

Powered Air Purifying Respirators (PAPRs) as an Alternative to N95 Respirators in a Health Care Setting: Supplemental Information

Key Messages

This supplemental information was generated to support decision-making and to provide information on powered air purifying respirators (PAPRs) during the novel coronavirus disease (COVID-19) pandemic.

We examined the recommendations from national and international health authorities and organizations and completed a targeted search of published literature. We found the following:

- One research study found that ultraviolet germicidal irradiation was effective in the decontamination of PAPRs from influenza virus, but fully automated reprocessing may not be feasible. A single crossover study found that wearing enhanced respiratory and contact precaution personal protective equipment was associated with greater contamination after doffing than PAPRs. Training and mechanisms for safe removal are needed for PAPRs.

Background and Context

On April 7, Ontario Health (Quality) received a request from the Ontario Health Secretariat for information around powered air purifying respirators (PAPRs) during the novel coronavirus disease (COVID-19) pandemic. In response to that request, this supplementary information provides a summary of the evidence from Ontario Health's rapid evidence summary (March 31) and from a targeted search for published scientific literature and guidance.

Guidance and Peer-Reviewed Studies

Reprocessing of PAPRs

Research Study: Ultraviolet Germicidal Irradiation

Heimbuch et al (2019)¹ concluded the following:

- Ultraviolet germicidal irradiation is effective at reducing viable influenza on half-mask elastomeric respirators (HMERS) and most PAPR surfaces, but its effectiveness can be limited by the materials involved (e.g., fabric strap)
- Manual reprocessing is time-consuming and relies on the ability of the reprocessor to be effective
- The design of some PAPR components limits the ability of PAPRs to be reprocessed using manual or automated methods (e.g., inaccessible crevices, electrical components, fabric straps)
- Both HMERS and PAPRs can be manually reprocessed up to 150 times with no significant degradation of performance
- Most HMER models can be reprocessed using automated methods (e.g., washer-disinfector), but the temperature conditions must be reduced for compatibility with existing commercially available HMERS
- The automated reprocessing of PAPR components has limited utility due to the incompatibility of the blower unit with washer-disinfectors and the potential reduction in visibility when visors are treated with the same method

Guidance

NEBRASKA MEDICINE COVID-19 PPE GUIDANCE: EXTENDED USE AND LIMITED REUSE OF DISPOSABLE FACEMASKS, RESPIRATORS AND PROTECTIVE EYEWEAR (2020)²

- Respirators include PAPRs
- Instructions for the *limited reuse* of PAPR hoods; Disinfection and storage of PAPR components including the hood for re-use; Disinfection, disposal and storage of used PAPR components

CENTERS FOR DISEASE CONTROL AND PREVENTION: INTERIM DOMESTIC GUIDANCE ON THE USE OF RESPIRATORS TO PREVENT TRANSMISSION OF SARS (2003)³

When elastomeric (rubber) respirators or PAPRs are used, their reusable elements should be cleaned and disinfected after use, in accordance with the manufacturer's recommendations. When half- or full-facepiece elastomeric negative pressure respirators are used by more than one person, filters should be replaced between users. When PAPRs are used, the filters should be replaced following the manufacturer's recommendations. All used filters must be safely discarded.

Contamination Risk When Donning/Doffing PAPRs

Research Studies

Zamora et al (2006)⁴ compared self-contamination rates and levels of contact and droplet protection associated with enhanced respiratory and contact precautions (E-RCP) and a personal protective system that included a full body suit, personal protective equipment (PPE), and a PAPR in a prospective, randomized, controlled crossover study. In the study, 50 participants donned and doffed E-RCP and PAPR in random order, and areas of contamination (fluorescein solution and ultraviolet-light-detectable paste) were counted and measured in square centimetres.

- Participants wearing E-RCP were more likely to experience contamination of any size, contamination with an area of 1 cm² or more, and a larger total area of contamination when it was present (all $P < 0.0001$). The anterior neck and the forearms, hands, and wrists were the zones most likely to be contaminated
- Donning and doffing protocol violations were more common in the PAPR group ($n = 15$) than in the E-RCP group ($n = 2$; $P = 0.003$).
- Donning and doffing of PAPR took significantly more time on average than donning and doffing of E-RCP ($P < 0.0001$ for both)

An abstract of a study from Chughtai et al (2018)⁵ examined PPE donning and doffing sequences recommended by various health organizations for Ebola. Sequences that used PAPRs and assisted doffing were generally associated with fewer problems and rated the highest. The authors recommended that protocols using PAPRs and assisted doffing should be preferred whenever possible during the outbreak of highly infectious pathogens.

Mumma et al (2018)⁶ conducted a human factors analysis of contamination risk behaviour among health care workers when doffing Ebola-level PPE. Key findings are summarized for PAPRs in Table 1 below; failures are presented in descending order of frequency.

Table 1: Mumma et al (2018)⁷—Key Findings

Doffing Step	Failures^a	Effect(s)	Estimated Contamination Severity
Remove PAPR hood	PAPR hood contacting exposed arms	Spreads contamination to HCW	Significant
Remove PAPR hood	Touching ties excessively	Spreads contamination to PPE	Significant
Remove PAPR hood	Squeezing front of face shield to remove from peg	Spreads contamination to PPE	Marginal
Remove PAPR hood	Pulling PAPR hood off by grabbing near front rather than the back	Spreads contamination to PPE, disrupts process sequence/delays process	Marginal
Remove PAPR hood	Touching face shield excessively	Spreads contamination to PPE	Marginal
Remove PAPR hood	Bumping into door (e.g., with PAPR hood, scrub shoulder)	Spreads contamination to environment	Significant
Remove PAPR hood	TO's arm contacting PAPR battery cord	Spreads contamination to PPE (TO)	Marginal
Remove PAPR hood	HCW almost handing PAPR hood to TO	Spreads contamination to PPE (TO), disrupts process sequence/delays process	Significant
Remove PAPR hood	Touching PAPR hood excessively	Spreads contamination to PPE	Significant
Remove PAPR hood	Dropping PAPR helmet onto floor	Equipment damage	Marginal
Remove PAPR hood	Grabbing PAPR hood too far back	Disrupts process sequence/delays process	Marginal
Remove PAPR hood	TO saying, "Unsnap PAPR hood" before "Untie PAPR hood"	Disrupts process sequence/delays process	Marginal
Remove PAPR hood	Unsnapping hood before untying ties	Disrupts process sequence/delays process	Marginal
Remove PAPR helmet	Wiping face with scrub shoulder	Spreads contamination to HCW	Critical

Abbreviations: HCW = health care worker; PAPR, powered air purifying respirator; PPE, personal protective equipment; TO, trained observer.

^aIn descending order of frequency.

Mumma et al (2019)⁸ studied behaviour and errors during Ebola PPE doffing protocols and found that common failures during the doffing of PAPR hoods were removing the PAPR hood by pulling from the front (not from the back) and inner gloves touching the face shield. Having a trained observer remove the PAPR hood mitigated the risk during removal.

Wong et al (2020)⁹ described the outbreak response measures of the anesthetic department staffing the largest (1,700-bed) academic tertiary-level acute care hospital in Singapore (Singapore General Hospital) and a smaller regional hospital (Sengkang General Hospital) during the COVID-19 outbreak. Based on their experience, they summarized the pros and cons of PAPRs (Table 2).

Table 2: Wong et al (2020)¹⁰—Pros and Cons of PAPRs

Pros	Cons
<ul style="list-style-type: none"> • Higher protective factor than N95 respirators • Provide eye protection (hooded models only) • More comfortable to wear than N95 respirators • Can be used if the user has facial hair (not possible with N95 respirators) • Hooded models do not require fit-testing (unlike N95 respirators) • Eliminate possibility of unexpected poor N95 respirator fit • Less likely to be dislodged when managing an agitated patient • Hooded models may provide additional protection against contamination compared to the typical gear worn with an N95 respirator 	<ul style="list-style-type: none"> • No definitive evidence that PAPRs reduce likelihood of viral transmission for potential airborne infections • Inability to auscultate for heart and lung sounds (for hooded models) • Challenges in communication • Patient apprehension (especially among pediatric patients) • Training on use, doffing, and care is needed to prevent contamination • Requires decontamination after use • More expensive than N95 respirators • Inability to reuse disposable filters between patients (need large supply of filters) • Need to train staff repeatedly to maintain competency if not frequently used • Risk of battery failure and inadvertent exposure

Guidance

The United States Food and Drug Administration¹¹ reissued a letter on March 28, 2020, incorporating an amendment to authorize the emergency use of (among other items) other powered air purifying respirators (PAPRs) approved by the National Institute for Occupational Safety and Health (NIOSH), in accordance with 42 CFR Part 84, and that are listed on the NIOSH CEL for PAPRs with particulate protection.

MASSACHUSETTS GENERAL HOSPITAL 2019 NOVEL CORONAVIRUS TOOLKIT: PLANNING DOCUMENTS FOR PATIENTS REQUIRING AIRBORNE ISOLATION + CONTACT ISOLATION + EYE PROTECTION¹²

- Doffing is the most important part of safely using PPE in these patients. Checklists demonstrate the appropriate doffing sequence when using an N95 respirator or a PAPR. Adaptation will need to be made based on an organization's PPE.
- Training of clinicians can be supported with videos. Links to videos using the included checklists are provided in this guidance. Except for PAPR, PPE should be removed at a doorway or in an anteroom if present.

3M TECHNICAL BULLETIN ON POSSIBLE ALTERNATIVES TO SURGICAL FILTERING FACEPIECE RESPIRATORS: HEALTHCARE¹³

- Key attributes of PAPRs
 - Effectively filter airborne biological particles such as viruses and bacteria
 - Designed to fit over some facial hair
 - Variety of styles and facepiece/headtop offerings
- Key potential advantages
 - Wide variety of headtops
 - Limited facial hair permitted for loose-fitting headgear
 - Eye protection (certain headgear)
 - More of face visible
 - Low breathing burden and increased comfort for longer wear time
- Key potential limitations
 - Storage, cleaning, maintenance
 - Care, charging, and life of PAPR batteries
 - Weight and size
 - Communication

PUBLIC HEALTH AGENCY OF CANADA: INFECTION PREVENTION AND CONTROL MEASURES FOR EBOLA VIRUS DISEASE IN HEALTHCARE SETTINGS¹⁴

“While some facilities have chosen to use powered air purifying respirators (PAPRs), these are not required for the care of patients with Ebola virus disease. Their removal poses a recognized risk for self-contamination if worn by health care workers who are not adept at their use and removal. Effective cleaning of reusable components of the equipment is challenging, requiring multiple steps.”

Use of PAPRs in Intensive Care Units or Emergency Departments During COVID-19

Research Studies

A targeted search revealed no research studies specifically set in the intensive care unit or emergency department.

Guidance

AUSTRALIAN AND NEW ZEALAND INTENSIVE CARE SOCIETY¹⁵

Powered air purifying respirators are above the recommended standard for staff protection against COVID-19. However, in units where their use is already in place and appropriate training is available,

they may be considered for aerosol generating procedures (AGP) such as semi-elective intubations or prolonged continuous care of non-intubated patients.

BRITISH COLUMBIA CENTRE FOR DISEASE CONTROL: USE OF A POWERED AIR-PURIFYING RESPIRATOR (PAPR)¹⁶

Current knowledge about the transmission dynamics of COVID-19 does not indicate the need for PAPR use. There may be unique individual circumstances (e.g. facial structure, unable to be successfully fit tested for an N95 respirator) that could interfere with correct surgical mask or N95 respirator use. In these cases, consult your health authority's workplace health and safety, medical microbiology and infection prevention and control personnel. In some health care worker roles, such as BC Ambulance/BC Emergency Health Services paramedics, where transport times may be very long and occur in small closed spaces, PAPR use may be warranted.

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