14 Personal Protective Equipment

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Key Terms

PPE	Personal protective equipment, specifically that worn or used by healthcare providers during patient care
HCW	Healthcare worker, may be physician, nurse, therapist, or laboratorian
Impervious	Resistant to penetration by liquids and small particles
Don(ning)	Putting on, as in gloves or clothing
Doff(ing)	Removing gloves or clothing
PAPR	Powered air-purifying respirators
ABHR	Alcohol-based hand rubs
Trained Observer	A person familiar with procedures and protocols, especially donning and doffing, whose role is to watch other staff for compliance while they perform those procedures
Aerosol generating	Procedures or acts that may produce very small droplets of body fluids
Proprioception	Awareness of where our body is in space
Mindfulness	Focusing one's attention at the present, being aware of one's situation and surroundings
Inoculation	The introduction of a microorganism into a person or organism

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Introduction

Mindfulness may not be a term usually associated with personal protective equipment (PPE), but it is a useful concept for the discussion of putting together, layer by layer, the protective barriers that allow the safe provision of care for patients with highly hazardous communicable diseases. Each piece of the full PPE ensemble will have limitations that must be understood by the wearer. Close and careful attention to behaviors in the patient care environment becomes good PPE etiquette. Donning, or putting on PPE, carefully and fully before attending to a patient's needs is fundamental but not intuitive. Doffing, or removing PPE, is a high-risk procedure that can be performed safely with practice, coaching, and observation. Mitigating risk depends on awareness to all areas of potential contamination and a mindful approach to delivering safe patient care.

The recommendations concerning PPE for healthcare workers (HCWs) have evolved in fits and starts, frequently prompted by outbreaks, such as severe acute respiratory syndrome (SARS), and emerging pathogens, such as HIV. It is inconceivable to many current healthcare workers that disposable glove use was neither mandatory nor recommended until the 1970s [1]. The recommendations for isolation, PPE use, and hand hygiene have continued to change as recently as the Ebola virus disease (EVD) outbreak of 2014–2016.

From the time it was recognized that germs could cause disease, ways to avoid those germs have been sought. Barrier methods, including early gloves made of sheep intestines, were the beginning of personal protective devices aimed to provide a boundary isolating the healthcare provider from some aspect of the patient thought to be infected, such as a wound [2]. Isolating patients is another means of separating HCWs from potentially infectious patients. As the understanding of pathogens and transmissibility has evolved, so has the use of isolation and barriers for protection.

The categories for isolation correspond to the type or portion of a patient that requires some barrier method, for instance, gloves for wound care in the 1970s become gloves for all blood and bodily fluids by the 1980s (Table 14.1).

Patients themselves are not the only source of risk for healthcare workers. As early as the 1500s, it was recognized that surfaces and materials that had contact with patients or their body fluids could also serve to spread disease from patient to patient and from patient to staff [3]. A fomite is any article or surface that can harbor pathogens. The length of time a pathogen can remain viable on such surfaces is highly variable, from minutes to hours and days. All surfaces within the patient care environment, including bed linens, walls, and floors, can be potential sources for contamination.

The method by which a person is inoculated inadvertently by a pathogen can be either through direct or indirect contact. Direct inoculation occurs when infective blood or body substance comes in contact with another person's mucous membranes or broken skin. Indirect inoculation occurs when contact is first made with a contaminated intermediary and then into the eyes, nose, mouth, or non-intact skin [1]. The goal of all PPE is to prevent direct inoculation. Adherence to PPE etiquette and a doffing protocol serves to minimize the potential for indirect inoculation.

Table 14.1 Changes in US isolation precaution recommendations [1]

1970	1983	1988	1996
Infectious disease specialty hospitals and TB facilities closed, moving these patients into the general population. Categories of isolation include:	Category or disease specific as chosen by facility. Categories of isolation include:	Universal precautions: Blood and bodily fluids containing visible blood, of all patients. Did not apply to non-bloody feces, nasal secretions, sputum, sweat, tears, or urine	Standard precautions include blood and bodily fluid for all plus transmission-based precautions which include:
Strict	Strict		Airborne
Respiratory	Respiratory		Contact
Protective	TB		Droplet
Enteric	Contact		
Wound/skin	Drainage/secretion		
Discharge	Blood/body fluid		
Blood			
PPE recommendations			
Disposable gloves, new in mid-1960s, for use with known infectious substances	Up to HCWs to decide likelihood of contamination and use gown, glove, mask if indicated by risk for known or suspected infected materials	Gloves for contact with blood or bodily fluids. Hand washing recommended after all glove removal. Masks and protective eyewear for procedures with splash risk, all patients	PPE for contact with blood and certain bodily fluids considered potentially infectious. Still excepted: feces, sputum, sweat, tears, urine, and vomitus unless blood is visible

Protective equipment, from the early gloves to N95 masks and new impervious surface gowns, has become a routine part of working inside western healthcare facilities. It is easy to assume that what is common is also simple and that assumption has been extended to PPE use. It is common in the hospital setting to assume healthcare workers are proficient in all aspects of PPE. The use of PPE by healthcare workers came under scrutiny during the West African outbreak of EVD in 2014–2016. Concerns were raised about the readiness to treat patients with highly hazardous communicable diseases within US hospitals [4]. While caring for patients in isolation is something that US healthcare workers do every day, that familiarity does not assure competency.

Multiple studies conducted before and since the Ebola outbreak confirm that contamination to the wearer can occur even with careful use of PPE [5, 6]. While healthcare workers may believe that adding more layers and items to their PPE ensemble increases their safety, this has not been demonstrated to be true [7]. In caring for patients with highly hazardous communicable diseases, risks are mitigated with information about disease transmission, the choice of the right PPE ensemble, training and practice, and the use of trained observers. The margin for error is small inside biocontainment units. It must be recognized by all team

members that violations of infection control protocols, including PPE use and etiquette, can negate the compliant work of others and put everyone at risk [8].

In examining the makeup of a PPE ensemble, the advantages and the liabilities of each piece will be examined. PPE etiquette, or good form, will be evaluated, from the donning of PPE through its use at the bedside to the importance of a safe and observed doffing procedure.

The CDC has issued guidelines for the PPE to be worn by healthcare workers in the care and treatment of Ebola patients, guidelines that were updated frequently during the outbreak [9]. Those guidelines, and the choices of PPE made by the hospitals that cared successfully for patients with Ebola, reflect the need for total body coverage, including respiratory protection. While Ebola virus disease is not generally considered an airborne disease, the care of these patients may keep healthcare workers in close proximity to patients for extended periods of time and require them to perform tasks and procedures that generate aerosols; thus, respiratory protection is warranted.

The choice of a PPE ensemble is dependent upon other previous decisions, many of which are made far from the bedside. Ultimately, the PPE that is worn by staff is made up of items that can be sourced reliably and affordably, complies with all safety regulations, and in which the staff have competency in using through regular training and education. Deciding on one uniform type of PPE is also dependent on facility design and work flow. Below is list of questions to consider that may affect the choice of PPE and the protocols for its use. These questions can help guide the formation of a PPE matrix ensuring that all staff are protected commensurate with their level of risk. All personnel who come in direct contact with the patient; patient belongings; patient waste, including packaged waste; as well as the patient's direct environment must use appropriate PPE and be trained in its use [10].

- Will all staff wear the same PPE?
- Where will staff don their PPE?
- What will staff wear under their PPE, including footwear?
- Can staff don and doff independently or will they need assistance?
- Is there a chair, stepstool, or grab bar available where donning and doffing occur?
- How long will each professional likely remain in the room delivering care?
- Will the staff sanitize their PPE in some manner before or during doffing?
- Where will staff doff?
- Is there a mirror for staff to check their PPE?
- Can staff be observed while doffing?
- Will you use a trained observer?
  - What will a trained observer wear?
  - What PPE will ancillary personnel, such as environmental services, wear?
- If PPE is reusable, who cleans it and what is worn while it is being cleaned?

Putting together the best PPE ensemble depends on availability, price, ease of use, and the amount and type of protection required. In the USA, most of the gowns and suits worn for isolation purposes are disposable, contrary to the reusable suits

Table 14.2 Fabric standards for protective clothing [12]

National standards and what they mean for PPE			
ANSI/AAMI standards			
Level	Test methods	Barrier effect	Limitations
1	Impact penetration (water splash)	Minimal – Some resistance to water spray	Only tested on water which has a higher surface tension than many body fluids
2	Impact penetration with hydrostatic pressure	Low – Resistance to spray and some resistance to water penetration under pressure	
3	Impact penetration and increasing hydrostatic pressure	Moderate – Resistance to water spray and some resistance to water penetration with constant contact or increasing pressure	
4	ASTM F1670 synthetic blood and ASTM F1671 viral penetration	Blood and viral penetration resistance	

worn in most of Europe [11]. It is imperative that infection prevention personnel, supervisors, and purchasing agents all understand what items are being used in the biocontainment unit or with the care of any patient with a highly hazardous communicable disease and what level of protection they provide. International standards exist for the fabrics gowns are made from, as shown in Table 14.2.

It is important for those planning, purchasing, and writing protocols for the use of PPE suits and gowns to recognize that only Level 4 material has been tested using fluids with lower specific gravity than water, which is true of most bodily fluids [12]. Materials in Levels 1–3 have not been tested with fluids of similar specific gravity to bile, blood, or liquid stool and may have no resistance to these.

Choosing PPE that provides the highest level of protection against synthetic blood and simulated blood-borne pathogens exclusively allows staff to train in and use one ensemble that provides protection against various pathogens regardless of their transmission route. While it may be argued that this is "over-isolating," this approach mitigates concerns when dealing with new pathogens, unknown pathogens, or as information emerges about the existence and persistence of pathogens in varying body fluids [8].

Risks to PPE exist in varying forms. Defects in manufacturing and assembly can leave seams and zippers open to penetration. Both the person donning and the trained observer should inspect PPE as it is being put on. Suit materials can be torn or cut by sharp edges within the environment, and breaches in suit integrity can occur with use while staff bend, stoop, and reach. Special populations of patients can also pose hazards to PPE integrity by grabbing, pulling, or holding onto staff. Whether intentional or unintentional, the potential for a contaminating breach must be mitigated by the care team to the extent it is possible and foreseeable. Patients, who are delirious or agitated, frightened, or simply active as in the case of toddlers, pose higher risks to staff and to the integrity of a PPE ensemble. If a breach occurs,

protocols must be in place first to guide the staff member in the safest extrication from danger and then to assess, treat, and monitor the employee as needed.

Gowns and Suits

Gown and suit choice should consider ease of donning and doffing, as well as how it functions during use. Gowns are generally easier and safer for staff to don, may be more familiar to HCW, and usually can be put on without assistance. Some other considerations for gowns involve a fit that does not allow the front of the gown to touch the floor when performing patient care tasks, that covers the entire back of the wearer, and that remains securely positioned during use.

Suit style PPE can offer additional coverage of underclothing, does not have a risk of falling off shoulders in use, and does not drape the floor with bending or stooping, but is more difficult to don and, because of sizing limitations, may fit better in certain areas of the body than others. Employees should know which size of suit fits them safely, reducing redundant fabric without compromising the wearer's ability to bend, crouch, or sit. Seams and zippers, if any, should be covered. Donning and doffing suit style PPE is a skill that should be practiced and considered a part of staff competency.

Both gown and suit style PPE compliant with the Level 4 ASTM/AMSI standards are fluid impervious under pressure, which is beneficial for many of the intimate contact tasks that may be required while caring for patients. An unintended consequence of that fluid repellence is an increased risk of liquid and body fluid running off to the lower legs, shoes, and floor. Boot and shoe covers should be worn [13]. If gowns are used, shoe covers should extend to an area higher on the leg than the lowest portion of the gown. Suits with built-in "booties" should be worn with shoe covers that can be changed in the case of gross contamination (Figs. 14.1 and 14.2).

Gloves

Gloves and glove etiquette is another area where familiarity with a product does not necessarily infer safe use. Staff may need to practice methods of glove removal that discourage contamination, whether a glove-in-glove or other method is utilized. Fluorescing solutions and UV flashlights make this an easy exercise and one that is key to good technique. Studies have demonstrated an increased safety to staff with double gloving, but most of these determinations were made when the threat to the staff was from substances such as bone cements and glues [2]. Double gloving by itself does not prevent contamination of the wearer from either poor technique or from unrecognized loss of glove integrity [14]. Balancing the need for increased protection with required tactile sensation is not easy. Staff will need practice performing required skills while in extra layers of gloves. Because the cuffs of gowns and suits are not required to be fluid impervious, it is important that gloves extend over that portion completely and may require the use of an extended cuff glove [11].

Fig. 14.1 Emory PPE

Some institutions have chosen to use longer and heartier sterile gloves as their outer layer, while others have opted for extended cuff length exam gloves designed for chemotherapy use to offer a similar level of protection. Triple gloving is another option, which provides an additional glove which can be exchanged during patient care activities.

The use of alcohol-based hand rubs (ABHRs) on gloved hands allows for sanitizing without exposing skin while in a patient care area. The application of alcohol-based hand rubs has not been shown to have a negative effect on the gloves themselves [15], at least during limited use. Sanitizing the outer layer of gloves after touching the patient or a patient care device or surface is an important step in reducing further contamination of the care space. When outer gloves have been in contact with known areas of contamination or with patient body fluids, they should be sanitized and then changed [2].

Another strategy for glove safety is to employ gloves that are different in color layer to layer. This allows a visual queue when the outer glove has been compromised. Gloves should be inspected when they are donned and again before they are doffed to ensure that they have remained intact. Breaches in glove integrity, if they

Fig. 14.2 Nebraska Biocontainment Unit PAPR level PPE

involve both layers or the inner layer alone, should be regarded as a potential staff exposure.

To provide a continuous impervious surface along the hand, wrist, and forearm, some facilities tape their gloves to their suits or gowns. Decisions to tape gloves should be considered in the larger context of the donning and doffing procedure to ensure that staff understand both the rational and the timing of applying and removing tape. The benefit of a smooth, continuous wipeable surface in one of the high-risk zones for contamination must be weighed against the risk for damage to the suit or gown, the potential of micro-spray created during tape removal, and adding complexity to the donning and doffing procedure.

Droplet- and aerosol-generating procedures and situations can be abrupt and unpredictable. They include coughing without appropriate mouth coverage; sneezing; spitting; suctioning; pouring liquid waste into toilet; emptying bedpans, catheter bags, or urinals; and being near patients when they are urinating or defecating, or when staff assist with activities such as tooth brushing. A powered air-purifying respirator provides the greatest and most complete protection from these potential events, especially for caregivers within the critical 3-foot zone around the patient [16]. For facilities and staff who do not have access to or have not been trained in the use of these respirators, an N95 face mask and shield or a N95 face mask and goggles may need to be used.

Face Shields/Goggles

While likely less protective than the enclosed head piece of a powered air-purifying respirator (PAPR), for short periods of time in biocontainment units, or when patients are no longer exhibiting symptoms, a combination of face shield or goggles and a mask may be used. Eye protection serves to avoid the two mechanisms for worker exposure – direct splash into the eyes and self-inoculation with contaminated hands. Goggles, like eyeglasses, may move on the face during wear, tempting the wearer to reach up and adjust them with contaminated hands. Face shields have the advantage of being able to be worn with eyeglasses. Top-down full face shields lend more protection as users lean forward while delivering care than the smaller shields that are attached to surgical type masks, which can expose eyes to sprays and droplets when the wearers head is down.

Masks

Masks fall into two larger categories, isolation type single use and the N95 respirator [17]. An N95 or its equivalent in protection, or a PAPR, is required for all airborne pathogens as well as high-consequence pathogens when the care of the patient requires staff members to be within 3 feet of the patient's mouth and nose and when that patient is coughing and sneezing or has copious oral or nasal secretions. Again, because aerosol-generating incidents, such as a sneeze, can occur without warning, when staff are required to be in very proximity to any patient suffering from high-consequence pathogens, appropriate eye, nose, and mouth coverage should be maintained. An isolation type surgical mask may be worn in conjunction with a face shield to prevent the direct inoculation of staff mucous membranes only when there is not a risk of airborne transmission.

Mask removal must occur with clean hands, and staff should be encouraged not to touch their faces, eyes, nose, or mouth until they have thoroughly washed. Once a mask has been used, it should be discarded.

Powered Air-Purifying Respirators

As is true with other types of personal protective equipment, PAPRs require training and practice to be used effectively and efficiently. With highly hazardous communicable diseases, ease of use is a lesser factor than the protection that a piece of equipment provides. Surgical masks are the easiest for wearers to put on and take off correctly. N95 masks require training and fitting and annual competency [18]. PAPRs require training and practice, and many facilities using PAPRs have staff retrain on a more frequent basis.

Generally, the PAPR motor and fan are attached to or contiguous with head covering that contains a large face shield. Airflow is directed past the face to maintain a continuous positive pressure inside the face portion of the hood. Motors, and the

Table 14.3 Pros and cons of powered air-purifying respirators

Advantages	Disadvantages
Comfort	Expensive
Increased wear time	Require practice and training
Good visibility	Require power source
Stability with movement	Produce noise and impair hearing
Increased protection from N95	External hose, when present, risk entanglement
Full face, hair, head, and neck coverage	Not all hoods or portions of hoods are impervious
Less risk of fogging	

battery pack powering them, can either be worn on a belt at the waist or can be integral to the helmet structure beneath a disposable hood. Care must be taken to assure that a battery pack does not lose power while in use.

PAPRs may offer improvement in comfort and cooling compared to N95 masks and face shields or goggles. When workers wear PPE longer and more comfortably, they can stay at the bedside longer, reducing the number of required doffings per day. This can substantially reduce overall risk as each doffing episode confers risk of contamination to staff and the work environment [14] (Table 14.3).

Other PPE

Additions to the PPE ensemble may be aprons, gowns, shoe covers, and hair/head covers. Hats and hair covers may be integral to the hood or head piece or may be applied separately. Generally, these hair covers must also be impervious if they serve as the outermost layer. Care should be taken to ensure that they do not slip or move while being worn and do not compromise visibility.

Aprons and gowns can help create a smooth wipeable surface on the front high-risk area of the wearer, mitigating the risk along seam and zipper lines. Aprons afford covering to the chest and torso, while surgical or plastic gowns add protection to the arms. Each addition to the PPE ensemble must also be considered with relation to where the item will fit in the donning and doffing procedures. Staff should consider whether these items can be safely cleaned while in use, with sanitizing wipes, or whether they can be removed and replaced safely while within the patient care environment. The addition of a gown or apron is now recommended by the CDC as the outermost layer of a PPE ensemble as it avoids the folds and seams of underlying fabrics and can provide a wipeable surface and allows for additional protection in what are considered the high-touch areas of the anterior chest, torso, and arms [12].

Shoe covers are utilized over existing foot and lower leg coverage to allow the outer layer to be removed if soiled. Soiling of the shoe and lower leg areas can occur from splashes of body fluids that fall from the impervious layers of the PPE above them as well as from spills and splashes that reach the floor. Protocols for staff are needed to ensure that they can remove and replace contaminated foot coverings if

needed, especially during the cleanup of spills. Suits that have built-in foot coverings should still have a removable foot covering added for likely contamination events.

Trained Observer

The duty of a trained observer in a biocontainment unit is like that of a safety officer, watching but not participating in patient care, donning and doffing, unless needed in an emergency. In such a case, another trained individual should be ready and able to step in to the role of trained observer. The role is not designed as punitive or for score keeping but for identifying potential breaches that could compromise safety. It is not possible for staff in full PPE to know when a portion of their ensemble has come in contact with the patient or part of the environment. Even with practice, bedside caregivers may occasionally omit hand hygiene or a step in the doffing process. All members of the care team should be aware of the actions of those around them and be watchful for omissions that could compromise safety.

PPE Etiquette

By itself, no PPE ensemble protects staff if it is not used and maintained properly. PPE etiquette involves every step a staff member takes while providing safe patient care, from avoiding touching their own PPE and hand hygiene while gloved, to proper cleaning of PAPR motors, helmets, and belts. Gloved hands can be sanitized with alcohol-based hand rubs (ABHRs) but should not be washed while in the patient care environment to avoid splashing. Beds and bed linens, doors, tables and chairs, and all items within easy reach of the patient, such as TV remotes and call lights should be considered contaminated even without visible soiling. Once a staff member has touched those high-risk areas, they should perform hand hygiene or change outer gloves. Cleaning those areas of high risk repeatedly becomes part of the work day for clinicians at the bedside of the patient with a highly hazardous communicable disease.

Performing tasks that are normally routine for staff can pose hazards when performed in PPE, so they should be practiced and drilled. Staff proprioception is altered in their PPE, and developing a new sense of where the edges of their PPE-encapsulated body are in space is vital. Through practice, staff can become accustomed to the hoses, battery packs, helmets, hoods, and boot covers that alter this proprioception.

Mindfulness of where and what has been touched during the performance of clinical duties can be augmented by using a trained observer but is ultimately a change in the fundamental way staff deliver care. Clinicians must become keen observers of what surfaces and objects a patient may have contacted, from call lights and bedside tables to door handles, bed rails, and bathroom fixtures. Every action inside the patient care area must be taken with safety in mind, avoiding those

hazards that can be difficult to see while in a PAPR or face shield, to feel while double gloved, or to hear due to the background hum of the PAPR motor.

Doffing

As employees prepare to leave the patient care area, they should examine their PPE for breaches and visible soiling. Sanitizing wipes may be used to clean high-risk or likely soiled areas of PPE. A trained observer may be used outside the patient room, or in an anteroom or hallway, to observe the doffing process. If the observing staff is not separated by a physical barrier such as a wall, door, or window, they must be protected from potential splashes that can occur during the removal of PPE or be in PPE themselves.

A mirror may be helpful for the staff member to see their entire ensemble. The doffing protocol may be posted so that both the person doffing and their trained partner can ensure that each step is followed, or staff can follow an electronic version that records their compliance.

Each PPE ensemble will require a unique doffing protocol and many employ the use of ABHRs or other sanitizing devices such as UV light sources to reduce the risk of contamination during the doffing process [19]. A step-by-step approach avoids errors that can result in the unapparent transfer of infective materials. Where doffing occurs will be best determined by the physical layout of the unit and the space available but should occur a minimum of 6 feet from the patient in an area that has been dedicated to this purpose and is maintained as cleanly as possible.

Once the entire PPE ensemble has been doffed and the staff member is outside of the direct patient care area, they should be reminded not to touch any part of their bodies until they have thoroughly washed their hands. This final redundancy prevents indirect inoculation of staff from disposing of their used PPE.

Conclusion

Perhaps one of the greatest challenges when clinical duties require PPE is for HCWs to place the safety of themselves and their team first. Nothing, including the sudden loss of airway patency, consciousness, or pulse, should drive a clinician into the room of a patient with a highly hazardous communicable disease without proper PPE. Being mindful of how long it can take to don PPE and how difficult it can be to move both quickly and safely in the patient environment means that staff members in biocontainment units must be even more vigilant than usual in observing patients for early signs of decline in condition. The ability to anticipate critical needs can prevent staff from reacting dangerously and without the proper PPE. We must consider the patient care area to be our scene, and our first question must remain, is the scene safe? The right PPE, donned in the correct order, worn in a safe manner, is what makes that scene safe for bedside healthcare providers. The safe,

observed, step-by-step doffing of PPE is what ensures the safety of the rest of the unit, staff, and facility.

While healthcare workers use PPE routinely, we are also responsible for at least some of the nosocomial infections that plague modern healthcare facilities. In biocontainment units, as well as many other areas in the healthcare system, such microbe spread can have deadly consequences. Research is needed to determine best practice with respect to PPE, including the type of gloves and glove removal techniques that avoid hand and clothing contamination. Development of PPE suits that fit all sizes and meet the needs of the bedside clinician is also necessary. Decontamination procedures for reusable suits that are efficacious and cost-effective could reduce the enormous cost associated with the disposable suits now in use.

In addition, behavioral research could lend credence to the frequency, timing, and scope of PPE training and protocols for doffing that are proven to reduce staff contamination. New technologies in sanitation, including the use of ultraviolet light, may reduce in-room fomites. The future is likely to be filled with larger and more frequent outbreaks of highly hazardous communicable diseases. When we can be assured that HCWs are using the right PPE with good PPE etiquette and following protocols that have been validated through robust research, the healthcare setting will be safer for everyone.

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