Personal protective equipment (PPE) for both anesthesiologists and other airway managers: principles and practice during the COVID-19 pandemic

Équipements de protection individuelle (EPI) pour anesthésiologistes et autre personnel en charge des voies aériennes: principes et pratiques pendant la pandémie de COVID-19

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Abstract Healthcare providers are facing a coronavirus disease pandemic. This pandemic may last for many months, stressing the Canadian healthcare system in a way that has not previously been seen. Keeping healthcare providers safe, healthy, and available to work throughout this pandemic is critical. The consistent use of appropriate personal protective equipment (PPE) will help assure its availability and healthcare provider safety. The purpose of this communique is to give both anesthesiologists and other front-line healthcare providers a framework from which to understand the principles and practices surrounding PPE decision-making. We propose three types of PPE including: 1) PPE for droplet and contact precautions, 2) PPE for general airborne, droplet, and contact precautions, and 3) PPE for those performing or assisting with high-risk aerosol-generating medical procedures.

Résumé Les professionnels de la santé sont confrontés à une pandémie de coronavirus 2019 (COVID-19). Cette pandémie pourrait durer plusieurs mois, soumettant le système de santé canadien à des pressions jusqu’alors méconnues. Il est essentiel de garder les professionnels de la santé en sécurité, en santé et disponibles tout au long de cette pandémie. Une utilisation cohérente des équipements de protection individuelle (EPI) adaptés nous aidera à garantir leur disponibilité et la sécurité des professionnels de la santé. L’objectif de ce communiqué est de fournir aux anesthésiologistes et aux autres professionnels de la santé de première ligne un cadre leur permettant de comprendre les principes et les pratiques entourant la prise de décision par rapport aux EPI. Nous proposons trois types d’EPI, soit 1) les EPI pour prendre des précautions contre les gouttelettes et le contact; 2) les EPI pour prendre des précautions générales contre les suspensions aériennes, les gouttelettes et le contact; et 3) les EPI pour les professionnels réalisant ou assistant des interventions médicales à haut risque de génération d’aérosols.
Keywords COVID-19 · personal protective equipment · coronavirus

The purpose of this article is to emphasize the primacy of personal protective equipment (PPE) in preventing anesthesiologists and other front-line healthcare providers from contracting coronavirus disease (COVID-19). Without a sustained workforce, healthcare systems risk wide-spread failure in the battle with COVID-19. Infection control training was strongly associated with a decrease in the severe acute respiratory syndrome coronavirus (SARS-CoV) healthcare provider infection rate, and, by extension, the same can be expected for SARS-CoV-2 infection rate. Of the many efforts that are being taken to address this accelerating threat, proper healthcare provider infection control training, on a firm foundation of its associated human factors and the provision of appropriate PPE, is critical.

A brief overview of COVID-19 and “flattening the curve”

On 11 March 2020, the World Health Organization (WHO) declared COVID-19, the disease caused by SARS-CoV-2, a pandemic. As of 14 April 2020, there have been 1,844,863 confirmed cases of COVID-19 in 213 countries, with 117,021 reported deaths; Canada has had 25,680 confirmed cases with 780 deaths. The SARS-CoV-2 virus is spread through inoculation of mucous membranes by droplets and aerosols containing the virus, as well as contact with droplet-contaminated fomites (i.e., surfaces of varying objects and materials). Fomites can act as live-virus reservoirs for hours to days.

Breaking the cycle of infection is a critical goal. Fortunately, the SARS-CoV-2 virus, an enveloped RNA virus, is highly susceptible to destruction with either alcohol-based hand sanitizers or simple soap and water when either is used during handwashing for at least 20 sec. Furthermore, agents used for routine hospital cleaning are sufficient for decontaminating any potential fomite surface.

Coronavirus disease has a spectrum of clinical presentations. Approximately 80% of those infected will have mild disease not requiring hospital care and 15% will have moderate disease requiring oxygen supplementation. Approximately 5% will have severe disease requiring hospitalization that may include intensive care unit admission, endotracheal intubation, and mechanical ventilation.

Predicting how many Canadians will be infected is challenging. Nevertheless, SARS-CoV-2 is highly contagious and without strict social distancing or isolation, it is estimated that each person with COVID-19 disease will infect approximately two to three people (i.e., $R_0 = 2.2–3.6$). Similarly, the SARS-CoV epidemic in 2003 had an $R_0 = 3$ without control measures, which was successfully reduced to 0.4 with control measures. For reference, the Spanish influenza pandemic in 1918 had an $R_0 = 1.4–2.8$, whereas seasonal influenza has an $R_0 = 0.9–2.1$.

Initiatives to “flattening the curve” are being implemented to prevent overwhelming healthcare systems through exponential disease growth. Public education regarding decreasing one’s personal $R_0$ through meticulous hand hygiene, avoidance of self-inoculation (touching one’s mucous membranes), regular cleaning of potential fomites, and social distancing (keeping at least 2 m between people) is the foundation of infection control and prevention. Decreasing inappropriate PPE use by members of the public and oftentimes, healthcare providers themselves, supports sustained access to appropriate PPE over the coming weeks and months, “flattening the curve” of inappropriate PPE use.

Over time, supplies of specific PPE will likely become depleted and equipment from other manufacturers may need to be sourced and substituted. Ensuring healthcare provider safety is a guiding principle of the COVID-19 response, therefore changing equipment and PPE policies can be a source of understandable anxiety. Such changes require clear, consistent communication between front-line healthcare providers and infection prevention and control (IPAC) as to how adherence to PPE principles will be maintained. Through concerns over one’s own welfare or potential shortages of PPE equipment, there may be a motivation to create “homemade” or “MacGyvered” solutions. Communication with IPAC is essential prior to use of these potential solutions. The guiding public healthcare principles of PPE being consistent, predictable, scalable, and evidence-based is fundamental to the COVID-19 response.

We have produced this communique to assist both healthcare providers and institutions in determining the type of PPE required for specific airway procedures and duties when caring for a patient with COVID-19. Our baseline PPE recommendations are in alignment with those of the WHO and Public Health Agency of Canada (PHAC), but we go beyond these baseline recommendations to propose a third tier of protection necessary for high-risk

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A The basic reproduction number, $R_0$, is defined as the expected number of secondary cases produced by a single (typical) infection in a completely susceptible population.
aerosol-generating medical procedures (AGMPs). This
communique presents the rationale for our proposal. As
more is known, these recommendations and our overall
national PPE strategy will likely change.

Respiratory droplets—what healthcare providers need
to know

Understanding respiratory droplet behavior helps to direct
healthcare providers to understand the most appropriate
PPE to use in various patient care situations. Ironically,
Yassi et al. in their 2005 article regarding SARS-CoV
infection of healthcare providers in Vancouver and Toronto
stated “More basic research is needed to determine how
infectious droplets produced by aerosolized procedures
differ from those produced by more ‘natural’ methods such
as coughing or sneezing in terms of their (droplet) size,
their spread, and their infectivity.” Although this
observation was made 15 years ago, basic questions
regarding nosocomial spread during the SARS epidemic,
and now the COVID-19 pandemic, have yet to be
answered. Therefore, it is important to remember that the
“absence of evidence does not mean evidence of absence.”
An observation during the 2003 SARS epidemic was that
droplet and fomite transmission was far easier to study than
airborne transmission, yet airborne transmission did occur.
As epidemiologic information evolves, basic questions regarding SARS-CoV-2 transmission will be
answered. The following reflects what we know thus far.

Respiratory secretions are emitted, and potentially
transmit disease, when a patient speaks, coughs, sneezes,
or when aerosol-generating medical procedures (AGMPs)
are performed. Respiratory secretions consist of water
and mucous that act as propellant envelopes for viral
aerosolization. The amount of viral exposure is
determined by the concentration of virus in the secretions
and the total volume of secretions to which the healthcare
provider is exposed. Therefore, even with appropriate PPE,
fly, it is recommended that the time period of close-proximity
exposure to the patient be as limited as possible (e.g.,
charting done outside the patient’s room).

When patients have an infectious respiratory illness,
average respiratory secretion size may become larger
(compared with uninfected individuals) because of
increased water and mucous production. Decisions
regarding appropriate PPE (e.g., donning a surgical mask
or N95 respirator) are based on the size and dispersion of
the respiratory secretions produced, and the size of droplets
known to be infectious for a specific virus/bacteria. These
characteristics are irrespective of the size of the virus (or
bacterium) itself.

Respiratory secretions can be categorized by size
(Fig. 1). The WHO defines droplets as > 5 μm in
diameter and airborne particles are defined as < 5 μm in
diameter. Specific characteristics of particles vary, with
other sources defining airborne particles as < 5–10 μm or <
10 μm in diameter. Airborne particles are also called
droplet nuclei. Droplets can be further subdivided into
large droplets that fall to the ground or on surfaces within
0.3–0.9 m and small droplets that fall to the ground or on
surfaces within 0.9–1.5 m. For further information
regarding respiratory secretions and their role in viral
transmission patterns, the reader is referred to these useful
reviews.

Droplets (> 5–10 μm) fall on adjacent surfaces (people
or surfaces/fomites) usually within 2 m from the patient’s
respiratory tract. The main mechanism of SARS-CoV-2
transmission and resulting COVID-19 disease include close
proximity to a patient’s respiratory tract or via contact with
fomites contaminated with droplets. To provide a
mechanical barrier to droplet spread (usually limited to
within 2 m of the diseased person’s respiratory tract), it is
advisable that every patient testing positive for SARS-
CoV-2 don a regular surgical mask (not an N95 respirator).
Maintaining a > 2 m distance from a patient with COVID-19 disease (i.e., just as with “social distancing”) should also be practiced whenever possible.

Aerosolized disease transmission is either by droplet or
airborne particle transmission. Aerosol-generating medical procedures (AGMPs) generate both airborne
particles (< 5–10 μm) and both large and small droplets
(> 5–10 μm). Accordingly, AGMPs performed on
patients with acute respiratory infections are thought to
substantially increase the risk of healthcare provider
infection. The risk of healthcare provider infection associated with various AGMPs during the SARS-CoV
epidemic in 2003 can be found in a systematic review by
Tian et al. The exact role that airborne particles (< 5–10
μm) play in the spread of COVID-19 disease remains
unclear. Airborne particle transmission is more
difficult to study compared with droplet transmission.
Nevertheless, in an elegant study by Yu et al., airborne
classical intubation, and tracheostomy (and by logical
extension, cricothyrotomy), are considered high-risk
AGMPs (Table 1).29 The amount of aerosols generated from placement and use of a supraglottic airway is currently unknown. Because of the hazards of suspended aerosolized respiratory secretions in closed spaces where AGMPs have occurred, healthcare providers who must enter those spaces for patient care should use airborne, droplet, and contact PPE.33

The time following the AGMP for which that airborne, droplet, and contact PPE would be required is determined by the time it takes to dissipate airborne particles. This amount of time is determined by a number of factors. The “dose” of airborne particles to be cleared will partly depend on the specific AGMP performed and the time taken to complete it. The number of air exchanges per hour of the patient’s room is another major determinant (Table 2).34 Whether the room is negative- or positive-pressure will determine the path of egress for airborne particles, not necessarily the time for egress.

Level of care determines appropriate PPE

On 13 March 2020, Dr. Michael J. Ryan, Chief Executive Director of the WHO Health Emergencies Programme, stated:

“One of the great things in emergency response and anyone who’s involved in emergency response will know this, if you need to be right before you move you will never win. Perfection is the enemy of the good when it comes to emergency management. Speed trumps perfection and the problem in society we have at the moment is everyone is afraid of making a mistake. Everyone is afraid of the consequences of error, but the greatest error is not to move. The greatest error is to be paralyzed by the fear of failure.”35

Here, we review evidence regarding transmission of COVID-19 as well as research findings prior to the present...
COVID-19 pandemic including those on SARS, middle east respiratory syndrome (MERS), and influenza A (H1N1). While details regarding SARS, MERS, and influenza may not be completely applicable, they provide models from which to work. Our recommendations align with current PPE recommendations of Ontario Public Health (6 April 2020) and the PHAC (24 February 2020). We present the rationale for our proposal of a third tier of PPE specifically for high-risk AGMPs not previously outlined by Ontario Public Health, the PHAC, or the WHO.

Likely the best information we have at present is found in a 2012 systematic review of SARS-CoV-infected healthcare providers based on their participation in a variety of AGMPs. Healthcare providers participating in specific AGMPs were compared with other healthcare providers not participating in these specific procedures, with the results expressed as odds ratios (Table 1). The primary studies tended to be small cohort or case-control studies with variable follow-up. As a result, some AGMPs have measures of association with wide 95% confidence intervals, reflecting the imprecision of what is currently known. Across multiple studies, the most consistent association with healthcare provider infection was tracheal intubation.

Table 1 contains examples of AGMPs that are known to be high-risk because of exposure to a high concentration of aerosols. Unfortunately, the risk of aerosol production is unknown for many AGMPs. Current airway management,

Table 1 Selected odds ratios of SARS-CoV transmission to healthcare professionals exposed and not exposed to AGMP

| Procedure                                      | Odds ratio (95% confidence interval) | Risk       | PPE |
|------------------------------------------------|--------------------------------------|------------|-----|
| Tracheal intubation                            | 6.6 (2.3 to 18.9)                    | high       | high-risk AGMP |
| Bag-mask manual ventilation before tracheal intubation | 2.8 (1.3 to 6.4)                    | high       | high-risk AGMP |
| Tracheotomy (and by extension, cricothyrotomy) | 4.2 (1.5 to 11.5)                    | high       | high-risk AGMP |
| Placement of supraglottic airway device (SGA)   | Unknown                              | assumed high based on bag-mask manual ventilation, no studies | high-risk AGMP |
| Tracheal extubation or SGA removal              | Unknown                              | assumed high, perhaps higher than tracheal intubation due to lack of paralysis and potential coughing during emergence | high-risk AGMP |
| Chest compressions                              | 1.4 (0.2 to 11.2)                   | unknown, may depend on tracheal intubation status of patient* | unclear |
| Defibrillation                                  | 2.5 (0.1 to 43.9)                   | unknown, may depend on tracheal intubation status of patient* | unclear |
| Manipulation of BiPAP mask                      | 6.2 (2.2 to 18.1)                   | high (based on single cohort study) | high-risk AGMP |
| Manipulation of oxygen mask                     | 4.6 (0.6 to 32.5)                   | unclear (2 cohort studies) | unclear |

All odds ratios are from Tran et al. AGMP and risk of transmission of acute respiratory infections in healthcare workers: a systematic review. PLoS ONE 2012; DOI: 10.1371/journal.pone.0035797. AGMP = aerosol-generating medical procedure; BiPAP = bi-level positive airway pressure; PPE = personal protective equipment SARS = severe acute respiratory syndrome

*Based on current knowledge of tracheal intubation effect on AGMP

Table 2 Time (in min) to remove airborne particles based on the air changes per hour (ACH) of a room*

| Air changes per hour | Time (mins) required for removal (99% efficiency) | Time (min) required for removal (99.9% efficiency) |
|----------------------|---------------------------------------------------|---------------------------------------------------|
| 2                    | 138                                               | 207                                               |
| 4                    | 69                                                | 104                                               |
| 6                    | 46                                                | 69                                                |
| 8                    | 35                                                | 52                                                |
| 10                   | 28                                                | 41                                                |
| 12                   | 23                                                | 35                                                |
| 15                   | 18                                                | 28                                                |
| 20                   | 14                                                | 21                                                |
| 50                   | 6                                                 | 8                                                 |

Derived from the CDC: Guidelines for Environmental Infection Control in Health-Care Facilities (2003). Available from URL: https://www.cdc.gov/infectioncontrol/guidelines/environmental/appendix/air.html

*Assuming airborne particles are NOT continuing to be generated (i.e., after tracheal intubation)

including primary use of videolaryngoscopy, supraglottic device placement for rescue oxygenation, and the simplification of cricothyrotomy in “can’t intubate, can’t oxygenate” emergencies may play a role in changing these odds ratios during COVID-19 compared with SARS. Healthcare provider risk during extubation of patients with SARS or COVID-19 disease currently remains unknown. Arguably, extubation is a higher risk procedure
compared with intubation given the lack of neuromuscular blockade, spontaneous ventilation, and patient coughing risk.

For PPE in the context of COVID-19, WHO, PHAC and other organizations have made recommendations for two different tiers of PPE precautions: *droplet and contact precautions* for direct patient care not involving AGMPs, and *airborne, droplet, and contact precautions* when aerosol generation is expected (e.g., AGMPs). There are specific healthcare provider exposure areas identified for certain high-risk AGMPs that airway managers may encounter. Both the potential for contamination at the wrist (despite a single pair of gloves) and at the neck have been reported.16,38,39

Given the increased risk of transmission from high-risk AGMPs that airway managers and their airway assistants will be performing, and evidence of incomplete coverage provided by standard *airborne, droplet, and contact precautions* alone, we propose modifications that include head and neck protection as well as a second pair of gloves.40 These additions address the heavy respiratory secretion contaminant load that occurs with high-risk AGMPs.41 Our recommendations advocate for a three-tiered approach to PPE (Fig. 2):

1. **Droplet and contact precautions**
2. **Airborne, droplet, and contact precautions**
3. **Airborne, droplet, and contact precautions for high-risk AGMPs**.

The COVID-19 patient should wear a surgical mask whenever possible. Surgical masks, also called face masks, are loose-fitting and inhibit droplet transmission of viral or bacterial diseases.42 N95 respirators are tight-fitting and prevent inhalation of 95% of airborne particles.42 Given the variation of facial size and proportions, N95 masks must be “fit-tested” to ensure an adequate user seal. Proper donning of an N95 mask (i.e., not pinching the nose bridge but ensuring it fits along the entire maxilla) is a critical step in adequate PPE.43

Personal protective equipment for *droplet and contact precautions* includes a surgical mask, eye protection (goggles or procedure mask with face-shield), an Association for the Advancement of Medical Instrumentation (AAMI) level-2 gown, and gloves that overlap the gown sleeve enough to prevent wrist exposure.

**Figure 2** Decision-making for appropriate PPE in COVID-19 for anesthesiologists and other airway managers. The decision as to the most appropriate personal protective equipment (PPE) to use in COVID-19 patients is based on the clinical care being undertaken. For care not involving high-risk aerosol-generating medical procedures (AGMP), use *droplet and contact precautions*, which include a surgical mask with face-shield, Association for the Advancement of Medical Instrumentation (AAMI)-level 2 gown, and single gloves, as shown in panel A (used with permission from Lockhart et al.).48 For a healthcare provider present in the room during an AGMP, use *airborne, droplet, and contact precautions* which include an N95 respirator, eye shield, head covering, AAMI level-2 gown, and single gloves, as in panel B. If you are performing (or directly assisting in) the AGMP itself, then *airborne, droplet, and contact precautions* should be worn that additionally include a AAMI level-3 gown, neck cover, and 2 pairs of gloves (both panels C and D are considered equivalent levels of PPE).
during movement.\textsuperscript{40} Gowns may offer better protection than aprons.\textsuperscript{40}

Personal protective equipment for \textit{airborne}, \textit{droplet}, and \textit{contact precautions} consist of head covering, eye protection, N95 respirator, an AAMI level-2 (or higher) gown, and a single pair of gloves overlapping the gown sleeve enough that movement does not expose the wrists.\textsuperscript{40} We recommend \textit{airborne}, \textit{droplet}, and \textit{contact precautions} be maintained for the period of time required to disperse airborne particles as per local IPAC guidelines. The expected dispersal of airborne particles in a room (as a function of air changes per hour) has been reported by US Centers for Disease Control (Table 2).\textsuperscript{34} The role that airborne particles (< 5–10 μm) play in the spread of COVID-19 disease remains unclear. Nevertheless, it has been shown to occur opportunistically\textsuperscript{19} during the SARS-CoV spread.\textsuperscript{20} The addition of \textit{airborne precautions} to the usual recommendation of \textit{droplet and contact precautions} is likely not required for most routine patient care situations. Once the recommended dispersal times following an AGMP has elapsed, \textit{droplet and contact precautions} can be resumed.

The use of PPE for \textit{high-risk AGMP precautions} should be reserved for healthcare providers only directly involved in the performance of high-risk AGMPs—e.g., airway managers and assistants. In addition to the \textit{airborne}, \textit{droplet}, and \textit{contact precautions} above, we recommend neck covering, a gown with AAMI level-2 (or higher), and two sets of gloves that overlap the gown sleeve enough to prevent wrist exposure during movement (Fig. 2). In a 2019 Cochrane review of PPE, double gloving was associated with less contamination than single gloving (relative risk, 0.36; 95% confidence interval, 0.16 to 0.78).\textsuperscript{40} It also allows the healthcare provider performing airway management to doff a heavily soiled pair of gloves without breaching their overall PPE.

Limiting the number of people in the room when a high-risk AGMP is taking place is critical as it reduces the number of people exposed and assists in preserving the PPE supply. Due to the nature of high-risk AGMPs, it may not be possible for the patient to wear a surgical mask; however, if possible, one should be donned by the patient.\textsuperscript{27}

There is some controversy over whether neck covering is required when performing high-risk AGMPs, we would advocate for its inclusion as long as it does not impair the operator’s neck movement, particularly during airway management. Neck protection helps decrease the droplet contamination shown to occur in this area.\textsuperscript{38,39} We recognize that neither neck nor head protection is included in the current WHO\textsuperscript{15} or PHAC\textsuperscript{37} guidelines for high-risk AGMPs. While the airway managers’ wrists are easily decontaminated through requisite hand-washing both during and after the doffing procedure, the neck and head areas are not. The neck area has been identified as a zone of high contamination during simulated airway management AGMPs.\textsuperscript{38,39} While the head and neck do not contain mucous membranes, they are in close proximity above and below facial mucous membranes. If contaminated, these exposed areas could serve as a source of further contamination both during the PPE doffing process or afterwards during clothing removal. This is particularly true when removing other clothing in an over-the-head fashion (e.g., surgical scrubs or sports bras). Therefore, we propose head and neck covering, when done properly in a coordinated manner with other PPE equipment, could potentially reduce the risk of subsequent self-contamination by reducing the amount of skin exposure and contamination at the outset while preforming high-risk AGMPs. We also advocate for the availability of resources to allow healthcare providers access to shower facilities after directly participating a high-risk AGMP, if possible. While a post-doffing shower has not been studied, there is likely little harm.

Importantly, there may be certain situations where personnel not directly involved in the high-risk AGMP must remain in the room—e.g., cardiac arrest or fetal distress. There is no clear guidance to inform the optimal PPE strategy in these situations and research is ongoing. Nevertheless, the International Liaison Committee on Resuscitation currently recommends that (assuming the patient is not already tracheally intubated) during chest compressions, the same PPE be used as for other AGMP, which is currently identified as \textit{airborne, droplet, and contact precautions}.\textsuperscript{44} Defibrillation, a time sensitive intervention, should be considered during the donning of high-risk AGMP PPE. An automated chest compression device (e.g., LUCAS Chest Compression System; Stryker Medical, Portage, MN, USA) should be considered to decrease healthcare provider exposure.\textsuperscript{45} Therefore, the minimum amount of PPE worn by all providers during cardiac arrest resuscitation should consist of \textit{airborne, droplet, and contact PPE}. If any airway management is required, those directly involved and unable to step away (or out of the room) should don PPE with \textit{airborne, droplet, and contact precautions} for high-risk AGMPs.\textsuperscript{45}

Disposable shoe covers may or may not increase risk of self-contamination during the doffing process as evidence is only from small studies.\textsuperscript{46} Coveralls with an integrated hood (i.e., “bunny suit”) may theoretically have the advantage of simplifying the doffing process (e.g., by removing a single garment that integrates gown, neck cover, and head cover). Nevertheless, doffing a one-piece coverall can also be complex and must be practiced. It does not eliminate the need for a doffing spotter or person to guide the doffer through the doffing process. There is
Table 3  Principles of personal protective equipment (PPE)

| PRINCIPLE                                                                 | PRACTICE                                                                                                                                 |
|---------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Protect healthcare providers through appropriate PPE                      | Appropriate PPE depends on exposure risk, separated into three types:                                                                      |
|                                                                           | (1) Contact and droplet precautions                                                                                                      |
|                                                                           | (2) Airborne, droplet and contact precautions                                                                                                |
|                                                                           | (3) Precautions for high-risk aerosol-generating medical procedures (AGMPs).                                                              |
| There is no “ideal” PPE                                                  | Supplies of specific PPE equipment may become depleted and other equipment substituted. Front-line and IPAC (infection prevention and control) healthcare professionals must work together locally to co-ordinate and train healthcare professionals on PPE equipment and donning and doffing procedures during these changes. |
| Do not “MacGyver” homemade combinations of PPE without IPAC approval      | Creation of “homemade” or “MacGyvered” PPE without IPAC knowledge and approval potentially places healthcare professionals at risk, and undermines the public healthcare principles of consistent, predictable evidence-based prevention of disease spread during an infectious outbreak. |
| During high-risk AGMPs, decrease exposure of healthcare providers by        | Only those required to perform the procedure should be in the room during an AGMP.                                                        |
| limiting those present to essential providers only                        | A dedicated “runner” donned in airborne, droplet and contact precautions outside the room for additional equipment is recommended.          |
|                                                                           | We recommend airway managers have the assistance they would normally require for that particular AGMP in the room with them, donned in PPE for high-risk AGMP. |
| Donning (putting on) PPE should be in accordance with institutional        | A checklist is essential. Donning should be performed with a spotter who can observe and correct inadequacies (e.g., tuck head covering into goggles to cover forehead) during the process. Appropriate donning of a fit-tested N95 respirator is critical. |
| guidelines                                                                |                                                                                                                                          |
| Pay attention to how you don to augment your ease of doffing              | For AGMPs, your N95 respirator goes on first so it can come off last. Tie a bow rather than a knot on the front of your surgical gown; loop rather than tying anything at the back of your surgical gown to aid easy removal and avoid tearing the gown. |
| Contamination of a healthcare provider can occur in the patient’s room or | Contamination in the patient’s room should trigger immediate careful doffing when it is safe to do so. Re-donning of PPE should occur outside the patient’s room should returning to the patient’s room be required. There are currently no specific measures recommended should self-contamination during the doffing process occur. We recommend consulting the institutional IPAC team as outlined below. |
| during the doffing process                                                |                                                                                                                                          |
| Doffing (PPE removal) is a high-risk procedure because of risk of self-   | Interruptions, distractions, and tangents during the doffing protocol are hazardous to all healthcare providers involved. Doffing should be considered a “sterile cockpit” situation. The most effective strategy to prevent self-contamination during doffing is the presence of a spotter, reading the doffing checklist step-by-step, and/or usage of clear signage describing the steps. |
| contamination that is not necessarily detected by the doffing healthcare  |                                                                                                                                          |
| professional                                                               |                                                                                                                                          |
| The surgical mask or N95 respirator should be the last item removed       | Removal should be done very last, and in the anteroom, or outside the patient’s room when there is no anteroom available. Avoid touching the front of the surgical mask or N95 respirator during doffing. |
| PPE donning and doffing requires education and practice prior to their    | Practicing PPE donning and doffing enhances patient safety by improving speed and efficiency. It also reduces PPE wastage by preventing the need to don and doff repeatedly due to self-contamination or breaching of PPE. |
| use during patient care                                                   |                                                                                                                                          |
| Hand hygiene performed throughout the donning and doffing processes      | Many PPE guidelines recommend hand hygiene be applied to gloves prior to the doffing process to decrease possibility of self-contamination by the healthcare provider’s hands should a doffing breech occur. |
| should be done according to your institution’s IPAC guidelines            |                                                                                                                                          |
Currently, no specific measures are recommended for self-contamination during the doffing process. Liaise with your IPAC to classify contamination as high, moderate, or low risk. A course of action can be determined based on risk of exposure. Some centres are recommending healthcare professionals take a shower with soap post-AGMP, whether self-contamination occurs or not. This seems reasonable at present until more guidance is known.

Doffing PPE

The exact PPE doffing process will depend on the specific components of the PPE used. Nevertheless, there are a few overarching principles worth highlighting. Doffing of PPE is the highest risk time for self-contamination. It is important to consider the interplay between the PPE itself and the human factors that can play a role in the safety of the healthcare provider. For example, the healthcare provider may be relieved that an AGMP has been completed successfully, upset that it has not, or psychologically stressed for various reasons. As a result, it is easy for the provider to “let their guard down” and lose concentration. In addition, for healthcare providers accustomed to doffing a surgical gown by ripping it off (as was routinely done prior to COVID-19), this must be “unlearned” to reduce the potential of contaminating oneself and others through secretions on the gown. Doffing of PPE involves an entirely different set and sequence of maneuvers.

Healthcare providers must routinely manage interruptions during the course of their work. Doffing should be considered a “critical moment” when nothing except communication related to the doffing itself should be discussed. This is similar to the concept of the “sterile cockpit” from the aviation industry. Other suggestions regarding donning and doffing can be found in Table 3.

In a 2019 Cochrane review studying PPE to protect healthcare providers in highly infectious situations, the biggest risk reduction was found in having a “doffing spotter” read aloud each of the various steps during the doffing process itself. Your health and safety depend on your complete attention and compliance to the doffing instructions. Proper education and training ahead of time, signage in the doffing area, and simulation/practice in doffing with a “doffing spotter” can help reduce self-contamination during the doffing procedure. The ability to self-assess contamination during the doffing process is inadequate.

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**Table 3 continued**

| PRINCIPLE                                                                 | PRACTICE                                                                 |
|--------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Track and protect PPE supply                                              | Alcohol sanitizer to the area of contamination for > 20 sec is reasonable. More recommendations may be produced as more is known. |
| Promote scalable, generalizable innovations in accordance with institutional IPAC | Some centres are recommending healthcare professionals take a shower with soap post-AGMP, whether self-contamination occurs or not. This seems reasonable at present until more guidance is known. |
|                                                                          | Educate staff around appropriate PPE use determined by level of care required (droplet/contact vs AGMP, infrequently airborne). |
|                                                                          | Get involved in innovative projects (e.g., 3D-printing, design, advertising for N95 masks from the community or companies etc.) |
Conclusions

Healthcare providers are facing a COVID-19 pandemic that may last for months, stressing the Canadian healthcare system (and others) in a way that has not been previously seen. Keeping healthcare providers safe and well through maintaining the availability of appropriate PPE supplies is essential to keep the healthcare system functional. We encourage all healthcare providers to engage with their infectious disease colleagues (e.g., IPAC). Collectively, we will manage this pandemic if we continue to work together for the safety and health of all.

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