

Personal Protective Equipment for COVID-19

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Personal Protective Equipment (PPE)

They protect the patient and the health care personnel (HCP) from infecting each other. This also protects the HCP from becoming a vector. PPE guidelines ANSI/AAMI PB70:2012 are published by the American National Standards Institute (ANSI) and the Association for the Advancement of Medical Instrumentation (AAMI) [1].

PPE include gown, respirator, eye protection (face shield or goggles), head, face and shoe covers and gloves [2]. Head and any facial hair should be completely covered. Shoe covers should be used [3].

PPE provide barrier protection for mucous membranes and broken skin. Sterile PPE are essential only when performing invasive procedures. Scrub suit is not included in PPE but should be made of tightly woven cotton-polyester, which is less porous than cotton.

PPE Protective

PPE reduce risk of infection. Risk is 0.2 times if physical distancing of greater than 1 meter is maintained [4]. The risk is further halved per additional meter of physical distancing. The risk is 0.15 times if a face cover is utilized. The risk is 0.04 times if an N95 respirator is utilized and 0.33 times if a surgical mask is utilized. The risk is 0.2 times if adequate eye protection is utilized.

Gowns and Gloves

There are four protection levels of gowns. Level 1 gowns provide only splash protection. Level 2 gowns provide splash protection and resistance to fluid under low pressure. Most surgical gowns are level 3, intended to provide protection against fluids under moderate pressure. The highest protection is provided by level 4 gowns, which provide protection against fluids and pathogens. Surgical gowns do not provide protection at the back of the gown, presumably because the surgeon is facing the patient. Isolation gowns differ by applying the standard to both the front and back of the gown. Level 4 isolation gowns protect front and back against fluids and pathogens.

Sterile gloves are usually made of latex or polyisoprene which is synthetic latex. Non-sterile gloves are usually made of nitrile.

Face Mask

A mask blocks most of the splashes and droplets but provides inadequate protection against aerosol or airborne particles [5].

The diameter of SARS-CoV-2 is approximately 0.1 μm . It is transmitted by respiratory droplets larger than 5 μm , airborne (aerosol) transmission less than 5 μm , and by contact with fomites. Utilizing a mask decreases the inoculum. It leads to decreased incidence of infection as well as decreased severity of infection among those who are infected [6].

A cotton layer combined with silk or chiffon or flannel layer is preferable [7]. These layers provide mechanical and electrostatic filtration. In a study, the fitted filtration efficiency (FFE) was 80% (for particles < 0.3 μm) and >90% (for particles >0.3 μm). For cotton only mask, use thick tightly woven three or more layers.

Loose fit of the mask decreases fitted filtration efficiency (FFE) [8]. Elastic ear loops lead to a loose fit, especially during motion. Top strap should be at the crown of head, bottom strap should be at the base of neck. Fit testing as well as fit self-checking at each donning is important. In a study, tight surgical mask with ties had FFE-72%. Procedural face masks with ear loops had FFE for men: 40%, women: 27% [8].

N95 Respirator

N95 particulate filtering facepiece respirator (FFR) are recommended for anyone exposed to aerosol. N means it is not oil resistant, 95 means it filters 95% of 0.3 μm particles. These respirators are made of non-woven polypropylene or other synthetic plastic fibers. Electrostatic charge enhances filtration. For a fibrous filter, the most penetrating particle size is 0.3 μm . This respirator standard is called FFP-2 in the European Union. The performance of Chinese KN-95 respirators varies with the manufacturer.

N95 Respirator Extended Use, Reuse, and Reprocessing

There is a shortage of respirators. According to CDC, N95 respirator use can be extended up to 8-12 hours for multiple patients without doffing [9]. N95 respirator can be reused up to 5 times with doffing between uses. N95 respirator should be discarded after aerosol generating procedure. For extended use or reuse of an N95 respirator, covering it with face shield or surgical mask is recommended. If reprocessing is performed with hydrogen peroxide, after 20 cycles filtration is preserved but the fit is inadequate. If ultraviolet germicidal irradiation is used for reprocessing, after 50 cycles filtration is preserved but the fit is decreased after 3 cycles. Dry heat 70-80°C is suitable for 2 cycles. Steam is not commonly used because it may distort

the mask. Ethylene oxide is not commonly used because it may leave a residue.

Mask and Respirator Protective

Of the HCPs who used mask or N95 respirator, 6% had antibodies. Of the HCPs who did not use mask or N95 respirator, 9% had antibodies [10]. Universal masking of HCP and patients was found to decreased infection [11]. Outside the OR the risk due to aerosol is generally lower than in OR.

Outside the OR N95 respirator may not provide greater protection than the mask [12]. Utilization of face covering reduced the risk of respiratory illness to 0.6 times. Risk of influenza-like illness was reduced to 0.34 times. Utilization of mask reduced the risk of severe acute respiratory syndrome (SARS) to 0.13 times [12]. Utilization of N95 respirator reduced the risk of SARS to 0.12 times. Thus, in this study N95 respirator did not protect better than mask.

Compared to surgical mask, N95 respirator did not reduce risk of infection, influenza-like illness, or workplace absenteeism [13]. Compared to surgical mask, N95 respirator did not reduce risk for laboratory-confirmed influenza [14]. Tight fitting surgical masks are adequate except during aerosol generating procedures.

Face Shield

It protects the face against droplets but not aerosol [15]. It prevents autoinoculation due to touching the face. It is inexpensive and can be reused indefinitely after disinfecting. There was 96% reduction in 8.5µm droplets, 68% reduction in 3.4µm airborne, but only 23% reduction in aerosol [16].

HCP were at risk in community despite utilizing 3-layer mask and other PPE. Adding face shield was protective [17]. Eyeglasses are protective [18]. Goggles may be more protective than eyeglasses. Tight-fitting goggles may not work well with eyeglasses or surgical telescopes.

Elastomeric Half-Facepiece Respirator (EHFR)

It is made of synthetic or natural rubber [19]. Elastomeric means rubber-like. Half-facepiece means it covers nose and mouth. It can be reused after disinfection.

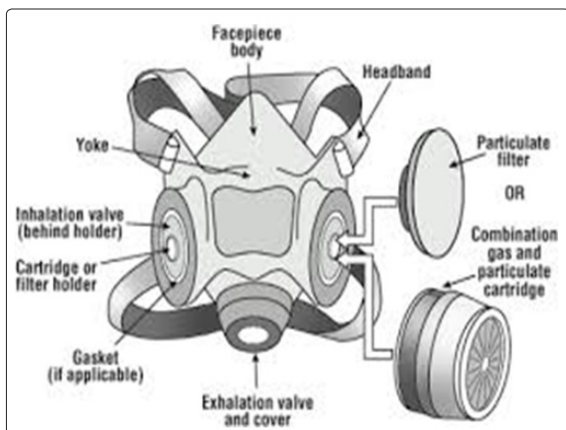


Figure 1: Elastomeric half-facepiece respirator (EHFR). Courtesy of National Academy of Sciences

Powered Air-Purifying Respirator (PAPR)

It utilizes high-efficiency particulate air (HEPA) P-100 filter [19]. P- oil proof, 100- removes 99.97% of 0.3 µm particles. It has a battery-powered air blower. PAPR is especially useful if HCP has labored breathing, fails fit testing, e.g., due to facial hair; or

requires eyeglasses or surgical telescopes. It is loose fitting and hooded or helmeted. No fit testing is necessary. A shroud like PAPR covers all around the head & neck. Mask, goggles or cap are not required with PAPR but may be utilized.



Figure 2: Powered air-purifying respirator (PAPR). Photo courtesy of 3M®.

Assigned Protection Factor (APF)

It is the aerosol concentration outside divided by inside the respirator. APF for N95 respirator & EHFR is 10. APF for PAPR is 25-1000. PAPR is superior but not necessary for adequate protection from SARS-CoV-2. An N95 respirator, goggle or face shield, head cover, and beard cover are adequate.



Figure 3: Disposable face shield. Photo courtesy of Sanford News

Donning PPE

Protocols for donning PPE vary. According to CDC Protocol, first perform hand hygiene [2]. Then put on in order: isolation gown, N95 respirator, face shield or goggles, and gloves. Nebraska Biocontainment Unit's protocol is more extensive [20]. Most protocols use 2 pairs of gloves and shoe covers.

Hand sanitizer with 60-95% alcohol or washing with soap and water for at least 20 seconds should be utilized. As a lipid encapsulated RNA virus, COVID-19 is readily destroyed by alcohol and soap. Visibly soiled hands should be cleaned with soap and water before using alcohol-based hand sanitizer.

Doffing PPE

There is a high risk of autoinfection at each step of doffing. Assistance from another HCP is recommended. According to the CDC protocol, remove gloves then gown, exit patient room [2]. Then perform hand hygiene, remove face shield or goggles,

respirator, then perform hand hygiene. Nebraska Biocontainment Unit's protocol is more extensive [21].

HCP at Increased Risk

Compared to the general population, HCP are at increased risk for COVID-19 but are under-diagnosed. According to CDC, 13% of infected persons are HCP [22]. Antibody to COVID-19 is present in 6% of HCP. 10 Of these 1/3 are asymptomatic and 2/3 are undiagnosed. More than 1,000 US HCP have died, many of them were minorities.

HCP at Increased Risk Despite Adequate PPE

HCP had twice the risk of a positive test and 1.3 times the risk of symptoms [23]. PPE reuse led to 1.5 times the risk, inadequate PPE led to 1.3 times the risk. When caring for infected patients, PPE reuse led to 5 times the risk, inadequate PPE led to 6 times the risk. When using adequate PPE, HCP risk was 2.4 times & 4.8 times when caring for suspected & documented COVID-19 patients, respectively.

In a multi-country study of 1718 HCP risk after performing endotracheal intubation [24]. 88% used adequate PPE to perform 5148 intubations, 67% of them for respiratory failure. After this, the test for COVID-19 was positive in 3.1% of the HCP. Additional 8.4% of the HCP had positive symptoms and self-isolated. In another study of resident MDs in New York, highest risk was among anesthesia residents [25].

Thus, studies indicate that PPE as used in practice, reduced the risk but did not eliminate it. This could have been due to inadequate adherence to protocol.

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