To PAPR or not to PAPR?

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The present outbreak of Ebola has health care professionals seeking guidance on isolation precautions for routine care and aerosol-generating procedures (AGPs). The most recent guidelines state that during AGPs, health care professionals should wear respiratory protection at least as protective as a National Institute for Occupational Safety and Health-certified fit tested N95 filtering face piece respirator or higher; for example, a powered air-purifying respirator (PAPR). The present review discusses the advantages and disadvantages of using a PAPR versus an N95 mask, and relates the experience of the Jewish General Hospital (Montreal, Quebec) of PAPR policy implementation. Training programs on proper donning and doffing of personal protective equipment and quality control systems need to be in place. Respiratory therapists are frontline during AGPs and need to be active in the decision making of the type of equipment chosen to protect them.

Key Words: *Aerosol-generating procedures; Ebola; Infection control; Personal protective equipment; Power air-purifying respirator*

Utiliser l'ARAA ou non?

La présente éclosion du virus Ebola incite les professionnels de la santé à chercher des conseils sur les précautions en matière d'isolement dans les soins habituels et les interventions produisant des aérosols (IPA). D'après les lignes directrices les plus récentes, pendant les IPA, les professionnels de la santé devraient porter un dispositif de protection des voies respiratoires qui leur procurera une barrière au moins aussi efficace qu'un masque N95 ayant fait l'objet d'un essai d'ajustement certifié par le *National Institute for Occupational Safety and Health*, tel qu'un appareil respiratoire à adduction d'air (ARAA). La présente analyse traite des avantages et des inconvénients de l'ARAA par rapport au masque N95 et rend compte de l'expérience de l'Hôpital général juif de Montréal, au Québec, qui a adopté une politique d'utilisation de l'ARAA. Il faut adopter des programmes de formation sur la mise en place et le retrait convenables du dispositif de protection personnelle ainsi qu'un système de contrôle de la qualité. Les inhalothérapeutes sont en première ligne pendant les IPA et doivent participer à la prise de décision sur le type de matériel retenu pour les protéger.

Infection prevention and control precautions are implemented for contact droplet/airborne transmissions, as well as routine precautions. These precautions include the appropriate use of personal protective equipment (PPE) as indicated by hospital policy. The present outbreak of Ebola viral disease (EVD) has health care personnel seeking guidance on the appropriate use of PPE for suspected cases that may arrive to their facility. The 2007 Centers for Disease Control and Prevention (CDC, Georgia, USA) Guideline for Isolation Precautions (1) emphasize that the route of transmission dictates recommendation for infection control measures; however, the question remains as to what PPE is required for aerosol-generating procedures (AGPs). Do we use powered air-purifying respirators (PAPRs) or N95 masks? Are there advantages or disadvantages to using a PAPR, and is there a recommended procedure for donning and doffing?

EBOLA ROUTE OF TRANSMISSION

Taking the Ebola outbreak as an example, we need to understand how it is transmitted. Ebola hemorrhagic fever is caused by infection with the Ebola virus, a member of the family *Filoviridae*, a severe and often fatal illness in humans. The mode of transmission to humans is through close contact with the blood, secretions, or organs of ill or deceased chimpanzees, gorillas or fruit bats. Human-to-human transmission occurs by direct contact (through broken skin and mucous membrane) with infected blood, body fluids, secretions or organs of an infected person (2,3). To date, airborne transmission has not been documented; therefore, early recognition of an individual with suspected EVD is critical for infection control (3).

Clinical symptoms of EVD include sudden onset of fever >38°C, malaise, myalgia, headache, conjunctival injection (red eye), pharyngitis, vomiting, diarrhea that can be bloody, gastrointestinal pain, and impaired kidney and liver function (4-6). The incubation period varies from two to 21 days, with seven days being the average. Currently, experimental treatments have been tested in animals, but have been provided/administered on a compassionate basis to humans without knowledge of effect or safety (3).

Exposure to the Ebola virus in the health care setting occurs when infection control precautions are not strictly practiced by health care workers (ie, not wearing appropriate PPE). The CDC has released infection prevention and control recommendations for hospitalized patients with known or suspected Ebola hemorrhagic fever in the United States (4). Table 1 summarizes of the main CDC recommendations for hospitalized patients with known or suspected EVD, and includes the standard contact and droplet precautions.

RESPIRATORS: N95 OR PAPR?

Respiratory protection in health care for contact droplet/airborne precautions commonly follows two filtering device paths, N95 mask respirators and PAPRs. Currently, the CDC and the WHO have no clear guidelines on AGPs and the use of N95 versus PAPRs. The N95 masks filter at least 95% of particles <5 µm in diameter and are not resistant to oil. These masks have the advantages of blocking aerosol (<5 µm) and droplet-size (5 µm to 50 µm) particles, are readily available, allow the use of stethoscopes, are noiseless and do not require a power source (Figure 1). Their disadvantages include requiring an initial and periodic fit testing, the possibility of being compromised by an improper fit (eg, because of facial hair), poor tolerance by users due to breathing resistance, and heat and moisture build up, the high cost of stocking different types and sizes, and the potential for contamination due to exposed face and neck (7,8).

A PAPR is a battery-powered blower that provides positive airflow through a filter, cartridge, or canister to a hood or face piece. The type and amount of airborne contaminant will dictate the type of filter, cartridge or canister required for the PAPR. The National Institute for Occupational Safety and Health (NIOSH) tests different respirator models in its laboratory to ensure they meet certain minimum performance standards and it is the employer's responsibility to assess the respiratory precaution needs and ensure that the correct filter, cartridge or canister is purchased (9). Cartridges/filters are colour coded; for example, P100 filters are coded purple.

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TABLE 1
Summary of the main Centers for Disease Control and Prevention (Georgia, USA) recommendations for hospitalized patients with known or suspected Ebola virus disease

Component	Recommendation	Comments
Patient placement	Single patient room (containing a private bathroom) with the door closed. Facilities should maintain a log of all persons entering the patient's room	Consider posting personnel at the patient's door to ensure appropriate and consistent use of PPE by all persons entering the patient room.
PPE	All persons entering the patient room should wear at least: • Gloves • Gown (fluid resistant or impermeable) • Eye protection (goggles or face shield) • Facemask Additional PPE may be required in certain situations (eg, copious amounts of blood, other body fluids, vomit or feces present in the environment), including but not limited to: • Double gloving • Disposable shoe covers • Leg coverings	Recommended PPE should be worn by HCP on entry into patient rooms or care areas. On exit from the patient room or care area, PPE should be carefully removed without contaminating one's eyes, mucous membranes or clothing with potentially infectious materials and either • Discarded, or • For reuseable PPE, cleaned and disinfected according to the manufacturer's reprocessing instructions and hospital policies. Instructions for donning and removing PPE have been published Hand hygiene should be performed immediately after removal of PPE
AGPs	Avoid AGPs for Ebola hemorrhagic fever patients If performing AGPs, use a combination of measures to reduce exposures from AGPs when performed on Ebola hemorrhagic fever patients Visitors should not be present during AGPs Limiting the number of HCPs present during the procedure to only those essential for patient care and support Conduct the procedures in a private room and ideally in an Airborne Infection Isolation Room (AIIR) that is a negative pressure room, when feasible. Room doors should be kept closed during the procedure except when entering or leaving the room, and entry and exit should be minimized during and shortly after the procedure HCPs should wear gloves, a gown, disposable shoe covers, and either a face shield that fully covers the front and sides of the face or goggles, and respiratory protection that is at least as protective as a NIOSH-certified fit-tested N95 filtering face piece respirator or higher (eg, powered air-purifying respirator or elastomeric respirator) during AGPs Conduct environmental surface cleaning following procedures If re-usable equipment or PPE (eg, powered air-purifying respirator, elastomeric respirator, etc) are used, they should be cleaned and disinfected according to manufacturer instructions and hospital policies Collection and handling of soiled reusable respirators must be performed by trained individuals using PPE as described above for routine patient care	Although there are limited data available to definitively define a list of AGPs, procedures that are usually included are bilevel positive airway pressure, bronchoscopy, sputum induction, intubation and extubation, and open suctioning of airways Because of the potential risk to individuals reprocessing reusable respirators, disposable filtering face piece respirators are preferred
Hand hygiene	HCPs should perform hand hygiene frequently, including before and after all patient contact, contact with potentially infectious material, and before donning and doffing PPE, including gloves Health care facilities should ensure that supplies for performing hand hygiene are available	Hand hygiene in health care settings can be performed by washing with soap and water, or using alcohol-based hand rubs. If hands are visibly soiled, use soap and water, not alcohol-based hand rubs

Data adapted from reference 4. AGPs Aerosol-generating procedures; HCP Health care practitioner; NIOSH National Institute for Occupational Safety and Health; PPE Personal protective equipment

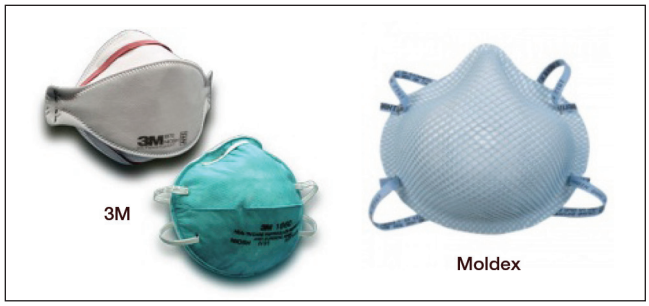

Figure 1) *Examples of National Institute for Occupational Safety and Health-certified N95 masks, courtesy of 3M (USA) (11) and Moldex (USA) (12)*

High-efficiency particulate air (HEPA) filters have a similar filtration as P100 (ie, they filter at least 99.97% of particles 0.3 µm in diameter and are oil proof) (9) and are the filters of choice for infection control airborne precautions. The use of HEPA filters in PAPRs implies that they have a greater level of respiratory protection than N95 masks. They also have the advantage of providing head and neck protection, do not require fit testing because of a full hood, are approved for use with facial hair and allow for continuous bedside care of a patient. Their disadvantages include difficulties in communicating due to their bulk and noise, the inability to use a stethoscope and a requirement for electricity (batteries) to ensure proper airflow rates into the hood. After use, filters are considered to be contaminated with infectious material; therefore, they pose a potential risk to individuals reprocessing reusable respirators (9).

Figure 2) *3M Air-Mate (3M, USA) belt-mounted battery operated respirator with disposable black tubing (left) and double-shrouded hood (right). Reproduced with permission from Powered Air, Supplied Air & Welding Solutions 3M Personal Safety Division (13)*

The most commonly used models of PAPRs available for respiratory protection are manufactured by 3M (USA) and Bullard (USA) (10); however, a list of NIOSH-approved respirators can be obtained online at www.cdc.gov/niosh/npptl/respusers.html. The 3M Air-Mate HEPA is the model purchased by the Jewish General Hospital in Montreal, Quebec. It consists of a mounted battery-operated respirator with disposable black tubing and a double-shrouded hood (Figure 2). The rechargeable battery must be tested routinely by a designated individual. Before using the PAPR, one must ensure that the HEPA filter and gasket are in place. The black tube connects to the PAPR and the blower is tested by placing a nipple in the tube and ensuring that it rises according to manufacturer's specifications (Figure 3). The tube is then attached to the hood and the blower turned on before placing the hood over the face (Figure 4).

The correct sequence of donning, doffing and hand hygiene is important to the effectiveness of the PAPR and the N95 mask. The greater protection provided by a PAPR over a N95 mask for droplet and airborne particles is reduced if one self-contaminates with a disease that is transmitted via contact; hence, the importance of proper training. When donning, the shoe cover (which may or may not be used) is first and then the gown (ensuring it is tied at the back). The N95 mask or the PAPR is secured after verifying the flow, and the face shield or the loose-fitting hood is placed over the face, with the inner shroud tucked inside the gown. Then hand hygiene, and the long-cuffed gloves go over the sleeves of the gown.

The removal of PPE should be performed at least 2 m away from the patient, near the door. The shoe cover, gloves and gown should be removed inside the room, and a trained assistant should be available to help you remove and clean the PAPR. The hood or face shield and N95 mask should only be removed outside the patient's room, and then placed in a biohazard bag. All PPE should be removed so as not to self-contaminate. Hand hygiene should be performed after glove removal – before removal of the face mask and after removal of all PPE (7,8). The advantage of using the N95 mask for AGPs is that it is disposable and does not place additional personnel at risk; hence, the CDC's statement for EVD "Because of the potential risk to individuals reprocessing reusable respirators, disposable filtering face piece respirators are preferred" (4).

In cases in which a health care worker cannot be fit-tested for an N95 mask or has facial hair, the use of a PAPR is an alternative. Also, in situations in which a live airborne virus is being handled, a PAPR may be preferred to the N95 mask.

EXPERIENCE AT THE JEWISH GENERAL HOSPITAL

The Ebola outbreak has reminded our team that we have PAPRs in our institution (purchased in anticipation of the H1N1 epidemic), and that we do not have a policy for when it is required and how it is used. Only two members of hospital staff were trained on donning, doffing and cleaning of the PAPR. We are now developing a policy on the use of PAPRs, which will be followed by training sessions for staff

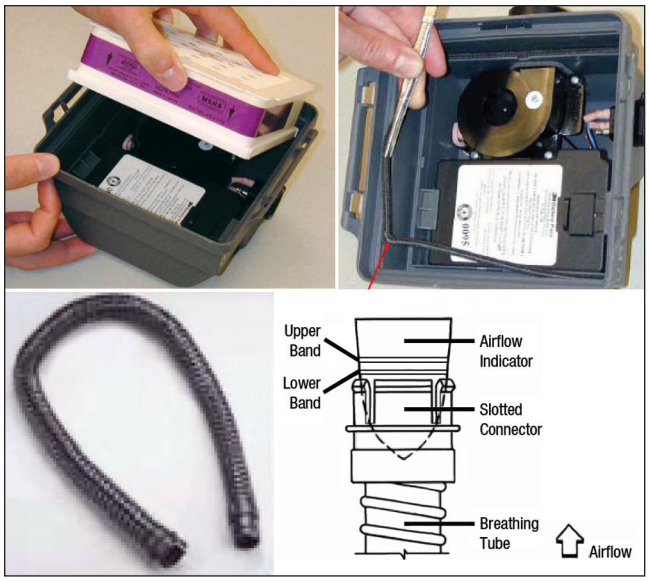

Figure 3) *3M Air-Mate (3M, USA) rechargeable battery, high-efficency particulate air filter (top left), black tube connecting to the powered air-purifying respirator and the blower (bottom left), manufacturer's specifications (bottom right). Reproduced with permission from Powered Air, Supplied Air & Welding Solutions 3M Personal Safety Division (13)*

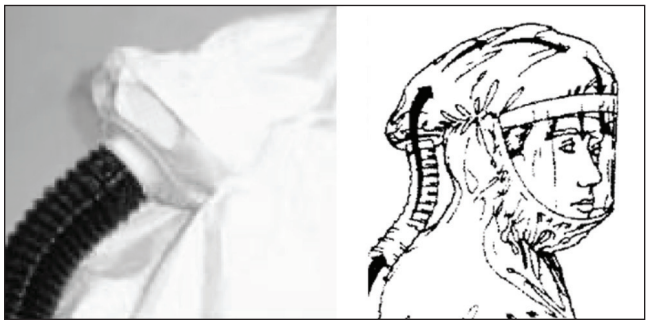

Figure 4) *3M Air-Mate (3M, USA) black tube attached to the hood and the blower (left), example of hood placed over the face (right). Reproduced with permission from Powered Air, Supplied Air & Welding Solutions 3M Personal Safety Division (13)*

identified as potentially requiring their use. During H1N1, we used the waterproof gown, long-cuff nitrile glove, N95 mask and face shield for all AGPs with success. As respiratory therapists, we still use N95 masks as a routine precaution during bronchoscopies and intubations because there have been situations in which samples returned positive for airborne infection and the patient was not under airborne precautions.

Hospital infection control policy makers have been left to decide whether a PAPR should be used for EVD. What is clear is that we must be proactive because it is just a question of time before an infected patient arrives in Canada. As part of a disaster infection control plan, there must be provisions for training in the use of all types of PPE for health care workers who may be involved in the care of an infected or suspected case, and there must be proper quality control systems in place. The decision to use a PAPR for AGPs without a program in place can lead to more self-contaminations than using appropriate PPE with a fit-tested N95 mask.

Additional information regarding EVD, including risk assessment, diagnosis and treatment, can be accessed at: www.cdc.gov/vhf/ebola/hcp/infection-prevention-and-control-recommendations.html. The Public Health Agency of Canada also has information for health care professional at: www.phac-aspc.gc.ca/id-mi/vhf-fvh/ebola-eng.php.

CONCLUSION

The use of PAPRs (although effective in the PPE armamentarium, similar to the other respirators) has its advantages and disadvantages. Its use has not yet found a specific niche, EVD being no exception. The Infection Prevention and Control Department of the Jewish General Hospital recently developed a policy for infection control precautions for EVD and ensured that it was reviewed by a multidisciplinary team including the respiratory therapy department. It is extremely important as respiratory therapists that we ensure that our role in AGPs is identified and our needs are met. All respiratory therapy departments should be proactive and ensure that their hospitals have policies in place.

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