# 46 | CHAPTER

# Personal Protective Equipment

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PPE, for personal protective equipment, has become a rather common acronym in the lexicon of health care providers. The acronym has been common in fire services, emergency medical services (EMS), and the military for quite some time. Essentially, PPE helps to ensure that individuals are safe from physical hazards that they may encounter in their work environment. PPE may be used to protect workers from general environmental threats (e.g., temperature extremes and noise), specific work-related threats (e.g., industrial equipment and falls from elevated work areas), or threats faced in an emergency situation (e.g., hazardous chemical and infectious agents). No equipment is appropriate for all individuals and threats: rather, equipment must be selected and properly used according to the setting of use and the level of risk.

The critical problem with most PPE, particularly in regard to chemically protective suits and respirators, is that with higher levels of protection come not only higher prices and required training levels but also a higher physiological and physical burden to the user. Thus a structured approach to assessment of risk and selection of proper equipment is important to achieve a reasonable level of protection in relation to the hazard.

In this chapter we review the concepts of PPE, including recent lessons learned, types of respirators, key regulations, and issues in the selection of PPE for emergency medical care and decontamination operations.

## HISTORICAL PERSPECTIVE

Previously PPE for medical providers received little attention short of the "standard precautions" of gloves, with the addition of simple masks, eye protection, and barrier precautions, as needed for respiratory and contact precautions. A number of events have highlighted the importance of PPE for first responders and health care workers. The 2003 Severe Acute Respiratory Syndrome (SARS) Epidemic, the 2009 H1N1 Influenza Pandemic, the 1995 Tokyo Subway Sarin Attack, the 1995 Murrah Federal Building Bombing in Oklahoma City, and the terrorist attacks of September 2001 are some examples of situations in which the lack of proper PPE or the improper use of it resulted in adverse health effects for health care providers. Such events and adverse outcomes have focused attention on PPE as a critical issue in routine emergency department operations and disaster response.

In March 1995, a crude form of the nerve agent sarin was released in the Tokyo subway system on separate cars bound for a common downtown station. This attack resulted in 12 deaths and more than 4000 persons presenting to the hospital for medical evaluation. None of the casualties was decontaminated before treatment or transport. Retrospectively, 135 prehospital and 100 hospital personnel reported symptoms consistent with nerve agent exposure. Fortunately, none required

emergency treatment.[1] Eleven physicians caring for the sickest victims (including one in cardiac arrest and one in respiratory arrest) were most affected, and six of them required treatment with specific antidote. All recovered fully and did not have to cease their patient care efforts because of symptoms.[2] Approximately 80% of victims self-referred to hospitals, which is consistent with U.S. experiences, indicating that few victims of chemical contamination events undergo decontamination before arrival at a medical facility.[3,4] This has caused most jurisdictions to reconsider historical plans that contaminated patients would not be in contact with medical care personnel until they were "clean." EMS and hospital personnel need to be prepared for contaminated patients presenting directly to them and recognize that in certain situations PPE may be required to safely provide care.

SARS posed unique risks and challenges to health care workers. This novel viral agent with incompletely defined transmission characteristics was controlled in 2002, with aggressive quarantine measures and use of PPE. In the first wave of SARS in Toronto, 79.2% of all cases were acquired in a health care setting.[5] Aggressive use of PPE, including N95 masks, barrier precautions, and gloves, was generally effective at preventing spread, although during one difficult and prolonged intubation attempt, at least 6 providers contracted SARS from a patient, despite complying with PPE recommendations.[6] This case led to recommendations that higher levels of PPE may be required during procedures that are likely to generate aerosols or provoke coughing, such as intubation, airway suctioning, positive pressure ventilation, and nebulized treatments.[7] Many of the lessons learned from the SARS epidemic, including the importance of appropriate respiratory PPE and compliance programs, were later applied to the 2009 H1N1 Influenza Pandemic. Even so, H1N1 took a toll on health care workers, and analysis of both of these events has led to future improvements for disaster preparedness.[8–12]

The National Institute for Occupational Safety and Health (NIOSH) and the RAND Corporation produced a comprehensive "lessons learned" report, summarizing issues from the 2001 terrorist bombings at the World Trade Center (WTC), anthrax incidents, and the 1995 Oklahoma City Murrah Federal Building Bombing. The report, titled *Protecting Emergency Responders: Lessons Learned from Terrorist Attacks*, describes in detail many of the challenges responders faced (Box 46-1).[13]

It is clear from the WTC events that a large number of jurisdictions responding, conflicting messages regarding use of PPE and safety of the environment, unavailability of appropriate PPE, poor design characteristics of current PPE models, and lack of a plan to implement respiratory precautions can complicate a response and potentially place providers at risk. WTC responders continue to suffer respiratory symptoms attributable to exposures at "ground zero."[14]

### BOX 46-1 Historical Hazards Faced by Responders to Terrorism Events

- Physical hazards including fires, burning jet fuel and explosions, rubble piles with sharp rebar and heated metal, falling debris (which resulted in the death of a nurse in Oklahoma City), hazardous materials, electrical hazards, structures prone to collapse, heat stress, exhaustion, and respiratory irritants
- Heat-related seizures while wearing chemically protective suits
- Eye injuries (usually related to particulate exposure), which accounted for 12% of all WTC disaster response worker injuries
- Potential for secondary hazards, including explosive devices and chemical, biological, and radioactive agents
- PPE shortcomings:
  - Heavy helmets hindered performance
  - SCBA was heavy and cumbersome
  - SCBA face pieces fogged (reducing visibility), and the equipment hindered verbal and radio communication
  - SCBA air bottle made it difficult to enter small spaces, and the limited air supply (up to 1 hour) necessitated leaving the operation to exchange the air bottle
  - Air tanks and/or filters were not interchangeable between teams, and teams worked under different standards
  - PAPR filters became clogged and were uncomfortable for long-duration use. Many workers instead opted to use dust masks (which offered little protection and caused nose-bridge chafing) or to wear the masks/hoods around their necks ("neck protectors")
  - Use of respirators made it difficult for workers to communicate with each other, often resulting in users breaking the face seal to talk
  - Turnout gear (the common protective garments used by firefighters) increased heat stress and physical fatigue
- At the WTC, the rubble pile was so hot in places that it melted the soles of workers' boots; providing wash stations to cool the boots resulted in wet feet and serious blisters for many workers; some 440 WTC disaster response workers sought treatment for blisters
- Steel-reinforced boots (soles and toes) protected against punctures by sharp objects but conducted and retained heat, which contributed to blisters and burns
- Structural firefighting gloves worked well until they got wet and hardened, reducing their dexterity
- WTC disaster response workers did not consistently protect their hands against potential hazards such as human remains and bodily fluids
- Safety glasses were readily available but often were open at the sides and did not offer adequate protection against airborne particles
- Goggles were uncomfortable, hindered peripheral vision, tended to fog, and did not fit well in conjunction with half-face respirators
- Many disaster response workers at the WTC (especially law enforcement officers) did not consistently use hearing protection, even around heavy machinery, because they needed to hear their radios and voices and listen for tapping when they were searching for survivors
- Most volunteers at the WTC, Pentagon, and Oklahoma City did not receive pre-event training on PPE and hazardous materials
- Although firefighters generally received detailed pre-event training, this was less true for law enforcement officers
- Accurate "real-time" hazard information was not readily available, especially during the anthrax incidents
- Protection from falls was available at some sites (in the form of ropes and harnesses) but was inconsistently used

## CURRENT PRACTICE

### Hazard Vulnerability Analysis

Selection of appropriate PPE begins with an analysis of the hazards that responders may encounter, as well as an assessment of responders' roles and responsibilities. Hazard vulnerability analyses (HVA) are required for community emergency planning grants and are required of health care facilities that are accredited by The Joint Commission, previously known as the Joint Commission on Accreditation of Health Care Organizations (JCAHO).[15,16] The HVA uses a numerical ranking of factors for specific threats (e.g., chemical release), including the risk of the event occurring, the current preparedness for the threat, and the risk to life. The numerical score determines the gravity of each threat to the community. Each community's HVA will reflect the unique risks that must be considered by its emergency responders. Choice of PPE may be affected by factors within the HVA, such as

- Population density of the community and surrounding area
- High- or moderate-risk terrorist targets in the community (e.g., government buildings, centers of commerce, or other symbolic sites)
- Chemical hazards posed by community industry (e.g., use of cyanide and hydrofluoric acid in the electronics industry)
- Risk of transportation incidents and major transportation routes, particularly highways and railroads
- Proximity of health care facilities, schools, or other key locations to these potential targets and industrial and transportation hazards
- Frequency of hazardous materials (HazMat) incidents in the community
- Resources available to respond to HazMat incidents (e.g., rapid access to on-site decontamination may decrease, but not eliminate, contaminated persons leaving the scene)

### Defining the Agency and the Facility Role

Stakeholders in emergency response, including EMS, fire and rescue, and law enforcement agencies, emergency management teams, and health care facilities, must clearly define the responsibilities of each entity and the support and resources that each may need or offer during an emergency, particularly one involving a HazMat release.

The EMS role in a HazMat event may vary depending on jurisdictional planning and the availability of resources. Fire services personnel may or may not be able to provide treatment in a "warm zone" (i.e., the area of reduced contamination outside of the immediate release zone) depending on their training. Nonfire-based EMS personnel may require PPE to triage and treat victims in the warm zone. In the event of a mass chemical exposure, victims will likely self-refer to visible ambulances, call for emergency assistance from locations removed from the site of release, or make their way to hospitals, by-passing organized EMS and fire services altogether. This movement of contamination on the bodies of patients essentially causes a "migrating" warm zone, resulting in contamination of previously clean ("cold") areas. This migrating contamination may require protective equipment for EMS responders and hospital personnel, and appropriate plans and equipment should be in place. The roles and responsibilities of the responders, as well as the equipment required, need to be defined and drilled in advance of an incident.

Hospitals usually have relied on fire services for patient decontamination at the hospital. These resources, however, are often deployed to the scene of the event and are thus unavailable to support the hospital. Most hospitals have recognized the need for at least some internal capacity for patient decontamination and are equipping their teams with PPE appropriate for decontaminating self-referred patients and the means to decontaminate patients prior to entry into the emergency department (ED). In some instances, the hospital teams integrate with

community HazMat teams, necessitating additional training and equipment as the mission then changes from a defensive decontamination response at the health care facility to an offensive response at the scene of release.

## Risks to Providers

Even though HazMat releases seldom cause serious traumatic injury in the absence of concomitant explosions, the potential exists for both scene responders and hospital receivers to suffer serious consequences of exposure. The Agency for Toxic Substance and Disease Registry (ATSDR) maintains a multistate voluntary accounting of hazardous substance releases. The National Toxic Substance Incidents Program (NTSIP), which replaced the Hazardous Substances Emergency Events Surveillance (HSEES) database in 2010, currently collects data from seven states on HazMat events.[17-19] From 1993 to 2001, 44,015 events were recorded in the database: 3455 (7.8%) of the incidents caused injuries, and 74% of victims were transported to a health care facility.[4] In another analysis of HSEES data, only 5% of victims required admission to a health care facility, with the vast majority of patients presenting with self-limited respiratory symptoms.[20] In 2011, the NTSIP reported 3128 separate incidents, resulting in 62 fatalities and an additional 1115 ill or injured patients. Carbon monoxide, chemicals for illicit methamphetamine production, paints/dyes, and petroleum products were the most common offending agents. A review of these events found that 344 of the patients were employees or first responders whose illness and injuries could have been prevented with appropriate PPE.[21]

HSEES data from 2003 to 2006 shows that of 33,157 documented events, secondary contamination of facilities and providers occurred in 15 (0.05%) cases, resulting in illness in 17 providers. Of these secondary contamination victims, only two had employed any PPE when the contamination occured.[22] Even though secondary contamination events are relatively rare, they pose significant risk to health care providers and to the entire health care system because emergency departments and transport vehicles may be closed or taken out of service for

proper decontamination. Events resulting in emergency department evacuation and/or provider illness are especially serious in situations of "off-gassing," where toxic gases are released from contaminated patients and/or their clothing.[23-28] The most serious of these incidents involve patients with suicidal ingestions of organophosphate pesticides.[23-25] Exposures to these patients have caused at least one provider to require intubation and receive aggressive treatment with specific antidote because of contact with pesticide in emesis and vapors during patient resuscitation.[23] Patients who have ingested organophosphate may "off-gas" for days and present an ongoing risk to health care workers.[25] In conjunction with the information from the Tokyo Subway Sarin Attack and the chemical terrorism risk posed by these agents, it is clear that these pesticides present a substantial risk of toxicity from secondary exposures.

Limited research is available to document the degree of the off-gassing that occurs from the bodies and clothing of contaminated patients.[29,30] Clothing removal and control may be expected to remove 90% of the contaminant and thus should be a priority.[30,31] Ideally, this should take place in an open-air environment.

## Chemical Protective Equipment

Providers may not initially recognize a chemical release when they arrive at a scene. Even though structural firefighting ensembles with self-contained breathing apparatus (SCBA) offer some chemical protection that may be sufficient for victim rescue,[32] the incident commander must determine what actions are appropriate for any given situation and maintain a high level of suspicion that a HazMat situation is present. Protective suits, gloves, boots, and appropriate respiratory protection must be donned as soon as possible when a chemical threat is recognized.

The Occupational Safety and Health Administration (OSHA) and Environmental Protection Agency define four basic levels of PPE for HazMat scene responses (Table 46-1 and Fig. 46-1; OSHA standard 29 CFR 1910.120, Appendix B). Generally, as the level of protection increases (Level A being the highest level), so do the weight, cost, and physiological

| TABLE 46-1 | **Categories of PPE** | | |
|---|---|---|---|
| **LEVEL** | **BRIEF DESCRIPTION** | **ADVANTAGES** | **DISADVANTAGES** |
| A | Completely encapsulated suit and SCBA | Highest level of protection available for both contact and vapor hazards | • Expense and training requirements typically restrict use to HazMat response teams<br>• Lack of mobility<br>• Heat and physical stresses<br>• Limited air supply<br>• Fit-testing requirements |
| B | Encapsulating suit or junctions/seams sealed, and SAR or SCBA | High level of protection adequate for entry into unknown environments | Same as for Level A<br>• SAR hose may pose a trip hazard or become dislodged |
| C | Splash suit and APR (note APR and PAPR considered equivalent in classification despite significant difference in protection) | • Significantly increased mobility<br>• Less physical stress<br>• Extended operation time with high levels of protection against certain chemical hazards<br>• No fit testing required for hood type | • Not adequate for some high-concentration environments, less-than-atmospheric-oxygen environments, or high levels of splash contamination<br>• Expense and training moderate |
| D | Usual work clothes | • Increased mobility<br>• Less physical stress<br>• Extended operation time<br>• More fashionable | • Offer no protection against specific hazards<br>• Expense and training minimal |

From Agency for Toxic Substances and Disease Registry. Emergency Medical Services Response to Hazardous Materials Incidents.
Available at: http://www.atsdr.cdc.gov/mhmi-v1-2.pdf.

Level A                                    Level B

Level C                                    Level D

**FIG 46-1 The four basic levels of PPE.** From the Agency for Toxic Substances and Disease Registry. Emergency Medical Services Response to Hazardous Materials Incidents. Available at: http://www.atsdr.cdc.gov/mhmi-v1-2.pdf.

burden of the appropriate PPE. Increasing protection also generally means decreasing mobility, dexterity, and scope of vision. Inherent risks to PPE include trip and fall hazards, reduced ability to complete tasks, heat stress, anxiety, and seizures.[28,33–37] Cardiovascular demand is dramatically increased as ensemble weight and heat retention increase. PPE must be selected on the basis that it does not impose unnecessary risks to the provider while at the same time offering an appropriate margin of safety against the hazard. Because the selection of PPE usually revolves around the selection of the respiratory component, various types of respirators must be reviewed. Each respirator has an assigned protection factor that reflects the degree of protection afforded to the user. Simply put, 1/protection factor equals the amount of exposure for the wearer. For example, a provider wearing a powered air-purifying respirator (PAPR) with an assigned protection factor (APF) of 1000 is exposed to 1/1000 the level of contaminant as compared with wearing no protection.

## Atmosphere-Supplying Respirators

Atmosphere-supplying respirators provide breathable, fresh air to the user, independent of the environment, via an air supply hose and/or tank, and thus offer a high level of respiratory protection. This type of respirator is required for entry into environments where the identity of and/or the potential quantity of a hazardous substance are unknown or where the quantity of oxygen in the air is unknown.

SCBA is the most common atmosphere-supplying respirator for emergency responses. It provides air via a tank, usually worn on the back. The operational time is limited by the capacity of the tank (usually less than 1 hour). Fire service personnel routinely use this form of respiratory protection, and fire-based EMS services personnel generally incorporate this PPE into their chemical protection planning. Limitations include the equipment's weight (approximately 25 to 30 pounds), cost, need for fit testing, duration of air supply, and need to refill air bottles. Even though SCBA provides excellent protection, its limitations make it inappropriate for many situations (e.g., caring for a patient with an infectious disease, providing hospital-based decontamination, or securing a perimeter in the warm zone). SCBA has an APF of about 10,000, the highest of any type of respirator.[38,39]

Supplied-air respirators (SARs) provide air via a hose line from a nearby clean air source (e.g., compressor or hospital supply line). To meet OSHA requirements for Level B, respirators must have a tight-fitting face piece and an emergency supply of air in case of line failure or problems.[40] Loose-fitting hoods with a supplied-air source do not meet Level B standards but are used by some decontamination teams when an additional level of protection is desired because of institutional preference or local hazard profile. Advantages include a potentially unlimited supply of fresh air and longer duration of use. Limitations are primarily mobility and thus flexibility of response. These respirators are best suited to health care provider use in a decontamination room or well-defined area in which the air lines are unlikely to be tangled, stretched, or become a trip hazard. The APF of a typical tight-fitting face piece SAR is 1000, although there may be variability among models and designs (e.g., tight-fitting mask vs. loose-fitting hood).[38,39]

## Air-Purifying Respirators

Air-purifying respirators (APRs) have cartridges that filter the air in the user's environment to remove particulate matter and specific chemicals that the filter is designed to capture. These filters do not affect the oxygen concentration of the ambient air and thus cannot be used in potentially oxygen-deficient environments. Only those chemicals for which the filter is designated are removed. In addition, the capacity of the filter can be exceeded by large amounts of contaminant, thus these respirators are designed for situations in which the concentration of the agent is either established to be or assumed to be below the threshold for the canister.

Nonpowered APRs use the wearer's work of breathing to pull ambient air through the filter. Examples include dust masks and military and civilian "gas masks." The APF of a nonpowered full-face piece APR is 50 when appropriate quantitative fit testing is performed.[38,39] Of note, this type of mask is used by military and tactical personnel for protection against dangerous lethal levels of nerve and other chemical agents. Advantages include low cost and long duration of use. Disadvantages include increased work of breathing and physiological stress, mask fogging, and the need for fit testing.

A PAPR uses a motor to pull air through the filter canisters, thus decreasing the work of breathing and risk of air entrainment around the respirator face piece. PAPRs are often supplied with a loose-fitting disposable or reusable hood that eliminates the need to perform fit testing and allows use by a broad range of individuals. Hooded PAPRs with "stacked" canisters that offer protection against common hazardous chemical and biological agents encountered by first responders and hospital personnel are in widespread use because of their low cost, weight, and the increased flexibility of use. Dependence on battery power, shelf life of the filters, and the need to be able to match the filter to the agent are limiting factors. The APF for a PAPR ranges from 25 to 1000, depending on the specifics of the model and how it is employed. Battery packs are usually either single use or rechargeable. Rechargeable battery packs require ongoing attention to ensure a proper charge, but they offer the flexibility of allowing PAPR reuse during a prolonged event.

Particulate filter masks such as those commonly used for patient care to protect against tuberculosis and other organisms are also considered APRs. Masks are classified N (not oil resistant), R (oil resistant), and P (oil proof). N95 refers to a filter (the entire mask) that removes 95% of a particulate challenge in the 3- to 5-μm range. N100 respirators filter 100% of the same challenge, yet simple half-face respirators offer an APF of only 10 because of the entrainment of air around the mask and other factors; therefore changing from an N95 to an N100 offers little additional protection unless a more robust mask ensemble, rather than a simple half-face mask, is used.[41,42]

Respiratory protection technologies are rapidly evolving, and respiratory program administrators should make sure they are familiar with the available options and their relative advantages and disadvantages. Regional cooperative planning and purchases may be helpful to allow for sharing of resources, including staff, during an incident.

## Chemical Protective Equipment

Chemically protective suits must be tailored to the type of use. Suits for hot-zone entry, where direct contact with a hazardous material is likely, must be much more robust than suits for patient decontamination activities. Selection should be guided by National Fire Protection Association (NFPA) standards 1992 and 1994, for site-of-release response activities, and by OSHA guidelines, for hospital decontamination activities.[43,44] Chemicals commonly found in local transit, agriculture, or industrial use should also guide selection. Appropriate PPE for perimeter control and EMS warm-zone operations remain topics of debate at this time. Generally, suits should be sized far more generously than standard work clothing, to prevent tearing during squatting and other activities (e.g., an average-sized 70-kg man should plan to wear a size XXL suit). Many suit configurations are possible, and the optimal configuration will depend on the mission and other equipment in the ensemble. For example, suits without "feet" are preferred when worn with boots (to allow taping over the boot) but those with integrated bootie "feet" are preferred when pull-on "sock" type butyl booties are to be used. These integrated feet should not be used as primary footwear at any time because they have poor abrasion resistance.

Boots supplied in sizes medium, large, and extra-large rather than fitted sizes may be preferred when equipment is purchased for a group (e.g., hospital decontamination team) rather than being purchased for an individual responder (e.g., firefighter). Butyl or other rubber boots probably afford appropriate protection for warm-zone operations. Butyl "sock" type booties may be used on very low abrasion surfaces (e.g., internal hospital decontamination room) but are not generally appropriate for outside use.

Nitrile undergloves with butyl overgloves provide protection against a broad range of hazards for warm-zone activities. The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) recommends 14-mil thickness butyl gloves (standard examination gloves are 4 mil) as a minimum for working with patients contaminated by chemical warfare agents or toxic industrial chemicals.[44,45] Overglove selection must balance the need for abrasion resistance and chemical protection with dexterity required to perform tasks and patient care (e.g., administer intramuscular antidotes or intubate).[44,45]

## Biological Protective Equipment

Very few situations require physical decontamination of patients exposed to biological agents. An exception would be patients who present after contamination with biological agents (e.g., anthrax spores) from a dissemination device. PPE for decontamination should consist of the same chemical protective suit and high level of respiratory protection, including a high-efficiency particulate (HEPA) or SAR that would be used for chemical decontamination activities. PPE for biological agents in relation to care of patients who are already infected and symptomatic is discussed in the following section.

Categories of PPE for biological agents include[46]:

- *Standard precautions:* Use of gloves and proper hand hygiene to prevent disease transmission for any potentially infectious patient. Gowns and eye protection are added only when patient care activities are likely to result in splashing or soiling.
- *Contact precautions:* Standard precautions plus use of barriers during all patient care activities to protect face, arms, and front torso to prevent contact with secretions, emesis, feces, etc. (e.g., enteric infections and many hemorrhagic fever viruses).
- *Droplet precautions:* Standard precautions with the addition of a droplet respirator (e.g., surgical mask) when working within 3 feet of the patient, to prevent transmission of infectious agents that travel by large-droplet spread; may not be protective against all droplet nuclei.
- *Airborne precautions:* Standard precautions with an N95 or higher protection respirator to prevent transmission of infectious agents that are spread by aerosols (e.g., airborne precautions are used against chickenpox, smallpox, and tuberculosis).
- *"Special pathogen precautions":* Based on the SARS experiences, a high-risk pathogen with respiratory spread probably requires greater levels of protection than previously recommended. Constant use of both contact and airborne precautions has generally been advised with the optional use of a PAPR rather than an N95 mask during "high-risk" interventions likely to generate aerosols or provoke coughing (e.g., suctioning, intubation, positive pressure ventilation).[6,7]

Patient care providers should have routine access to nonsterile examination gloves, barrier gowns that protect the arms and anterior torso, standard surgical (droplet) masks, and face shields that provide adequate splash protection (which may be integrated with the mask, a separate face shield, or goggles) according to the OSHA bloodborne pathogens standards.[47,48]

When needed, providers should have easy access to higher levels of protection. "Precaution carts" or "Bad bug bags" may be preassembled

with appropriate gowns, gloves, face shields or goggles, N95 or PAPR respirators, and other supplies so that health care providers do not have to assemble the necessary components when hazards arise. Instruction sheets for donning or doffing and disinfection procedures can be included in these kits.[49,48]

Practitioners fitted for N95 respirators may use these for patient care, and others should have access to a PAPR until they can undergo fit testing for an N95 respirator. Plans to rapidly fit test additional employees during an event that might require prolonged use of airborne precautions (e.g., SARs) should be in place.

## Regulations and Training

All PPE must be part of an ongoing program for respiratory protection and HazMat or decontamination responses within the agency or institution, to ensure that employees who are expected to use protective devices are competent and comfortable with the indications, use, and limitations of their equipment. Numerous regulations apply to the selection and proper use of PPE. All persons using PPE must conform to OSHA standards on respiratory protection (29 CFR 1910.134), PPE (29 CFR 1910.132), eye and face protection (29 CFR 1910.133), hand protection (29 CFR 1910.138), hazard communication (29 CFR 1910.1200), and bloodborne pathogens (29 CFR 1910.1030). State OSHA agencies may have stricter requirements than the federal standards. Most occupational or employee health services of agencies and facilities where PPE is used are very familiar with these standards and their application to employees.

The NFPA has numerous standards for training and equipping HazMat responders, including EMS personnel (e.g., NFPA standards 471, 473, 1981, 1992, 1994, and 1999). Specific guidance is also provided for urban search and rescue teams (NFPA standard 1951).[43] Responders to HazMat releases are covered by OSHA's HAZWOPER (Hazardous Waste Operations and Emergency Response) standard 29 CFR 1910.120, which is perhaps the most comprehensive standard guiding hazardous materials responses.

OSHA requires use of a minimum of Level B equipment (i.e., an atmosphere-supplying respirator and chemically protective suit with sealed seams) during a response into a contaminated environment until the concentration of the agent is shown via air monitoring to be below the threshold required for the safe use of an APR or other lesser degree of protection.[50] This requirement presents difficulty for EMS and hospital providers because the agent is often unknown at the time that medical care is provided in the warm zone (i.e., an area where the level of contamination is minimal and controlled). Particularly for hospitals, confusion existed as to what constituted appropriate protection for decontamination team members who provide medical care for contaminated patients and to what degree the HAZWOPER standard applied to community responders geographically separate from the site of release.

OSHA clarified this issue for health care facility providers in two letters of interpretation[51,52] and a comprehensive guidance document on PPE and training released in 2004.[44] In this document OSHA codifies use of PAPRs as the minimum level of respiratory protective equipment for hospitals under certain conditions:

- The facility acts as a "first receiver" for self-referred contaminated casualties, not as a responder to a release zone.
- The facility itself is not the site of the hazardous substances release.
- An HVA has been conducted to identify specific hazards to the community and facility.
- The victims must present at least 10 minutes after exposure (to allow time for some of the contaminant to evaporate or dissipate). It will usually take at least this long to get personnel into PPE at the facility.
- The victims' clothing must be rapidly removed and contained.

- Decontamination must occur in a well-ventilated area, preferably outdoors.

When these conditions are met, and absent any particular threats within the community that require higher levels of protection (such as close proximity to a specific chemical production, storage, or disposal site), the minimum level of respiratory PPE is a PAPR with a protection factor of 1000 or greater, which filters organic vapor, acid gas, particulate matter, and biological agents (at the HEPA level).[44]

HAZWOPER also defines training requirements for responders.[53] The application of these regulations to hospital decontamination teams was also clarified in recent OSHA guidance.[44] Awareness training is required for individuals involved in a HazMat response who will not be using PPE or taking actions beyond recognizing and reporting an incident (emergency department staff, law enforcement officers).[44]

At a minimum, all responders who will use chemical PPE must be trained to the operations level (8 hours minimum)[44] so that each responder can

- Understand his or her role in the response and the emergency response plan.
- Assess site safety, including risks to self.
- Select and safely use appropriate PPE.
- Understand decontamination procedures.

HazMat-awareness educational competencies must also be met by providers trained to the operations level. The awareness competencies may be included in the 8 hours of operations training or conducted separately.[44]

In addition, any personnel using respiratory protective equipment must be in compliance with OSHA's respiratory protection standard (29 CFR 120.134). Key features of this standard are

- Respirator selection procedures
- Proper use of respirators in routine and reasonably foreseeable emergency situations
- Medical clearance before use (at minimum, a screening questionnaire; see Appendix C of the standard)
- Fit testing before use and annually thereafter (see Appendix A and B1 of the standard)
- Inspecting, cleaning and disinfecting, storing, repairing, and maintaining the equipment
- Training and education on topics such as the types of respiratory hazards they might be exposed to, proper use (including donning and doffing), limitations, and maintenance

Most medical facilities and response agencies have a respiratory protection program in place. This existing foundation and the subject matter experts in occupational safety and health, infection control, or other related disciplines can assist with implementation of new technologies and protocols.

## ⚠ PITFALLS AND ONGOING CHALLENGES

PPE technology continues to change rapidly. Hopefully, technologies that are lighter weight, less expensive, and less heat-retaining can be developed. There is experimentally developed PPE that are easier to don and doff, and which provide improved mobility and visibility to perform procedures. In one project completed at Brown University in conjunction with the Rhode Island School of Design, engineering and industrial design students paired up to develop a new model of Level B PPE that could be donned in half the time with a single user compared to two users with traditional PPE. Even though a prototype was developed and showcased, there were no clear funding sources available to bring this design to market.[54] Technology change is occurring far more rapidly than the current approvals process and new standards that have arisen in the wake of recent events. Clear guidance on

appropriate technologies for warm-zone activities is lacking at this time. This can lead to confusion and difficult choices for agencies and facilities, knowing that their PPE selection may be either too much or too little to satisfy future standards. Currently, there is no recommendation or consensus on the level of PPE that is required for hospital-based personnel, much to the consternation of hospital preparedness leaders. Some have proposed a PPE Level H to meet this need. Additional research is clearly needed regarding safe but comfortable PPE, methods of decontamination, modeling of airborne concentrations of specific agents, and PPE selection.

Further, detection technologies are needed that can provide better environmental screening for a wide range of hazardous substances and a quantitative assessment of agent concentration. Currently, incident commanders may remain confused about appropriate PPE, and this may result in PPE selection that is overly conservative (risks provider noncompliance and adverse effects from the PPE) or overly liberal (risks provider injury from the contaminant).

Finally, providers need to be educated about the consequences of not using PPE appropriately, including acute chemical effects and delayed pulmonary effects.

In general, communities and regions can help to reduce issues of PPE interoperability by planning, purchasing, and training together whenever possible, which allows for caches of materials to be deployed that are true replacements for usual materials and thus will be better accepted and require minimal training.

For too long, jurisdictions have been reluctant to share their problems, issues, and roadblocks in the area of PPE, lest the agency be seen as having problems protecting its responders. Better dialogue and sharing of best practices and lessons learned are of immense value, and better HazMat response and planning should be encouraged. The NIOSH/RAND report[13] and release of select after-action reports are welcome changes in this history.

Defining hazards in this age of potential chemical terrorism is fraught with peril because we are unable to truly assess the scope of the threat. Thus PPE must be chosen that will protect appropriately against a broad range of threats without being so restrictive that in the heat of the moment, the provider decides to forgo the PPE and is at risk of becoming a casualty of the event. Balancing cost, ease of use, and scope of protection concerns are delicate decisions with few answers at this time, particularly for those who may have long-duration job tasks in a warm-zone environment.

We can only hope that we are not forced to learn too many more harsh lessons about PPE use in the future. In the meantime, we should strive to prepare our communities by selecting appropriate protective technologies in relation to perceived threats and practicing our responses so that our personnel both are comfortable using their PPE and understand the consequences of not doing so.

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