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chapter 36

Personal Protective Equipment

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Personal protective equipment (PPE) recently has become a rather common acronym in the lexicon of healthcare providers, even though it has been common in the fire services, emergency medical services (EMS), and military for quite some time. Essentially, PPE helps 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, noise), specific work-related threats (e.g., falling objects, falls from heights), or threats faced in an emergency situation (e.g., hazardous chemical and infectious agents). No equipment is appropriate for all individuals and threats, but it 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.

This chapter reviews the concepts of PPE, recent lessons learned in regard to PPE, types of respirators, key regulations, and issues in the selection of PPE for emergency medical care and decontamination operations.

HISTORICAL PERSPECTIVE

Until recently, PPE for medical providers received little attention short of the "standard precautions" of gloves, with the addition of simple masks and barrier precautions, when needed. The 2003 severe acute respiratory syndrome (SARS) 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 resulted in adverse health effects for healthcare providers and thus focused attention on PPE as a critical issue in 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.[1,2] 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 antidotal therapy. Fortunately, all recovered fully and did not have to cease their patient care efforts due to symptoms.[3] 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.[2,4] 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 to recognize that in certain situations, PPE may be required to safely provide care.

SARS posed unique risks and challenges to healthcare 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 healthcare 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 six 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 nebulization treatments.[7]

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 36-1).[8]

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, 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."[9]

CURRENT PRACTICE

Hazard Vulnerability Analysis

Selection of appropriate PPE begins with an analysis of the hazards that responders may encounter and an assessment of responders' roles and responsibilities. Hazard vulnerability analyses (HVA) are required for community emergency planning grants and are required of healthcare facilities that are accredited by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO).[10] 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 another symbolic site)
- 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 healthcare 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/Facility Role

Stakeholders in emergency response, including EMS and healthcare facilities and fire and rescue, emergency management, and law enforcement agencies, 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.

EMS roles in a HazMat event vary depending on jurisdictional planning. Fire services personnel may or may

BOX 36-1 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
  - Self-contained breathing apparatus (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
  - Powered air-purifying respirator (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

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. Non-fire 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 911 from sites removed from the site of release, or make their way to hospitals, by-passing organized EMS and fire services. This movement of contamination on the bodies of patients essentially causes a "migrating" warm zone, causing contamination of previously clean ("cold") areas. This migrating contamination may require protective equipment for EMS responders, 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, until very recently, usually 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 now recognized the need for at least some internal capacity for patient decontamination and are equipping their teams with PPE appropriate for decontaminating self-referred contaminated patients. A few hospital teams integrate with community HazMat teams, necessitating additional training and equipment as the mission then changes from a defensive decontamination response to an offensive response at the scene of release.

Risks to Providers

HazMat releases seldom cause serious injury, but 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, excluding petroleum-related incidents. The Hazardous Substances Emergency Events Surveillance (HSEES) database currently involves 15 states.[11] From 1993 to 2001, 44,015 events were recorded: 3455 (7.8%) of the incidents caused injuries, and 74% of victims were transported to a healthcare facility.[4] In another analysis of HSEES data, only 5% of victims required admission to a healthcare facility.[12] The vast majority had self-limited respiratory symptoms. In 2001, the chemicals with highest potential for injury were chlorine (injury occurred in 18.8% of releases), ammonia (18.2%), acids (14.2%), and pesticides (17%).[13]

HSEES data from 1996 to 1998 show 348 responder injuries in 126 incidents out of a total of 16,986 incidents (0.7%). Law enforcement officers and firefighters accounted for the vast majority of responder injuries, which usually consisted of nausea and respiratory irritation. Hospital admission occurred in 6.6% of cases. No deaths were reported in this 3-year period.[4]

Hospital personnel were injured in 0.3% of the total HazMat events and represented 0.1% of the victims.[4] Six events involved emergency department staff contact with contaminated patients, and five events were HazMat releases at the healthcare facility itself. No provider required hospital admission, and no chemical PPE was used. Other reports of emergency department evacuation and/or provider illness due to off-gassing from contaminated patients have been summarized.[14–19] The most serious of these incidents involve patients with suicidal ingestions of organophosphate pesticides.[14–16] Exposures to these patients caused at least one provider to require intubation and receive aggressive antidotal therapy due to contact with pesticide in emesis and vapors during patient resuscitation.[14] Patients who have ingested organophosphate may off-gas for days and present an ongoing risk to healthcare workers.[16] NIOSH has documented 46 healthcare worker injuries from pesticide agents between 1987 and 1998.[14] 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.[20,21] Clothing removal and control may be expected to remove 90% of the contaminant and thus should be a priority.[21,22] 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,[23] the incident commander must determine what actions are appropriate for the situation. Protective suits, gloves, and 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 36-1 and Fig. 36-1) (OSHA standard 29 CFR 1910.120, Appendix B). Generally, as the level of protection increases (A being the highest level), so do the weight, cost, and physiological burden. Increasing protection also generally means decreasing mobility, dexterity, and scope of vision. Inherent risks to PPE include trip and fall hazards; a reduced ability to complete tasks; heat stress[19,24–27]; anxiety[28]; and seizures, which, although rare, have been reported.[19] 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 on the provider while at the same time offering an appropriate margin of safety against the chemical 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.

TABLE 36-1 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 • Lack of mobility • Heat and physical stresses • Limited air supply • Fit-testing requirements
B	Encapsulating suit or junctions/ seams sealed, and supplied-air respirator (SAR) or SCBA	High level of protection adequate for entry into unknown environments Same as for Level A	• SAR hose may pose a trip hazard or become dislodged
C	Splash suit and air-purifying respirator (APR) (note APR and PAPR considered equivalent in classification despite significant difference in protection)	• Significantly increased mobility • Less physical stress • Extended operation time with high levels of protection against certain chemical hazards • 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 • Expense and training moderate
D	Usual work clothes	• Increased mobility • Less physical stress • Extended operation time • More fashionable	• Offer no protection against specific hazards • Expense and training minimal

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 services 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.[29]

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.[30] 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 due to 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 healthcare provider use in a decontamination room or a well-defined area in which the air lines are unlikely to be tangled, stretched, or a tripped hazard. The APF of a typical tight-fitting face piece SAR is 1000, although there may be variability among models and types (e.g., tight-fitting mask versus loose-fitting hood).[29]

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. Also, 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.[29] Of note, this type of mask is used by the military for battlefield protection against 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 the 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 com-

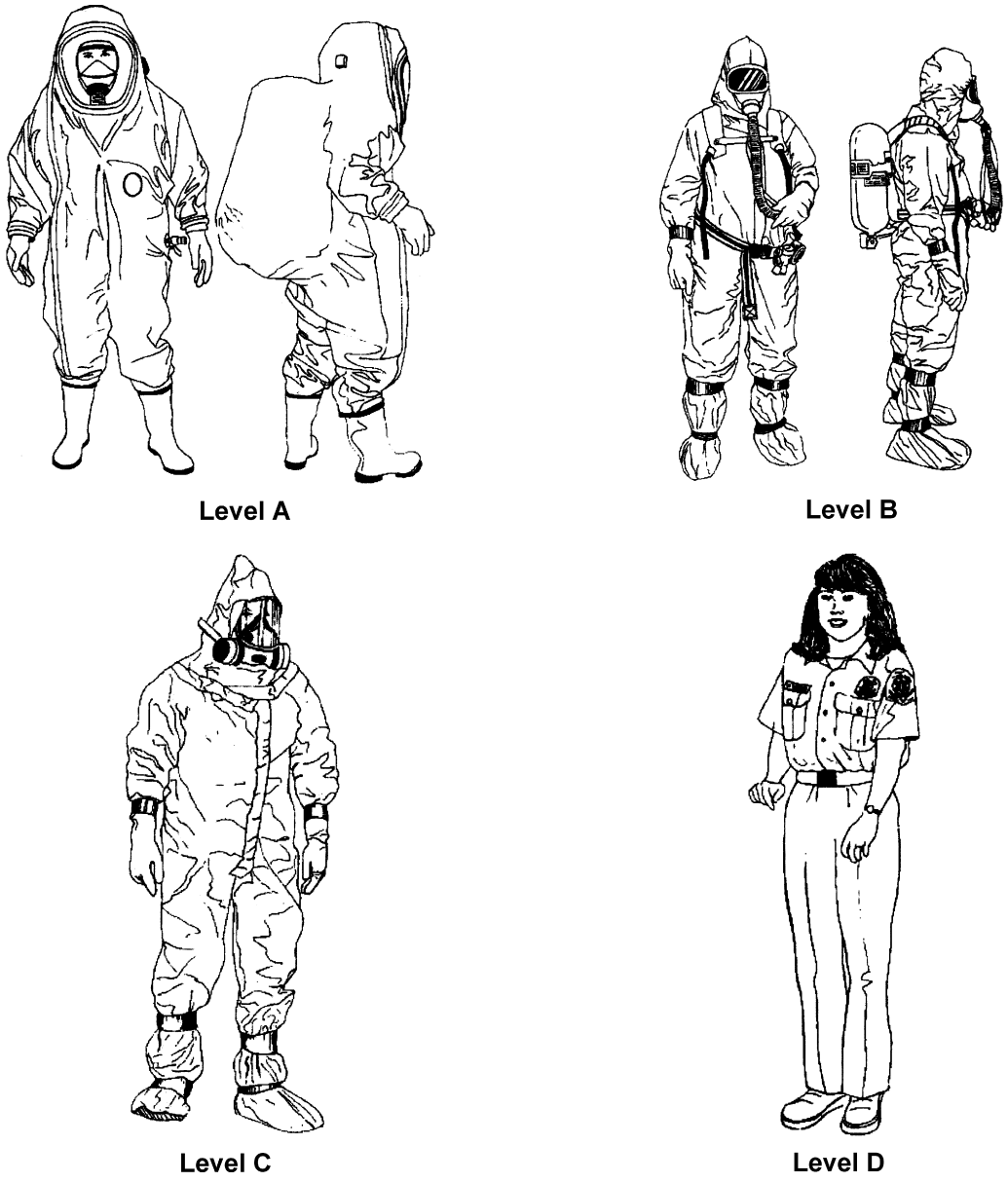

FIGURE 36–1. Levels of PPE. (From Agency for Toxic Substances and Disease Registry. Emergency Medical Services Response to Hazardous Materials Incidents. Available at: http://www.atsdr.cdc.gov/mhmi-v1-2.pdf.)

mon hazardous chemical and biological agents encountered by first responders and hospital personnel are in widespread use due to their relatively low cost, weight, and the increased flexibility of response allowed. 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 currently proposed APF for a PAPR is 1000.[29] Directions for use must be carefully followed; one particular model provides a protection factor of 20,000 when properly donned, but when the inner hood is not tucked in, the protection level declines to 1000 and less[31,32] (personal communication, 2001). 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 re-use during an infectious disease 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 due to 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.[33,34]

Respiratory protection technologies are rapidly evolving, and respiratory program administrators should make sure they are familiar with the available options and their relative advantages/disadvantages. Regional cooperative

planning and purchases may be helpful to allow for sharing of resources during an incident.

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 recent OSHA guidance for hospital decontamination activities.[35,36] 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 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. Silver Shield gloves are more expensive but may be better suited for particular compounds when the agent is known. Overglove selection should balance the need for abrasion resistance with dexterity required to perform tasks (e.g., to administer intramuscular antidotes). The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) recommends 14-mm thickness butyl gloves (standard examination gloves are 4 mm) as a minimum for working with patients contaminated by chemical warfare agents or toxic industrial chemicals.[37]

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.

Categories of PPE for biological agents include[38]:

1. *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.
2. *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, many hemorrhagic fever viruses).
3. *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 (e.g., cirborne precautions are used against plague); may not be protective against all droplet nuclei.
4. *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).
5. *"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] These precautions are the subject of current discussion.

Patient care providers should have routine access to nonsterile examination gloves, barrier gowns that protect the arms and front torso, standard surgical (droplet) masks, and a face shield that provides adequate splash protection (which may be integrated with the mask, a separate face shield, or goggles) according to the OSHA bloodborne pathogens standard.[39]

Providers should have ready access to higher levels of protection when needed. "Bad bug bags" may be assembled with appropriate gowns, gloves, face shields/goggles, N95 or PAPR respirators, and other supplies so that healthcare providers do not have to assemble the recommended components. Instruction sheets for donning/doffing and disinfection procedures can be included in the bag.[40]

Practitioners fitted for N95 respirators may use these for patient care, and others should have access to a PAPR until they are fitted 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 of respiratory protection and HazMat/decontamination response within the agency or institution to ensure that employees who are

expected to use these protections 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/facilities where PPE is used are very familiar with these standards and their application to employees.

The NFPA has numerous standards for the training and equipping of responders (including EMS personnel) to a HazMat incident (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).[35] 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.[41] 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 healthcare facility providers in two letters of interpretation[42,43] and a comprehensive guidance document on PPE and training released in 2004.[36] 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).[36]

HAZWOPER also defines training requirements for responders.[44] The application of these regulations to hospital decontamination teams was also clarified in recent OSHA guidance.[36] 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).[43]

At a minimum, all responders who will use chemical PPE must be trained to the operations level (8 hours or to competency)[43] so that each responder can:

- Understand his or her role in the response and the emergency response plan.
- Identify the presence of a hazardous substance through signs and symptoms of exposure.
- 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.[36]

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/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. Technology

change is occurring far more rapidly than the current approvals process and new standards that have arisen in the wake of the events of 2001. 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. More 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 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 (which risks provider noncompliance and adverse effects from the PPE) or overly liberal (which 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. This also 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 to better HazMat response planning and should be encouraged. The recent NIOSH/RAND report[8] 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, however, 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 are comfortable using their PPE and understand the consequences of not doing so.

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