



# REPORT IN FOCUS

## BY THE COUNCIL OF CANADIAN ACADEMIES

### Influenza Transmission and the Role of Personal Protective Respiratory Equipment: An Assessment of the Evidence

Seasonal influenza and its complications send, on average, about 20,000 Canadians to hospital every year, and approximately 4,000 die. Pandemic influenza occurs when a new strain of the human influenza virus emerges for which people have little or no pre-existing immunity and that can spread efficiently from person to person and become geographically widespread. It is impossible to predict when the next influenza pandemic might occur or how virulent the virus will be.

Given the likelihood of another pandemic, governments and international bodies have developed various plans to help minimize the health, social and economic consequences of such an event. In the context of updating the Canadian Pandemic Influenza Plan for the Health Sector, the Public Health Agency of Canada asked the Council of Canadian Academies to appoint an independent expert panel to assess the current science that is relevant to the following questions:

a) How and where are seasonal influenza and pandemic influenza transmitted based on existing reviews, or where needed, original literature generated from seasonal influenza outbreaks and from previous pandemics?

b) Based on the conclusions of this review, what is your assessment of the contribution that N95 respirators or surgical masks will make to the prevention of transmission of seasonal and pandemic influenza?

The report, *Influenza Transmission and the Role of Personal Protective Respiratory Equipment: An Assessment of the Evidence*, represents the consensus findings of the Expert Panel on Influenza and Personal Protective Respiratory Equipment.

Despite the seasonal occurrence of influenza and its clinical and economic consequences, definitive evidence is lacking regarding the transmission of influenza and the relative contribution of each of the possible modes of

transmission. In the absence of definitive evidence, the panel sought to agree, where possible, on what was most likely.

#### MODES OF INFLUENZA TRANSMISSION

There are two primary routes by which influenza virus exits the respiratory tract of an infected person: (i) expulsion of the virus into the air through sneezing, coughing, speaking, breathing or through aerosol-generating medical procedures, or (ii) by direct transfer of respiratory secretions to another person or surface. The new host acquires the virus either by inhalation of the infectious particles from the air or by contact with infectious material directly or via self-inoculation through a contaminated hand.



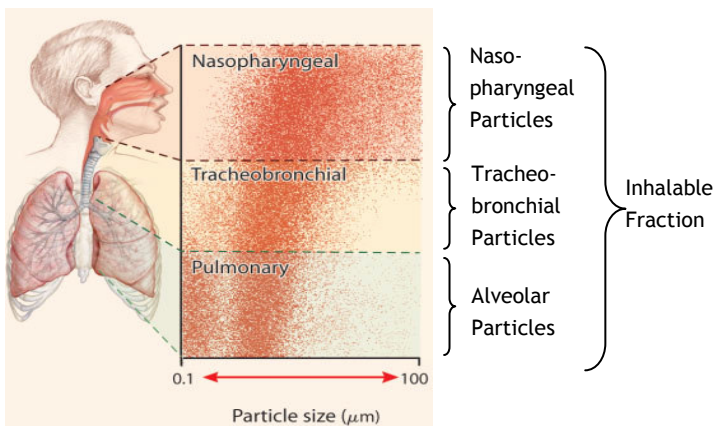
Particle mist created upon sneezing (Davidhazy, 2007).

Traditional infection control terminology has categorized influenza transmission as occurring either by “contact,” “droplet” or “airborne” modes. Since both droplet and airborne transmission involve the inhalation of infectious particles into the respiratory tract, for the purpose of the report these two modes were grouped together under the term “inhalation transmission.”

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A person emits respiratory particles in a wide range of sizes. Expelled particles can be categorized into two groups depending on how they travel – “ballistic” particles and “inhalable” particles. Ballistic particles are those with a mean aerodynamic diameter of greater than approximately  $100\ \mu\text{m}$  and are predominantly affected by gravity, as opposed to air resistance. Their infectious range lies very close to the original point of departure – generally less than a metre. Inhalable particles are those with aerodynamic diameters falling approximately in the range of  $0.1$  to  $100\ \mu\text{m}$  and, depending on size and shape, they may remain in the air from seconds to days.

Where particles are deposited in the respiratory tract of the potential host depends primarily on their size. Ballistic particles can be deposited directly onto mucous membranes but have a low probability of being inhaled. The inhalable particles can be classified into three size categories that have different deposition behaviour. Nasopharyngeal-sized particles range from approximately  $20$  to  $100\ \mu\text{m}$  in diameter and tend to travel no further than the upper respiratory tract. Tracheobronchial-sized particles have a diameter ranging approximately from  $10$  to  $20\ \mu\text{m}$  and are capable of depositing as far down as the tracheobronchial region. Alveolar-sized particles are less than approximately  $10\ \mu\text{m}$  in diameter. They are the only particles capable of reaching the alveolar region but can be deposited anywhere in the respiratory tract.



Deposition regions of the respiratory tract for various particle sizes (adapted from Roy & Milton 2004).

#### **Long-range and Short-range Transmission via Inhalation:**

There is accumulating evidence that, while the risk of acquisition of respiratory pathogens decreases with increasing distance, transmission of infection across distances of greater than one metre may occur. The U.S. Centers for Disease Control and Prevention (CDC) have recently reconsidered the traditional “short-range” distance benchmark (often referred to as the “three-foot rule”) and expanded it to two metres. In the report, *short-range transmission* is defined as infection occurring within about two metres of the source, and *long-range transmission* as infection at distances greater than about two metres.

The persistent survival of influenza virus in ambient air under common environmental conditions suggests that long-range inhalation transmission of influenza is possible. However, direct evidence of its contribution to influenza trans-

mission is sparse. The panel considered a number of studies that bear on the question of long-range transmission of influenza (including all of the most widely-cited), but was unable to draw any conclusions from them as to the presence, absence or relative importance of a long-range mode of transmission of influenza.

Previous reviews and reports have focussed discussion of short-range transmission on the concept of “droplet transmission.” This, however, does not take into account the full range of particle sizes that are expelled from a potentially infectious individual. All particles of inhalable size, whether nasopharyngeal, tracheobronchial or alveolar, can contribute to short-range transmission of influenza. The panel concluded that there is evidence that influenza is transmitted primarily at short range.

**Contact Transmission:** Contact transmission involves transfer of virus either by direct contact (e.g., by kissing) or by indirect contact (e.g., by touching contaminated surfaces). Influenza virus has been shown to persist on external surfaces for upwards of 24 hours depending on the surface type, and on hands for up to five minutes after transfer from the environmental surfaces. It is thus reasonable to assume that mucous membrane inoculation of influenza virus via contaminated hands could subsequently occur. Once present on mucous membranes, viral particles must migrate to a region that contains appropriate receptors, such as the nasopharynx. Although the panel was unable to find evidence of experimental or natural infection of humans with human influenza virus via the mouth or eyes, there is a theoretical possibility that this could occur.

The panel concludes that although the occurrence and relative importance of the contact route for influenza transmission have not been demonstrated, or indeed studied in humans, contact transmission likely occurs. No evidence has been found that hand hygiene or other interventions that might prevent contact transmission (e.g., glove use in healthcare facilities) prevent the transmission of influenza.

**Role of Setting:** Evidence as to the effect of setting on influenza transmission is sparse. One setting in which transmission of influenza is of particular interest is healthcare institutions. Since healthcare workers care for patients with influenza, it may seem logical that they would be at higher risk than others of being infected. While the panel found some evidence that healthcare workers are at higher risk of contracting influenza than the general adult population, these data are not conclusive.

**Seasonal and Pandemic Influenza:** Although there is no evidence to suggest that the modes of transmission of influenza would differ between pandemic and seasonal influenza, there is evidence to suggest that lower inoculums may be required to cause infection during a pandemic because of the absence of prior immunity. This may also mean that infected persons shed virus in higher concentration or for longer periods of time. These factors could increase the risk of transmission, but it is not known if they would alter the *relative* contribution of different modes of transmission as between pandemic and seasonal influenza.

### Conclusions on Modes of Influenza Transmission

1. Ballistic, nasopharyngeal, tracheobronchial and alveolar-sized particles are all emitted from the human respiratory tract.
2. Evidence about the relative contribution of the different modes of transmission to the spread of influenza is sparse and inconclusive.
3. There is evidence that influenza is transmitted primarily at short range.
4. There is evidence that influenza can be transmitted via inhalation of tracheobronchial and alveolar-sized particles at short range.
5. There is evidence that deposition of nasopharyngeal-sized particles in the upper respiratory tract can cause infection.
6. There is evidence that contact transmission can occur. The current weight of evidence suggests that transmission of influenza by inhalation is more probable than by indirect contact.
7. The evidence is lacking to determine whether long-range transmission of influenza occurs, but it cannot be ruled out.

### PROTECTIVE MEASURES AGAINST INFLUENZA TRANSMISSION

The only interventions that have been tried and shown unequivocally to reduce the spread, and to mitigate the impact, of influenza in populations are vaccines and antivirals. Other interventions are nevertheless needed because vaccination will not be 100 per cent effective, and because a vaccine is unlikely to be available during the first wave of a pandemic.

Public health, and occupational health and safety practitioners use a multi-component “hierarchy of control” when developing infection control measures for any disease. The hierarchy comprises three categories – engineering controls, administrative controls and personal protective equipment (PPE). No one category is intended to be used alone. Each component works in conjunction with the others to provide a system of multi-layered protection.

Engineering controls include physical controls such as ventilation requirements, relative humidity and temperature controls, among others. Their biggest benefit is the fact that effectiveness is not dependent on individual practice. Administrative controls are procedural and behavioral measures – e.g., hand hygiene, respiratory etiquette, measures to identify individuals who are likely infected and require separation from others. Effective implementation of such controls has shown to be effective in preventing disease and controlling outbreaks from various pathogens in both healthcare and non-healthcare settings. Administrative controls have two important limitations: (i) individual adherence to preventive practices is needed for success; and (ii) the diffi-

culty of identifying persons who are infectious. Personal protective equipment (PPE) – e.g., goggles, gloves, gowns, surgical masks and respirators – is considered the “last line of defense” against exposure and supplements engineering and administrative controls. Personal protective respiratory equipment (PPRE) is a sub-category of PPE designed to block inhalation of hazardous airborne contaminants.

**Respirators:** The charge to the panel specifically referenced “N95 respirators”, a commonly used term in Canada that refers to NIOSH-certified, disposable, particulate filtering, half facepiece respirators. Only this type of respirator is discussed in the report.<sup>2</sup>

Respirators are designed specifically to ensure capture of particles in the size range that can be inhaled into the respiratory tract, including the entire range of nasopharyngeal, tracheobronchial and alveolar-sized particles. Transmission of infectious material could nonetheless theoretically occur as a result of release back into the surrounding environment of particles that had been trapped in the respirator filter, or by the improper handling of respirators. While there are very few studies that examine particle release from the filter, those that have been carried out suggest that such release is insignificant and unlikely to be of concern. There might also be concern that inadvertent infection could result from improper handling of a contaminated respirator when it is being taken off (“doffing”). Since there are currently no published studies regarding the handling of used filters, it is unknown whether there is a risk associated with handling respirators that have been exposed to infected persons.

The major factor affecting the efficacy of a respirator in preventing inhalation of particles is the adequacy of the seal between the respirator and the user’s face (the “fit”). N95 respirators vary substantially in the quality of fit that is provided to different facial structures. Adequate training of individuals in assessing the fit of the respirator each time it is used, and qualitative or quantitative fit-testing of individuals, have been shown to improve facial fit.

The response of individuals to the use of respirators involves both physiological and psychological factors. The dominant physiological effect is the increase in inspiratory resistance brought on by the airflow resistance provided by the respirator. For most healthcare work, physiological stress is not significant. However, physiology alone cannot adequately explain respirator tolerance. The interplay of various psychophysical sensations such as increased facial skin temperature created by a respirator can overwhelm the capacity of some workers to tolerate the device. Healthcare workers may also perceive that use of a respirator interferes with their ability to communicate with a patient, or otherwise provide patient care.

User compliance with institutional protocols for PPRE is known to be less than 100 per cent. Workers who have been engaged in the planning steps of institutional protocols and feel properly trained in the use of their protective equipment are far more likely to comply with institutional safety policies.



**Surgical Masks:** Surgical masks are not certified to serve as respiratory tract protection for their wearer and are not considered to be PPRE by occupational health and safety practitioners. They are intended to be worn by healthcare workers to protect patients during surgery. Surgical masks have, however, been used for decades to prevent the wearer from exposure to infectious large droplets and from contamination of oral/nasal membranes via the contact route. The relative importance and the effectiveness of surgical masks used to prevent exposure are unknown, as they are typically employed simultaneously with other control measures such as vaccination, antivirals, handwashing, and contact precautions.

Surgical masks worn by infected persons may play a role in the prevention of influenza by reducing the amount of infectious material that is released into the environment. If worn to prevent exposure, surgical masks offer a physical barrier to contact with contaminated hands and ballistic trajectory particles. Their biggest limitation is that they do not provide an effective seal to the face, thereby allowing inhalable particles access to the respiratory tract. In addition, the efficiency of the filters of surgical masks in blocking penetration of tracheobronchial or alveolar-sized particles is highly variable and their efficiency in blocking nasopharyngeal-sized particles is unknown.



Photo of a Surgical Mask – These masks are not considered to be PPRE by Ontario Health and Safety Practitioners.

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Photo of a Particulate Filtering Face Piece – The performance of these respirators depends on the filter efficiency and the fit.

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**Seasonal and Pandemic Influenza:** The protective capacities of PPRE and other interventions apply to both seasonal and pandemic influenza. During a pandemic the absolute benefit of these interventions in preventing disease transmission may be greater than for seasonal outbreaks for reasons related to the previously-noted differences between seasonal and pandemic influenza – e.g., in a pandemic there will be no prior immunity; the disease may be more severe; and a vaccine is unlikely to be immediately available.

#### Conclusions on Protective Measures Against Influenza Transmission

1. The primary elements of protection against influenza transmission are engineering and administrative controls. When exposure to an infected person is required or unavoidable, PPRE is the final layer of protection.
2. N95 respirators protect against the inhalation of nasopharyngeal, tracheobronchial and alveolar-sized particles.
3. Surgical masks worn by an infected person may play a role in the prevention of influenza transmission by reducing the amount of infectious material that is expelled into the environment.
4. Both surgical masks and N95 respirators offer a physical barrier to contact with contaminated hands and ballistic trajectory particles.
5. The efficiency of the filters of surgical masks to block penetration of alveolar and tracheobronchial-sized particles is highly variable. When combined with the inability to ensure a sealed fit, these factors suggest that surgical masks offer no significant protection against the inhalation of alveolar and tracheobronchial-sized particles.
6. The efficiency of the filters of surgical masks to block penetration of nasopharyngeal-sized particles is unknown. The lack of a sealed fit on a surgical mask will allow for the inhalation of an unknown quantity of nasopharyngeal-sized particles.

<sup>1</sup> A micrometer, also called a micron, denoted “ $\mu\text{m}$ ,” is  $10^{-6}$  metre (m).

<sup>2</sup> A filter marked N95 means that it is not resistant to oil and is at least 95 per cent efficient at removing test particulates at the most penetrating particle size of approximately  $0.3 \mu\text{m}$  diameter. (NIOSH refers to the U.S. National Institute for Occupational Safety and Health.)



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