi:10.1056/NEJMoa2001316; (4) Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020; 395: 497–506; (5) Burke RM, Midgley CM, Dratch A, Fenstersheib M, Haupt T, Holshue M,et al. Active monitoring of persons exposed to patients with confirmed COVID-19 — United States, January–February 2020. MMWR Morb Mortal Wkly Rep. 2020 doi : 10.15585/mmwr.mm6909e1external icon; World Health Organization. (6) Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19) 16-24 February 2020 [Internet]. Geneva: World Health Organization; 2020.

states that one of the "Knowledge gaps and key questions to be answered to guide control strategies…" is the "Role of aerosol transmission in non-health care settings."

The Scientific Brief concludes with this: "Based on the available evidence, including the recent publications mentioned above, WHO continues to recommend droplet and contact precautions for those people caring for COVID-19 patients. WHO continues to recommend airborne precautions for circumstances and settings in which aerosol generating procedures and support treatment are performed, according to risk assessment." These conclusions are not warranted by information contained in the cited authorities.

I leave it to readers to consider the scientific ethics of the misrepresentations outlined above, and the implications for health care workers around the world.

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Appendix 3 – High Risk Routine Encounter Scenarios for Health Care Worker COVID-19 Transmission

Type of Patient / Client[20] Expiratory Action	Estimated Quantity of SARS CoV-2 Emitted from Patient / Client Breathing Zone[21]	Comments on Drivers of the Estimated Quantity	Scenarios Where Aerosol Transmission Could Occur[22]
Breathing Only (with no Talking, Coughing or Sneezing)	100 per minute	While virus concentrations are higher in lung fluid than saliva, breathing generates a very small total volume of expelled liquid, and the small droplet size distribution precludes presence of virus in most droplets and hence nuclei	Well Ventilated Indoor Locations[23]: Face-to-face interactions with infected persons at a distance of 1.5 meters or closer for a cumulative duration of 10 minutes or more during a work shift. Note: if two patients / clients are close together such that there is simultaneous proximity of 1.5 meters or less, that counts as a double exposure for purposes of tallying up total exposure duration. Poorly Ventilated Indoor Locations: The scenario above applies. In addition to the above, cumulative unprotected presence at a distance of more than 2 meters away from the patient's breathing zone, in a single patient / client room for 2 hours per shift. Reduce this pro rata

[20] I use both patient and "client" in recognition of (1) there being care-giving settings where the individual is not ill and not receiving treatment for an illness (e.g. nutrition, counselling, physiotherapy, etc.), and may not be thought of as a "patient", and (2) the likelihood that in those care settings there is a statistical likelihood that the percentage of persons getting care who are SARS CoV-2 positive, asymptomatic and unidentified, will be comparable to the percentage in the general population.

[21] Totals are for inhalable fraction only, which includes any droplet that is originally 100 microns or smaller at the time of expulsion, or which converts to a droplet nucleus 100 microns or smaller before being transported away from the breathing zone of the health care worker. Particles larger than 100 microns are unlikely to be inhaled for aerodynamic reasons.

[22] Patients / clients are assumed to not be masked or have other devices in use to block their expiratory actions.

[23] Herein, "well-ventilated" means a space with total and outside supply air volumes, air velocities, and exhaust volumes (where applicable) in line with recommendations provided in ASHRAE 62.1-2019, or ASHRAE 170-2017.

			for rooms with more than one patient (e.g. maximum 1 hour in that case).
Talking (with no Coughing or Sneezing)	1000 per minute	Higher total volume of liquid expelled, increasing droplet size distribution permits increased prevalence of viruses in expelled droplets.	Poorly Ventilated Indoor Locations: The scenario above applies. In addition to the above, cumulative unprotected presence at a distance of more than 2 meters away from the patient's breathing zone, in a single patient / client room for 12 minutes per shift. Reduce this pro rata for rooms with more than one patient (e.g. maximum 6 minutes in that case).
Coughing	6000 per cough	Much higher total volume of liquid expelled per event, larger droplets almost certain to contain one or more virions. However, virus concentrations in saliva have been found to be one or more orders of magnitude lower than in respiratory fluids, so the larger liquid volume doesn't result in proportionately greater virus shedding.	Well Ventilation Indoor Locations: Any face-to-face interactions with infected persons who are coughing. Poorly Ventilated Indoor Locations: Any entry into a room where the person is present and is, was, or likely will be coughing.
Sneezing	70,000 per sneeze	Very high total volume of liquid expelled per event, most emanating from the sinuses. In addition to underlying low volume distributions of small lower airway droplets, sneezing discharges most of its volume in high velocity liquid sheets that immediately sheer to form large ballistic droplets. The total droplet count can be close to half-million, but most fallout ballistically and / or are too large to be inhaled. Sneezing theoretically presents contact and fomite transmission risks not associated with the other	Well Ventilation Indoor Locations: Any face-to-face interactions with infected persons who are coughing. Face or eye protection also recommended. Poorly Ventilated Indoor Locations: Any entry into a room where the person is present and is, was, or likely will be coughing. Face or eye protection also recommended.

		expiratory events above. While total liquid discharge volume is high, virus concentrations in sinus and oral fluids are much lower than in lung respiratory fluids.	