

# Personal Protective Equipment for Frontline Health-Care Workers during COVID-19 Pandemic: A Review

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## Abstract

The coronavirus disease-2019 (COVID-19) pandemic has thrown health systems indiscriminately across the globe into turmoil. The important route for the spread of COVID-19 is through aerosolized droplets that are expelled at the time of coughing, sneezing, or breathing, but there are also concerns for possible airborne transmission. COVID-19 pandemic has placed an unprecedented stress on the health-care system. Sudden increase in demand and limited availability of personal protective equipment (PPE) is making risks on health-care workers, which hamper their ability for effective management of the patients. Several health-care workers are dying in this global outbreak because of the improper protective measures during performing the high-risk procedures. Limited availability of the vaccine to health-care workers in all parts of the world and inadequate supply of proper therapeutic agents, such as personal protective measures, among health-care workers for restricting the COVID-19 spread are an important requirement. Regardless of the debate among the medical community for the use of PPE, a greater number of countries in the world are moving ahead with recommendations or mandates for using PPE in clinical interventions or caring for the COVID-19 patients. Some have attributed the death of health-care workers to inadequate supply of the PPE. However, there are some concerns about the improper use of PPE by the health-care workers. Policy makers, government, and health experts have increased the importance of manufacturing more PPE for the safety of the health-care professionals particularly frontline workers for COVID-19 patients. This review article provides an overview of PPE for frontline health-care workers in the COVID-19 pandemic.

**Keywords:** COVID-19 pandemic, health-care workers, personal protective equipment, SARS-CoV-2

## INTRODUCTION

Coronavirus disease-2019 (COVID-19) is a rapidly spreading infection caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which affected to 216 countries in just a few months.<sup>[1]</sup> The first case of COVID-19 was identified in Wuhan, China in the early part of December 2019.<sup>[2]</sup> To reduce the spread of COVID-19 infections, it requires several measures such as physical distancing, wearing face mask, and hand hygiene. However, health-care professionals must use personal protective equipment (PPE) to reduce the transmission from COVID-19 patients to the health-care workers.<sup>[3]</sup> Health-care workers should wear PPE in this current pandemic for reducing the transmission of the infections during dealing with patient care particularly at the time of aerosol-generating medical procedures (AGMPs). Viral

droplet nuclei can travel a long distance through aerosol and also stay in the air for a long period of time. Aerosols are not effectively filtered through surgical masks and so can be inhaled directly into the airways and lungs. When the health-care workers are at the risk of getting infections from the aerosols, airborne rather than droplet precautions are needed.<sup>[4]</sup> If there is a shortage or lack of personal PPE in the current COVID-19 pandemic, it will endanger patients and health-care professionals.<sup>[5]</sup> PPE use is the most effective method for reducing virus

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transmission from patients to the health-care workers.<sup>[6]</sup> The compulsory use of the PPE by health-care workers in a proper way will greatly control the COVID-19 pandemic by preventing infections to them.<sup>[7]</sup> There is lack of high-quality research on the PPE for protecting from infectious diseases during the pandemic. This review article discusses details about epidemiology, viral transmission in the COVID-19 pandemic, PPE, and its benefits for the health-care workers.

## METHODS FOR LITERATURE SEARCH

The research articles related to PPE for frontline health-care workers during the COVID-19 pandemic were searched through multiple approaches. First, we conducted an online search of the PubMed, Scopus, Google Scholar, and Medline databases with the following keywords: personal protective equipment, frontline health-care workers, and COVID-19 pandemic. A search strategy using Preferred Reporting Items for Systemic Reviews and Meta-analysis guidelines was developed. Randomized controlled studies, observational studies, comparative studies, case series, and case reports were evaluated for the eligibility. This article focuses only on PPE for health-care workers who are working for confirmed or suspected COVID-19 patients. Review articles with no primary research data were also excluded. The abstracts of the published articles were identified by this search method and other articles were identified manually from the citations. This review article reviews the epidemiology, SARS-CoV-2 virus, viral transmission, frontline health-care workers, COVID-19 patients, and PPE. This review article presents a baseline from where further prospective trials can be designed and help as a spur for further research in this important protective method such as PPE for health-care workers in the COVID-19 pandemic where not many studies are done.

## COVID-19 VIRUS

The causative microbiological agent for COVID-19 infection was identified as a novel coronavirus, which was known as SARS-CoV-2 and this disease is called coronavirus disease-2019 (COVID-19) by World Health Organization (WHO).<sup>[8]</sup> SARS-CoV-2 was earlier known as 2019-nCoV, positive-sense, single-stranded RNA virus with a diameter of 60–140 nm.<sup>[8]</sup> SARS-CoV-2 is included in the genus of beta coronavirus.<sup>[9]</sup> So far, this is the seventh member of the coronavirus family, which can infect human beings. The incubation period of SARS-CoV-2 ranges from 1 to 14 days with a median of 5–6 days.<sup>[9]</sup> Although the recent study reports that the incubation period may extend to 24 days,<sup>[10]</sup> a longer incubation period has implications in quarantine policies and prevention of the spread of the disease. Respiratory droplets are primarily responsible for transmission of the infection. However, blood and stool also cause transmission of the SARS-CoV-2 virus, so raising the question regarding the mode of

transmission of the infection.<sup>[11]</sup> It can be easily transmitted through aerosols of different sizes.<sup>[12]</sup> When health-care workers or any individual is working in close proximity to the infected patient, both larger droplets and smaller those inspirable aerosols can produce a significant risk. During performing AGMPs, the risk of contamination is even higher.<sup>[13]</sup>

## MODE OF VIRAL TRANSMISSION

The SARS-CoV-2 is mainly transmitted through respiratory droplets, contact, or aerosols.<sup>[14]</sup> The airborne transmission occurs during aerosol-generating procedures. Contact transmission may occur via direct physical contact with virus-laden airway secretions from the infected persons or indirectly through contact with inanimate objects or environments contaminated with SARS-CoV-2.<sup>[14]</sup> Conventionally, the respiratory transmission of the virus is classified into either droplet or airborne. The droplet transmission occurs through deposition of large droplets (>5 µm in diameter) on the mucous membrane of nose, mouth, and eye of the susceptible person. Respiratory aerosols typically have droplet nuclei less than 5 µm in size.<sup>[15]</sup> Droplets usually fall to the ground at rates inversely proportional to their size. A 10-µm diameter size settles in approximately 8.2 min as compared with 1.5 h for a 3-µm-diameter particle and 12 h for a 1-µm particle.<sup>[16]</sup> If the rooms are not well ventilated, the droplets can become more concentrated over the time. Clinicians who are susceptible to be infected by COVID-19 infection and those who are working in close proximity to the infected persons for longer period may be exposed to large infectious doses of the virus. COVID-19 usually infects the upper aerodigestive tract with the highest viral loads found in the nasal cavities.<sup>[17]</sup> The nose, throat, and conjunctiva are the potential routes of transmission of the virus from infected persons. During aerosol-generating procedures, the clinicians or surgeons get closer to the source of aerosol and the particle density increases exponentially as per the principle of diffusion.<sup>[18]</sup>

## IMPORTANCE OF THE PROTECTIVE MEASURES OF HEALTH-CARE WORKERS

The health-care workers are the center of the patient care in the current COVID-19 pandemic. The use of PPE protects the health-care workers from getting infected during posting in COVID hospital and performing medical or surgical interventions in suspected or confirmed COVID-19 patients.<sup>[19]</sup> Precautions must be implemented by the health-care professionals during assessment of the COVID-19 patients. The WHO and other national and international health authorities are implanting safety procedures for health-care workers.<sup>[19]</sup> However, the protective equipment and safety protocols are not available in many centers dealing with COVID-19 patients. Many health centers around the world have

facilities to an appropriate number of human resources, diagnostic, and therapeutic protocols for providing care to the admitted and ambulatory COVID-19 patients.

## HEALTH-CARE WORKERS

The emergence of the COVID-19 pandemic presents challenges for providing adequate protection and prevents transmission of infections among the health-care workers. There are concerns regarding the potential routes for transmission, the severity of the disease, and absence of the effective treatment and vaccinations lead to different preventive measures.<sup>[20]</sup> For ensuring the health and safety of the health-care workers in the COVID-19 pandemic, three levels of the protection are made.<sup>[21]</sup> In the case of standard patient care and routine examination of the patient and no interventions are performed even in patient of SARS-CoV-2 positive, Level 1 PPE (droplet protections) is useful. As per the clinical experiences, Level 2 PPE (airborne precautions) gives adequate protection to the health-care workers during the short period of AGMPs like endotracheal intubations, even in case of SARS-CoV-2 positive. In the case of longer duration AGMPs such as high-risk procedures like sinonasal surgery using drills, in patients known to be SARS-CoV-2 positive, a greater level of protection is required, that is, Level 3 PPE. The health-care workers working close to the SARS-CoV-2 positive patients should use at least level 2 PPE. If available, the negative pressure room should be used for performing the procedures and the number of the health-care workers exposed should be minimized.<sup>[22]</sup>

## PERSONAL PROTECTIVE EQUIPMENT

PPE includes hand hygiene, gown, face mask, face shield, and hand gloves.<sup>[23]</sup> There are different levels of the PPE such as standard, contact, droplet, and airborne precautions.<sup>[24]</sup> The guidelines for standard precautions by the Center for Disease Control and Prevention (CDC) include hand hygiene, respiratory hygiene with cough etiquette, proper placement of the patient, cleaning of the equipment, devices, environment and laundry as well as following safety procedures.<sup>[25]</sup> The contact precaution is usually used when the transmission of infection through direct contact with an infected person or with contaminated items or body fluids.<sup>[24]</sup> Contamination of the mucous membranes is the most important method for transmission of the infection. So, respirators and goggles are essential to provide a tight seal and minimize the chance of direct aerosol transmission and also prevent accidental self-contamination by touching the mucosal surfaces. Full face or hood powered air-purifying respirators (PAPRs) are specially made to provide even higher protection to the health-care workers against hazardous particles and minimize the risk of the potential face seal leakage, particularly in those who cannot be successfully fit tested with help of respirators.<sup>[26]</sup> The choice of the PPE [Figure

1] is decided on the risk of exposure and possible mode of transmission of infections. The level of protection given by the PPE is based on the standards and test methods. So, understanding them is the important step for selecting the proper PPE. The global comparison of the PPE is given in Table 1.<sup>[25]</sup>

## POWERED AIR-PURIFYING RESPIRATORS (PAPRS)

There are some controversies regarding the clinical utility of PAPRs or controlled air-purifying respirators (CAPRs) at the time of the aerosolizing procedures. PAPRs are made to provide greater protection in comparison to N95 respirators and use HEPA filters (the minimum filtration efficiencies for 0.3  $\mu$ m particles for N95/FFP2:95% HEPA:99.97%).<sup>[27]</sup> Occupational safety and health administration (OSHA) standards, the assigned protection factors (APFs), for PAPRs vary from 25 for loose filtering



**Figure 1:** A health-care worker with PPE



**Table 1: Worldwide comparison of PPE for health-care workers working for suspected/confirmed COVID-19 patients**

Protections	WHO	CDC	UK	Australia	China	ECDC (Italy, Spain, France, Germany)
Respiratory Protection	Surgical mask	N95 respirator mask	Fluid repellent surgical mask	N95 respirator mask		FFP2/FFP3 respirator mask
Body protection	Long-sleeved gown	Gown	Plastic apron	Long-sleeved gown	Long-sleeved medical protective uniform, shoe cover, hat	Long-sleeved water-resistant gown
Eye protection (goggles or face shield)	Yes	Yes	Depends on the clinical setting, proximity to patient and/or assessment of risk	Yes	Yes	Yes
Hand protection (gloves)	Yes	Yes	Yes	Yes	Yes	Yes

**Table 2: Standards of different respirator mask**

Respirator mask	Filtration efficacy
FFP1	At least 80%
FFP2	At least 94%
N95	At least 95%
N99 and FFP3	At least 99%
N100	At least 99.97%

facepieces to 1000 for full facepieces, whereas the APF for N95 mask is 10.<sup>[27]</sup> An APF of 10 represents that one-tenth (10%) of the contaminants to which health-care workers are exposed can leak into the inside of the face mask. In the case of PAPR with APF of 50, this is only 2%. Although PAPRs have greater protection factors in comparison to N95 respirators in the laboratory settings, there is no evidence showing that PAPRs are highly effective in lowering the risk of viral airborne transmission in health-care settings. PAPRs can be used by the health-care workers who cannot be successfully fitted with N95 respirators and are more comfortable who worn for longer periods.<sup>[28]</sup> If the respirators are used by health-care workers, then the use of N99/FFP3 respirators will give a higher level of protection with higher minimum filtration efficiencies (99%) to small (aerosolized) particles in comparison to N95/FFP2 respirators (94%–95%). If N99/FFP3 respirators are not available to health-care workers, an N95 mask seems enough. At the time of initial months of the COVID-19 pandemic, N95/FFP2 respirators provide enough protection during AGMPs like intubations.<sup>[29]</sup> Different respirator masks used by health-care workers are given in Table 2.<sup>[29]</sup>

## N95 MASK

CDC insisted that N95 respirators should be used by health-care workers who are coming in contact with COVID-19 patients. N95 masks (equivalent to FFP/P2 in European countries) are made up of electrostatically charged polypropylene microfibers designed for filtering the particles measuring 100–300nm in diameter with 95% efficacy.<sup>[30]</sup> N99 (FFP3) and N100 (P3) masks are available, although not used widely, provide 99% and

99.97% efficacy, respectively, for the same range of particle size.<sup>[30]</sup> An N95 respirator protective device is designed to achieve a very close facial fit along with effective filtration of airborne particles. The edges of the N95 mask form a seal around the mouth and nose. N95 masks are usually used in hospital settings and are a subset of N95 filtering facepiece respirators (FFRs), often called as N95s.<sup>[31]</sup> Food and Drug Administration (FDA) cleared that N95 masks are labeled as single use, disposable devices. The N95 mask is soiled or damaged or breathing difficulty occurred during use; it should be removed or discarded properly and replace with new one. For safely discard the N95 mask, it should be placed in a plastic bag and put in the trash. Hand should be washed with soap water or sanitizer after handling with N95 mask.

## FACE SHIELD

Face shields are PPE devices, which are used by health-care workers during dealing with patients in current COVID-19 pandemic. It protects the facial areas, nose, mouth, and eyes from the droplet spread of infections.<sup>[32]</sup> Face shields are often used along with head cap, face mask, goggles, and so face shield is called as adjunctive PPE. The face shield should snugly fit around the head without any leak or gap between the forehead and shield. The readymade available plastic bands are not tight enough and even fall off after repeated use. Sometimes use of the sponge in between the forehead and face shield provide good comfort; however, such face shields should be used as disposable as sterilization of the sponge is not enough. The reusable face shields should be free from sponges or any sticking materials or any stapler pins for getting good sterilization. The front side of the face shield should not be touched. The face shield should be removed by gloved hands from behind by untying the ribbon knot and disposed along with hand gloves. The face shields are usually sterilized by 1% sodium hydrochloride solution for minimum of 10min.<sup>[33]</sup> It can be kept in sun light and cleaning with sanitizers with gloved hands.<sup>[33]</sup> The face shield can also be sterilized with 2% glutaraldehyde for 10min and then wash with normal saline and again dry it. The best way to sterilize the face shield is ethylene oxide (ETO).<sup>[33]</sup>

## DONNING AND DOFFING

During donning and doffing of the PPE, it is always suggested that a second health-care worker should present for assisting and ensuring if the donning and doffing is done correctly as it can result in self-contamination even in case of experienced health-care professionals.<sup>[34]</sup> The chance of self-contamination is high when the health-care professionals are unfamiliar with donning and doffing. So, training sessions should be arranged for health-care workers as essential part of the infection control program and coordinated by local infection control experts. It is always recommended that donning and doffing at the time of the medical or surgical procedures should be minimized as much as possible for lowering the chance of the contamination.<sup>[35]</sup>

## CONCLUSION

During current COVID-19 pandemic, the safety and health of the health-care workers are essential for ensuring ongoing care of the patients and protect from the collapse of the health-care system. The strict recommendations for preventing infections will minimize the chance of the SARS-CoV-2 infections to the health-care workers. Because of its potential benefit and lack of any obvious harm, the PPE is strongly recommended for health-care workers during managing the COVID-19 patients. PPE shortages endanger the health-care workers and patients during the current COVID-19 pandemic. PPE should be selected appropriately and used rationally. Health-care professionals should keep in mind that PPE is the last line of protection in current pandemic and its use alone does not effectively minimize the transmission risk. Furthermore, basic infection control measures such as frequent hand washing, environmental disinfection and cleaning should be emphasized. When aerosol-generating procedures are not performed, the chance of transmission of COVID-19 infection may occur through airborne transmission which is still in debate. So, PPE recommendations are subject to change as per future study result. Health-care workers and hospitals should be vigilantly aware of such changes for recommending the PPE and prepare for future.

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## Conflicts of interest

There are no conflicts of interest.

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