REVIEW ARTICLE

Personal Protective Equipments (PPE) – Prerequisites, Rationale and Challenges during COVID 19 Pandemic

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Abstract

Personal protective equipment (PPE) usage is pivotal in prevention of COVID19. Access to PPE for health workers has become a key concern. Electronic databases were searched for studies, guidelines, reports and policies on PPE, COVID19 and respiratory infections. In total 20 research articles were included, 10 guidelines and 06 reports from various health organization and National governments were included. There are different types of masks available, it is essential to understand the role of each kind of mask in preventing the spread. Minimizing the need for PPE in health care settings, ensuring rational and appropriate use of PPE and Coordinating PPE supply chain management mechanisms are key strategies in addressing global PPE shortage. Ensuring consistent PPE standards and guidance on quality control of the PPE will help in better infection control. We need to apply a risk-based approach based on purpose of use, risk of exposure, vulnerability, setting, feasibility and type of PPE. Government of India is taking several steps and have deliberated on the adequacy and quality of PPEs. Prevention and mitigation measures are the key for prevention of transmission in the Community which include Hand hygiene, Respiratory hygiene, maintaining social distance of two metre and wearing an appropriate PPE. Adequate provision of good quality PPE is just the first step in promoting the safety of health care workers and containing the spread of COVID 19.

Keywords

Personal Protective Equipments; COVID-19; Rationale; Challenges

Personal protective equipment (PPE) is essential in preventing workplace injuries or illnesses among health care providers by providing a physical barrier between microorganism and wearer. PPE complements in control of infection transmission from patients to health care workers, other patients and attendants effectively when used with other infection control practices.(1)

SARS-CoV-2 is known to be more contagious and more serious than influenza, and may have different patterns of spread. COVID-19 (Corona Viral Disease - 2019) is spread by : Direct contact/ fomites and droplet infection being the major route of

transmission followed by airborne transmission particularly during procedures such as intubation, nebulization and faeco-oral.(2,3) PPE includes gloves, protective eye wear (goggles), mask, apron, gown, boots/shoe cover and hair cover. PPE usage has become pivotal after the emergence of life-threatening infections such as severe acute respiratory syndrome, Middle East Respiratory Syndrome and now COVID 19. There is a need for efficient infection control programs in all health care settings (3) and research into standard precautions has been carried out in many countries.(4,5)

Worldwide, as millions of people stay at home to minimise transmission of corona virus, health-care workers go to clinics and hospitals, putting themselves at high risk from COVID19. Data from China's National Health Commission show that more than 3300 health-care workers have been infected as of early March and, according to local media, by the end of February at least 22 had died. In Italy, 20% of responding health-care workers was infected, and some have died.(6)

As the pandemic has accelerated, access to PPE for health workers has become a key concern. Medical staffs are prioritised in many countries, but PPE shortages have been described in the most affected facilities. Alongside concerns for their personal safety, health-care workers are anxious about passing the infection to their families.

In addition, since the start of the COVID-19 outbreak, prices of PPE have surged. Cost of surgical masks has seen a sixfold increase, N95 respirators have trebled and gowns have doubled. Supplies can take months to deliver and market manipulation is widespread, with stocks frequently sold to the highest bidder.

Aims & Objectives

To review Personal Protective Equipments – Prerequisites, Rationale and Challenges during COVID 19 Pandemic.

Material & Methods

We searched the following databases for articles published in English from January 1990 to April 2020: Pub Med, Science Citation Index and the Cochrane Library. We searched for articles using the following key words. #1: 'facemask', 'Personal Protective equipment', 'mask', 'respirator', 'gloves', 'plastic aprons', 'goggles', 'gowns', 'Face protection'. #2: 'influenza' 'COVID 19' 'respiratory virus', 'respiratory infection'.

The search results were surveyed for methodological articles and following studies were included:

- Research studies on efficacy of personal protective equipments,
- Identified knowledge and compliance related to appropriate selection and usage of PPE
- Interventions aimed at improving knowledge and compliance to PPE use

In addition, we also included relevant guidelines, policies and Government reports that have a direct reference to Personal Protective equipment from various countries and health organizations. Articles reporting findings at hospital and community settings were included. All articles were reviewed to determine inclusion. Studies not written in English were excluded from the review. In total 20 research articles were included, 10 guidelines and 06 reports from various health organization like World Health Organization, Centre of Diseases Control, Food and Drug Administration and National governments were included.

Types of Masks: The dust mask and single layer face mask do not offer protection against COVID infections. The surgical mask is made up three layers. The innermost layer is made up of an absorbent material that absorbs moisture from the wearer's breath, the middle layer is made up of a melt-blown material that acts as a filter, and the outer layer is made up of material that repels liquid. Surgical masks need to conform to the following quality standards: bacterial filtration efficiency >98%, particulate filtration efficiency <99% for 0.1micron particle size, differential pressure that measures ease of breathing <3mm, and fluid resistance of 80 mmHg. As of now, there is no certifying body in India for Surgical Masks unlike other countries. The surgical mask does not offer a tight fit and there is enough space for the air to leak from all the sides of the mask. Surgical masks are intended to be used only once between 3 to 8 hours and then safely disposed. They should never be washed and reused. Ensuring correct method of wearing and removing masks are important. Fake surgical masks are flooding the market all over the world and it is important to ensure that one is not wearing one.(7)

Respirator Mask (N95, N99, N100; FFP1, FFP2, FFP3): A respirator mask is a tight-fitting mask with a filtration system that prevents the wearer from

being exposed to noxious particles, gases, oils or microorganisms. The filter of the N95 mask is made up of millions of microfibers of polypropylene layered on top of each other that have been permanently electrostatically charged. The electrical charge is necessary to retain its ability to filter microorganisms or microparticles. N stands for 'not oil resistant', and the number next to it represents the percentage of filtration efficacy of >0.3 µ particles. Breathing with the mask is difficult. The valve N95 mask respiratory are not suitable for patients suffering with COVID-19 as during exhalation they will allow the virus to pass out easily and can potentially infect neighbouring people. The N95 mask should be National Institute for Occupational Safety and Health (NIOSH) approved and CE (standards as per European Economic Area) certified. A genuine N95 respirator mask should have all the markings as shown in (Figure 1).

They have tried various methods to reuse N95 mask for re use like Heat in an oven(8), Dry heat in a rice cooker for 3 minutes, until the temp is 149 -164 degrees Celsius(9), Chemical sterilization with H_2O_2 for 45 minutes sterilizes the filter without destroying it.(10) Attempts made for cleaning the mask with soap and warm water or alcohol or bleach or exposure to ultraviolet radiation or isopropranolol or microwaving have all been unsuccessful as they damage the electrostatic charge and significantly reduce the filtration capacity.(11)

Cloth Masks are cheap, easily available, washable and reusable for general public for community use in developing countries as N95 is expensive and surgical masks need to be changed frequently. The cloth mask is mandatory to be used by patients who visit hospitals. However, they provide only 67% of protection and reduces the trans mission of virus by 40%. (7)

Personal Protective Equipment kit - Personal Protective Equipments (PPEs) are protective gears designed to safeguard the health of workers by minimizing the exposure to a biological agent. The PPE Kit for Contact & Airborne precautions consists of Gloves, Coverall (medium and large) /gown, Goggles, N-95 Masks or higher efficiency, Shoe and head Covers, face Shield. (12)

The complete PPE kit needs to worn by all personnel working with COVID 19 cases such as the screening area, laboratory sample collection, COVID19 wards and COVID19 ICU. The correct method of donning and doffing also needs to be known. All the PPE kit items shall go to the yellow bag for safe bio medical waste handlings.

Types of PPE Kit: Based on the thickness of the material used

-Basic KIT 45GSM: It shall be used by all housekeeping staff, Canteen workers, Administrative staff, Pharmacy staff and all the visitors.

-Medium Kit 70GSM: It shall be used by OPD staff, Pathology staff, Radiology staff, Ambulance staff, Mortuary staff, OT staff and Patients attendants.

-Advanced Kit 180GSM: It shall be used by doctors, Intensivist, nurse, Housekeeping staff at COVID positive ward/ICU

A recent Cochrane review on PPE published following findings. Covering more of the body leads to better protection, but associated with increased difficulty in donning on and doffing of PPE leading to more contamination. Respirators worn with coveralls may protect better than a mask worn with a gown, but are more difficult to put on. More breathable types of PPE may lead to similar levels of contamination but be more comfortable.(12)

Rational use of Personal protective equipment in the COVID-19 Pandemic:

WHO recommends rational use of PPE in healthcare and community settings.(13)The lack of agreement on the selection and use of type of masks and respirators is reflected in inconsistent and conflicting policies worldwide.(14,15) Masks and respirators are commonly used to protect healthcare workers from respiratory infections, particularly during the initial periods of outbreaks/ pandemics when other control measures not yet available.(16,17) Official UK guidance released in February 2020 claimed that both standard and respirator masks provide 80% protection against SARS-CoV-2.(18)However, this claim referenced a 2017 systematic review that was undertaken before the emergence of SARS-CoV-2 and based largely of trials in seasonal influenza.(19)

PPE is only one effective measure within administrative, environmental and engineering controls, as described in WHO's Infection prevention and control of epidemic and pandemic-prone acute respiratory infections in health care.(20)It is crucial to ensure to protect frontline health care workers. This includes advocating for the urgent increased

production of PPE. PPE shortages are currently posing a tremendous challenge to the many healthcare system because of the COVID-19 pandemic.(21)CDC's optimization strategies for PPE offer options for use when PPE supplies are stressed, running low, or absent. Contingency strategies can help stretch PPE supplies when shortages are anticipated.(14)

This increase in use of face masks by the general public exacerbates the global supply shortage of face masks, with prices soaring(22)and risks supply constraints to frontline healthcare professionals. As a response, a few countries (eg, Germany, South Korea and India) banned exportation of face masks to prioritize local demand.(23)The capacity to expand PPE production is limited, and the current demand for respirators and masks cannot be met, because of widespread inappropriate use of PPE.

WHO carefully considered **last-resort temporary measures** in crisis situations to be adopted only where there might be serious shortages of PPE or in areas where PPE may not be available. Temporary measures include PPE extended use (using for longer periods of time than normal according to standards); Reprocessing followed by reuse (after cleaning or decontamination/sterilization) of either reusable or disposable PPE; Considering alternative items compared with the standards recommended by WHO.(7,8,9,10)

In view of the global PPE shortage, the following strategies can facilitate optimal PPE availability

1. Minimize the need for PPE in health care settings: Using telemedicine to evaluate suspected cases of COVID-19, using physical barriers to reduce exposure such as glass or plastic windows in triage areas, the registration desk, or at the pharmacy window. Restrict health care workers from entering the rooms of COVID-19 patients. Avoiding of visitors wherever possible.
2. Ensure PPE use is rational and appropriate: Respirators were used for an extended time during previous public health emergencies involving acute respiratory illness when PPE was in short supply.(24) The same respirator can be used while caring for multiple patients who have the same diagnosis without removing it, and evidence indicates that respirators maintain their protection when used for extended periods. One respirator for longer than 4 hours should be avoided.(25,26,27)Among the general public, persons with respiratory symptoms or those caring for COVID-19 patients at home should use medical masks. (28) For persons without symptoms, wearing a mask of any type is not recommended and when not indicated may cause unnecessary cost, procurement burden and create a false sense of security that can lead to the neglect of other essential preventive measures. (29)
3. Coordinate PPE supply chain management mechanisms: These include: using PPE forecasts based on rational quantification models to ensure the rationalization of requested supplies; Monitoring the end-to-end distribution of PPE and controlling the distribution of PPE from medical facilities stores.(29)

Guidelines on rational use of Personal Protective Equipment in India (13)

This guideline uses setting approach in different area for health care workers and others working in points of entries, quarantine centres, hospital, laboratory and primary health care / community settings. It is explained in (Table 1)

Aerosol Box to cover patient head during intubation/extubation made of transparent polycarbonate sheet/ acrylic can be used to minimise exposure. It has to be cleaned with 70% alcohol and reused for next patient. COVID WISK is another innovative approach engaged to avoid exposure to Health Care Professionals and minimise the need for PPE while collecting samples from suspects. Thos also reducing the PPE use. This was first initiated in Korea now also introduced in Various Indian states.

One must remember that hand hygiene is the single most effective tool available for prevention of the transmission and one needs to practice hand hygiene, before, during and after donning or doffing of any PPE like mask, hair cap, gown, boot cover, gloves or the whole PPE. Hand hygiene practiced with PPE is almost 100% effective in prevention of transmission of COVID19.

Ideal PPE requirements:

No consistent PPE standards and guidance on quality control of the PPE being used were available. To provide recommendations on product consistency and standards for each of the individual PPE elements (gloves, masks, eye protection, gowns, overalls, boots, aprons, etc.), the WHO published a rapid advice guideline for PPE with technical

specifications in October 2014. (30,31) The following characteristics were recommended in (Table 2).

1. **Design feature**: PPE should be designed to prevent exposure of the health worker at the frontline's mucous membrane areas (mouth, nose, and eyes) and skin from becoming contaminated with the body fluids of infected patients and from inadvertent self-contamination. The number of junctions where PPE elements meet should be minimized. Junctions must be comfortable and leak-proof. Provide a PPE design with no-fog and the range of vision to be as broad as possible against all climates. Enable communication (speaking, hearing and seeing). Health worker using PPE must be protected and stay comfortable throughout the duration of the work period.
2. **Material performance**: This ensures the protective effects of PPE will withstand disinfection and the PPE packaging can maintain its integrity in tropical climate. Pressure points (elbows, knees, and seat) of the PPE will need to be protective when pressure is applied. The protection should be effective for the work period to beyond 40 minutes and up to 4 hours. Function and integrity should be maintained after multiple cleaning and disinfection procedures for PPE that is meant to be used again. Proper storage often requires a dry and clean place that is not subject to temperature extremes.
3. **Use desirability**: Donning and doffing PPE are multi-step processes that can cause confusion and frustration for the health worker at the frontline. A standardized and easy to follow protocol is necessary to guide the health worker at the frontline through the steps for each process. A massive amount of waste can be generated in the healthcare setting including contaminated, discarded PPE. This needs to be discarded appropriately.

Challenges for PPE usage in COVID 19 Pandemic:

Medical masks should be reserved for health care workers. WHO offers advice to decision makers so that they apply a risk-based approach based on purpose of use, risk of exposure, vulnerability, setting, feasibility and type of mask. There may be potential advantages of the use of mask by healthy people in the community setting.(32,33)

Caregivers or those sharing living space with persons suspected of COVID-19 or with mild symptoms should wear a medical mask when in the same room as the affected person. (34) There is now a growing body of evidence to suggest that asymptomatic transmission occurs in the community. Infected people can shed the virus via aerosol droplets even 2.5 days before they start developing symptoms. Asymptomatic transmission accounted for 66% (range: 45-84%) in a Singaporean cluster and 77% (range: 65-87%) in the Tianjin cluster.(35)

Countries that have a culture of wearing masks routinely, such as Hong Kong, Singapore, South Korea and Taiwan seem to have shown a flatter curve on the COVID-19 trajectory. A case report from China, clearly suggests that wearing a mask protects others from catching the infection.(36)

One study that evaluated the use of cloth masks in a health care facility found that health care workers using cotton cloth masks were at increased risk of infection compared with those who wore medical masks reinforcing the use of medical masks among health care workers.(37)

Hand washing alone was shown to reduce the risk of SARS virus transmission by 55%, wearing a mask by 68% and hand-washing, wearing a mask, gloves and a protective gear, all together by 91%.(38)It is critical to emphasize on other measures to prevent spread.

Government of India is taking several steps along with the States/UTs for the prevention, containment and management of COVID-19 in the country. They have deliberated on the adequacy on PPEs, N-95 masks and ventilators.(39)Viability of PPEs is an acute problem in India because they were not manufactured locally. With the help of the Ministry of Textiles, all the potential domestic and foreign manufacturers based in India were contacted and provided handholding support to make good quality PPEs. Exports for PPE items have been banned since January 31, 2020 to ensure the continued availability of these items in the country. Foreign supplies have been tied up and we hope that there will be a steady supply available in future.(40)

Future research is required in the development of ideal PPE, Conduct research on the interoperability of the combined mask, head cover and face shields to provide effective protection with no-fog visibility. Research should evaluate the impact of wearing a full PPE ensemble in hot, stressed conditions on mental acuity, body temperature, and heart rate to understand the thermal effects of PPE and can assist

in defining an appropriate work-to-rest ratio.Manufacturers, engineers and designers should examine the different types of fabric and materials that may allow for better breathability, durability and liquid repellence. Fabrics may also be produced to have virucidal/bactericidal properties. Research and testing considerations are needed to determine if innovations in this area can yield desired outcomes. There are standards defining minimum performance criteria for aprons, hoods, and boots/boot covers, or junctions (e.g., leakage at glove/body suit interface) but they lack harmonization and performance requirements making the PPE selection process more cumbersome. It is right time for the GOI to Form a R&D and regulatory authority to certify the standards about PPE. A board comprising Ministry of Health, Defence, Textiles, Home, and Commerce should be constituted to formulate standards, avoid hoarding and regulate commerce. Health care personnel have to be taught about importance of Hand-washing and dynamics of viral transmission. PPE and wearing a glove merely shouldn't give them a false sense of Protection against the Virus.

Authors Contribution

All authors have contributed equally.

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Tables

TABLE 1 NOVEL CORONA VIRUS DISEASE 2019 (COVID-19): GUIDELINES ON RATIONAL USE OF PERSONAL PROTECTIVE EQUIPMENT

Area/Patient care activities	Activities	Surgical mask	N-95	Gloves	Gown/ Coverall	Goggles	Head Cover	Shoe cover
At point of entry								
Health Desk	Information for travellers	√	x	√	x	x	x	x
Immigration check /customs/airport security	Services to the passengers	√	x	√	x	x	x	x
Temperature recording station	Record Temperature	√	x	√	x	x	x	x
Holding area/ Isolation facility of APHO/ PHO	Interview/ Clinical examination by doctors/ nurses	x	√	√	x	x	x	x
Isolation facility of APHO	Clinical management-doctor/nurse	x	√	√	x	x	x	x
Isolation facility of APHO	Attending to severely ill passenger	x	√	√	√	√	√	√
Sanitary staff	Cleaning all surfaces/cleaning linen	x	√	√	x	x	x	x
Administrative staff	Providing administrative support	x	x	x	x	x	x	x
Hospital Inpatient services								
isolation rooms (Individual / cohorted)	Clinical management	x	√	√	x	x	x	x
ICU/ Critical care	Critical care management	x	√	√	√	√	√	√
ICU /critical care	Dead body packing	x	√	√	√	√	√	√
ICU/ Critical care	Dead body transport to mortuary	√	x	√	x	x	x	x
Sanitation	Cleaning all /changing linen	x	√	√	x	x	x	x
Other Non COVID treatment areas of hospital	Attending to non COVID patients	x	√	√	x	x	x	x
Caretaker accompanying the patient	Taking care of the admitted patient	√	x	√	x	x	x	x
Emergency Department								
Emergency	Attending emergency cases	√	x	√	x	x	x	x
Emergency	Attending severely ill SARI patients	x	√	√	√	√	√	√
Pre-hospital (Ambulance) Services								
Transporting patients not on any assisted ventilation to designated hospital		x	√	√	x	x	x	x
Management of SARI patient while transporting to designated hospital		x	√	√	√	√	√	√
Ambulance Transfer to designated hospital	Driving the ambulance	√	x	√	x	x	x	x

Other Supportive/ Ancillary Services								
Laboratory	Sample collection and transportation	x	√	√	√	√	√	√
Laboratory	Sample testing	x	√	√	√	√	√	√
Mortuary	Dead body handling	x	√	√	x	x	x	x
Mortuary	While performing autopsy	x	√	√	√	√	√	√
Sanitation for COVID Patients	Cleaning all surfaces/cleaning linen	x	√	√	x	x	x	x
CSSD/Laundry	Handling linen of COVID patients	x	√	√	x	x	x	x
Other supportive services	Administrative, Financial, Engineering, Security, etc.	x	x	x	x	x	x	x
Health Workers in Community Setting								
ASHAs/Anganwadi/ other field staff	Field Surveillance	x	√	√	x	x	x	x
Doctors - conducting field investigation	Field surveillance/ Clinical examination	x	√	√	x	x	x	x
Quarantine facility								
Persons being quarantined		√	x	√	x	x	x	x
Healthcare staff working at facility	Health and temperature monitoring	√	x	√	x	x	x	x
Healthcare staff working at facility	Clinical examination of symptomatic pt	x	√	√	x	x	x	x
Support staff		√	x	√	x	x	x	x
Home Quarantine								
Persons being quarantined		√	x	√	x	x	x	x
Designated family member	Taking care of quarantined person	√	x	√	x	x	x	x
Other family		x	x	x	x	x	x	x
Colour coding	No Risk	Low Risk			Moderate Risk		High Risk	

TABLE 2 CHARACTERISTICS OF AN IDEAL PPE (13)

	Group		Characteristics
1	Design Feature	A	Protect mucous membrane
		B	Minimize the number of PPE element junctions
		C	Provide unobstructed range of vision
		D	Enable communication capacity
		E	Use human factor design for size and comfort
2	Material Performance	A	Able to protect for the duration of work period
		B	Able to withstand repeated disinfection (Non disposable elements)
		C	Manufacture packaging to withstand tropical climate storage conditions
3	Use desirability	a	Standardize donning and doffing protocol with minimum steps
		b	Dispose PPE in non toxic and environmental friendly manner

Figures

FIGURE 1 ENSURING AUTHENTICITY OF N-95 MASK (41)