

Systematic Review

Personal Protective Equipments Preventing transmission of COVID-19, Crisis Capacity Strategies and Continued Preparedness: A Systematic Review

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Abstract

Coronavirus infectious disease, Covid-19, is spread by contact predominantly followed by droplet nuclei. Certain procedures are associated with generation of aerosol where these viruses remain suspended for hours. These virus particles if inhaled can lead to infection. Healthcare workers taking care of Covid-19 patients are at risk. Risk can be reduced by creating awareness and emphasizing the role of standard precaution. Personal protective equipment constitutes one of the major components and plays a very pivotal role in prevention of infections. It becomes important to identify the various protective gears, to rationalize their use and avoid misuse. This article will help the readers with an overview of rational use of PPE in conventional period and will span around reuse and extended use of PPEs in crisis capacities. Besides, it will also help in surge capacity planning and evaluation.

Keywords: Coronavirus, Covid-19, Contingency Capacity, Gloves, Goggles, Gown, Masks, Personal Protective Equipment, Pneumonia, Respirators, SARS-CoV-2.

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Introduction

On 11 March 2020 WHO declared novel Corona Virus (SARS-CoV-2) as pandemic since it was associated with lakhs of cases and thousands of death [1]. Wuhan city, Hubei province in China reported the first case of coronavirus in early December 2019 [1], which is now known to be caused by a novel beta-coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Within few months, COVID-19 became pandemic [2]. Data published in literatures report five percent of cases with critical illness requiring intensive care, 80% of infected individuals develop a mild influenza like illness (ILI), 14% land up with serious symptoms [3].

The amount of cases is increasing worldwide till date due to its rapid transmission from human to human. Its transmission rate is very high; infecting healthcare workers (HCW) and patients in health care facilities [4]. Patient care activities specially those generating aerosol, are associated with high risk of transmission. This Covid -19 pandemic has created significant challenges in health care facilities, particularly with severe shortages of personal protective equipment (PPE) which is used to protect HCWs. Here in this article we will be discussing about rationale use of PPEs, their extended use and reuse with special emphasis on respiratory protective devices.

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Mode of Transmission

In the beginning this disease was said to be spread from bat and seafood market in China.[1,5] Later it was published that human to human spread is also possible[4,6]. Many countries reported community or stage 3 spread[7]. Transmission occurs from persons harboring the disease but not having any symptoms, and from symptomatic persons with features of upper respiratory tract infections (URTI)[8]. The incubation period diverges from 2 to 14 with mean incubation days 5 days. 97% will develop symptom by 11.1 days in a report. In a study it was found that virus shedding appears to be 2 to 3 days before onset of symptom (pre-symptomatic stage). During pre-symptomatic stage the virus transmission can occur in 48% to 62% of cases. The virus shedding decreases by day 8 but can be prolonged up to 37 days [9-12]

Transmission is known to be by contact, droplet nuclei and airborne[13]. There is no transmission on aircraft and no outbreak in HCW catering Covid-Covid-19 patients who are not using airborne precautions and N95 masks but high risk present in household. These studies suggest that SARS-CoV-2 is primarily spread by large respiratory droplets [14]. However, considerable contamination of near-patient atmosphere has been documented. Some studies have acknowledged the existence of viral RNA in air or air vents at an appropriate distance from patients which suggest airborne transmission nature of this virus [15]. The infectious dose and living nature of this virus is still unknown.

Respiratory protection prevents droplets/droplet nuclei from touching the mucous membranes of a person's nose and mouth. Aerosol

generating procedures (AGP) in healthcare set up can produce highly infectious small particle (<0.5 micron) that can increase the exposure risk of HCWs. Various AGP from different organization is shown in **Table 1** and risk of transmission associated with those procedures is shown in **Table 2**. [16]. Consequently, high quality of respiratory protectors is needed for HCW to avoid inhalation of aerosolized particles. N95 and other high quality respirators with extra filtering capacity can provide extra protection; for example disposable filtering facepiece respirators (FFPR), powered air-purifying respirators (PAPR), and elastomeric respirators. Goggles or face shield are needed for protection of eyes. [17]

Personal Protective Equipment [19,27]

During Ebola outbreak in west Africa, WHO provided technical information on appropriate available essential medical devices for treatment center, but on 31 October 2014, WHO declared that the rapid PPE is most vital in preventing transmission of the Ebola virus. A novel coronavirus named 2019-nCoV disease broke out in Wuhan, China in December 2019. The front-line healthcare workers needed to use PPE (gloves, surgical masks/N95, face shield, goggles, and protective clothing for long periods of time. PPE is one of the major essentials of standard precautions.

PPE refers to highly specialized clothing or personal items worn for safety against infectious agents to prevent transmission of infectious disease, accidental injuries in industries, factories and other fields. PPE is important for maintaining the safety and health of front line workers. Medical workers who work in close proximity with cases and carriers are recommended to wear PPE for protection to ensure complete safety. The demand of PPE is increasing in developing countries for the safety purpose.

Classification

PPE are classified according to the working environment, into 2 categories;

- In civilian PPE; 4 levels are included; Level 1 is for high risk protection and level 4 for low risk protection. It usually provides protection to respiratory system, skin and eye. It includes mainly industrial and agricultural workers, health care staff and technological workers.
- In Military PPE - Mission-Oriented Protective Posture (MOPP) Gear is provided for high risk of respiratory droplets transmission, skin protection and protection against chemical agents.

Basic requirements for PPE

- Providing the best level protection to employees in the workplace, necessary requirements for maintaining safe and healthy work environment.
- Performing "hazard assessment" of the workplace and to identify and control those hazards.
- Appropriate PPE for employees to be provided.
- To provide frequent training for use, care, proper disposal and need for replacement of the breached PPE.
- Regular audit for evaluating the effectiveness of the program.

Components of PPE [20]

PPE includes surgical mask/ N95 mask, gloves, coverall/gowns (with or without aprons), eye protection, head cover and shoe cover.

Surgical masks

Masks act as a barrier and protect general public from infected person. It also gives protection to HCWs when they come in contact with splashes of large droplets of blood and body fluids. The microorganisms can be easily trapped within these masks. [14] Surgical masks and medical masks are used interchangeably in this document.

Respirator

These devices are used to protect HCW from airborne particles generated during AGP. It includes N95, FFPR, "mask-like" respirators (ex. N99, N100) and powered air purifying respirators (PAPRs) and controlled air purifying respirators (CAPRs).

Gown

Protective gear made of polyester or cotton fabric to cover the entire body.

Gloves

Physical barrier to protect hands during patient care. These are sterile or non-sterile, clean.

Eye Protectors

These include goggles, face shield, which covers the forehead to chin, and side of the face

Shoe cover

Physical barrier to protect shoes.

PPE extended use

The term is used when PPE is worn for more than one patient without using additional devices, (e.g. a face shield over a surgical mask). It is endorsed all through emergency or crisis capabilities. [17-20] In such cases panel comments that if HCW is involved with AGPs on suspected or confirm Covid-19 patients, then they must use a face shield or surgical mask over N95 respirator. It is also known as conservation of PPE. During Covid-19 pandemic, the extended use and reuse of N95 masks can be followed for HCW protection rather than working with no mask.

PPE reuse

The PPE after doffing can be reused again after a period of time or a processing step. This process is also recommended in crisis capacities. [28]

Masks and respirators

Different organisations have different opinion for the use of masks. While the Centers for Disease Control and Prevention (CDC) recommends the use of masks in low-risk and high-risk situations, the World Health Organization (WHO) and Ministry of Health Family Welfare (MOHFW) advises applying masks in low-risk situations and respirators in high-risk situations. European center for disease control (ECDC) recommends use of class 2 or class 3 when managing suspect/confirmed case. Class 3 must be used during AGP. Description on various classes is shown in **Table 3**. Infectious Disease Society confirmed Covid-19. [17,18,20,29,30] **Figure 1** shows diagrammatic representation of use of respirators among HCWs.

In a study 493 healthcare workers were included and divided into two working groups - with N95 masks in quarantined area with more Covid-19 cases and without N95 masks (open area). The Covid-19 infection was 3.7% in HCW without mask. [31] Another systematic study and meta-analysis done by Offedu et al showed the importance of masks and respirators which decreased the rate of infection. [32] In a randomized control trial study in US and a study by Liang Du et al, it was found that there is no significant difference in the both groups although there was slight higher rate of infection in masks group. [33,34] A systemic review and meta-analysis on medical/surgical masks, cotton masks is represented diagrammatically in **Figure 2** and details of the studies is shown in **table 4**. It is also said that in contingency or crisis situation the HCW can wear either surgical masks or N95 which can be reused as per manufacturers guidelines [20]. There are certain masks which have been approved equivalent to NIOSH.

Certain local and individual factors (humidity and shift length) decide the duration of extended use of PPE which is equivalent to six hours in many cases. This strategy of extended use should be prioritized over reuse. The effectiveness of reprocessing methods to inactivate coronavirus (or other enveloped virus) on a medical mask and maintaining its integrity is not found in any study till date. Potential alternatives can be using a face shield alone or a combination of a non-medical, approved fabric mask and face shield. It is not proved in any study that non-medical fabric masks provide protection to HCW and therefore these are not considered PPE, there are studies which reported a false sense of protection among HCW and even increase in influenza-like illness relative to wearing a medical mask [35,36]

Disinfection/Decontamination

The rate of infection among HCW is increased three times of the general population in countries having equipment shortages which reduces the ability of hospitals to provide adequate care and increases Covid-19 patient death rates.[52] No guideline(CDC/IDSA/WHO/ECDC/NIOSH/OSHA) recommends re-use or extended use but in times of emergency or crisis following strategies can be utilized.US FDA does not approve using EUA FDA mask for reuse.[39]Table 5 shows various procedures employed for disinfecting masks.There are other methods like autoclaving at 160°C,usingpropanol (70%),dry heat, microwaving and soap and water. These methods were associated with considerable degradation to both filtration.[63]

Ethylene oxide and bleach were also evaluated but with little success.[60,61]. A new compound which is being talked and discussed is chlorine dioxide. It can be used with greater efficiency on filtration, microbial decontamination and mild detrimental effect on fit testing.

Risk associated with extended use/ Reuse/ Decontamination process [64]

- Loss of Fit
- Loss of effectiveness or efficacy
- Source of Infection
- Discomfort

To mitigate the transmission of pathogens from FFPR to the wearer, a strategy is designed where the HCW is issued 5 respirators. One FFPR is worn daily and repeated with a minimum of 5days gap. In meanwhile the others are kept in paper bag and due care and precaution are taken for reusing FFPRs.It should be kept in a paper bag after each shift and can be later on reused. [65]

GLOVES

Nitrile gloves are preferred over latex. They resist chemicals, disinfectants such as chlorine. Latex gloves are associated with skin allergies like contact dermatitis among users. However, latex gloves can be used in case of shortage of nitrile gloves. Powdered gloves are not preferred.[29]

The IDSA/CDC/ECDC guidelines do not recommend double gloving whereas WHO recommends double gloving during donning. Though FDA has not approved any particular gloves for Covid-19 but as per CDC non-sterile, clean, disposable gloves, which are normally used for patient care in healthcare settings, can be used for care of Covid-19 patients or suspected cases[66].In a study double-gloving versus single-gloving, using a simulation system with MS2,it was found that double gloving can reduce the risk of viral contamination. Nonetheless, the hand hygiene step was not included during doffing.[67-69]

It is thought that there can be a possibility of risk of organism transfer from contaminated PPE to hands after doffing. In case of severe crisis gloves can be used beyond manufacturers date or can be decontaminated 6times by alcohol based hand solution (ABHS), 10 times by soap and water,and bleach solution. But no study has been done to prove this transmission till date.In case of extreme shortage; besides disposable medical gloves,other gloves which are used in food or chemical industries can be used where HCW are not exposed to pathogens.[70]

3. Shoe cover

The IDSA/CDC/HICPAC/PHE/European commission guidelines do not recommend the use of shoe covers for HCWs caring for suspected or known Covid-19 patients whereas WHO recommends close work shoes and MoHFW recommends shoe cover .[17,18,22]

4. Eye Protection: [71]

Eye protection commodities include Safety Glasses, Eye Shields/Face Shield, Goggles. Conventionally they are single used and disposed as per guideline but also available as reusable items. Goggles used during patient care can be reused after thorough disinfection. It is recommended to use powered air purifying respirators (PAPRs) or full-face elastomeric respirators which have

built-in eye protection. Extended use of eye protection is defined as wearing of the same eye protection devices for all the patients in one setting and not removing the devices in between patient care. Extended use of eye protection can be applied to reusable and disposable devices.

It is important to ensure that the reprocessed devices are used by same HCW and it should be removed whenever visibly soiled or damaged. It is required to perform hand hygiene after touching eye protection and removal of eye protection is done after leaving the isolation area of the patient.

In crisis situations it is recommended to cancel all planned and non-urgent procedures and use eye protectors beyond the manufacturer-designated shelf life during patient care. Manufacturer instructions should always be followed for cleaning and disinfection. If no instruction is available in case of single use disposable devices it is recommended to wipe the inside, followed by the outside of the eye protection devices using a clean cloth saturated with neutral detergent or EPA registered hospital disinfectant solution. It should then be fully air dried.

GOWN

Nonsterile clean, disposable impermeable isolation gown [conventional] or reusable or washable[crisis] gowns are recommended for HCW catering Covid-19 suspected/ confirmed cases. Disposable gowns are made of a spun bound synthetic material. Reusable gowns are made of polyester or polyester cotton mixed fabric; which can be safely laundered and reused provided they are in good condition. If no gowns are available then the disposable aprons, disposable laboratory coats, patient gowns, reusable cotton or cotton-mixed fabrics, fabrics laboratory coats, long sleeve patient gowns or laboratory coats can be used. [72, 73]

RATIONAL USE OF PPE[18,30]

Location wise use of PPE is shown in Table 6.

Fit Test for PPE

This test provides complete protection to any HCW who has to perform AGP on suspected/confirmed Covid-19 patients. Various available respirators are tested to ensure appropriate fit. Occupational Safety Health Administration (OSHA) recommends an initial fit test to find out the suitable model, perfect style and size of the respirator. Few points to be taken into consideration regarding fit test like inward leakage , qualitative fit test , quantitative eight-step fit test, fast five-step test , and even a panel passing rate in few respirators. In case of crisis fit testing is not required rather it is recommended to use best facial fit respirators.[74]

Burn App calculator [17,20]

It is spreadsheet-based model that will help healthcare settings to plan and improve the use of PPE during pandemic. It is calculated by entering the number of boxes of individual PPE in stock and the total number of in-patients at any facility. The device then provides the average consumption rate that is known as "burn rate," for various types of PPE entered. On the basis of average consumption rate it is easy to estimate the average time the supply will last.

Skin damage by PPE

PPE related skin damage is reported in 40% of HCWs catering Covid-19 infected patients. Industrial and medical protective clothing are tightly fitted, which may cause device-related pressure injuries due to friction between the clothing edge and the skin and also keeps the skin over the whole body in a humid environment and makes it prone to injury[75,76].

Factors associated with risk for skin injury

- Device induced pressure
- Poor air permeability,
- Heavy sweating causing friction
- Long duration of wearing PPE

Susceptible parts of skin prone to injuries

- Nose bridge and cheeks: N95 respirators or surgical masks and goggles compress the nose bridge and cheeks.

- Ears: The mask strap may compress the ears and cause pain.
- Forehead: The face shield and surgical cap compress the forehead.
- Skin: Hands become dry, red, cracked due to repeated use of hand rub.

Mechanism of skin damage

Skin damage is attributed to- device related pressure. Tight fitting PPE causes decrease blood supply at the site leading to ischemia and hypoxia. The gas exhaled out from mouth and nose is collected inside the mask in form of water vapour for long duration. The moist area and the friction between the PPE and skin lead to itching, redness, ulcers. Thus, the skin becomes prone to secondary infections. Masks with elastic loops are more irritant than masks with ties. It causes device-related pressure injuries behind the ear. Due to poor permeability of the skin gloves and shoe cover, the sweat accumulates causing irritation, itching, redness, ulcers.

Allergic skin conditions

The appearance of eczema is often related to the impaired permeability of PPE or skin barrier damage. Moisturizing is important to restore the skin damage. Rarely does it lead to intake of oral antihistamines. The most common bacterial infections caused by PPE are folliculitis and furuncles, mainly due to Staphylococcus aureus infection.

Skin damage associated with repeated hand washing and disinfectants

Repeated hand washing and regular disinfectant usage by HCW may lead to dryness, itching, redness and erosions. In a study it was found that high frequency of hand wash was associated with eczema in 52% of medical staff.

Prevention of skin damage

Following can be done to prevent skin damage

- Avoid use of face masks for long hours.
- Use a good fitted PPE.
- Use moisturiser before wearing PPE.
- Use masks with ties.
- Regular water drinking.

Public Awareness[77,78]

Covid-19 pandemic changed our life styles like lockdown, social distancing, and strict isolation, regular and strict use of face masks. Facemasks need to be used more widely and compulsorily. It can reduce the transmission of viruses. Cloth masks may prevent coronavirus spread too. Most virus transmission occurs via larger particles in secretions like respiratory droplets, when infected person sneezes, coughs, or speaks and some become aerosol sized particles when water evaporates from these droplets. Cloth masks, made of several layers of cotton fabric, can be used to limit droplet and aerosol contamination of the environment, thus reducing the transmission of Covid-19.

According to the review research, published in the journal of Internal Medicine, every virus-laden particle captured in a mask is not able to hang in the air as an aerosol, thus reducing community transmission. On 15 April 2020 guideline related to the use of 'fabric' face masks as an additional preventative measure against Covid-19 was published by the National Department of Health (NDoH). The department has laid down guidelines on preparation and use of fabric masks in the community. Recently WHO has published another guideline on the use of mask in public and among healthcare workers.

A policy at individual healthcare facility level and within facility for different location must be laid down and implemented. The implementation of these policies will help healthcare facilities to judiciously use their PPE for longer duration.

Guidelines and basic rules of using face masks are

- Face masks should be tightly fitted, covering nose and mouth.
- It should not be touched frequently from inside and outside
- It should not be lowered while talking, coughing, or sneezing;
- It can be washed easily with soap and water and iron when dry.

To spread the Public awareness for the use of mask, the Prime Minister updated his profile picture on Twitter with his face covered with 'gamcha'. It is just for reiterating use of face covering, no matter with homemade masks or cloth. Masks are not only a primary preventative measure but hand hygiene and social distancing are equally important.

Role of Universal masking to prevent Covid-19 transmission

It not only provides personal protection, but also reduces the transmission of SARS-CoV-2 from presymptomatic or asymptomatic or symptomatic patients to other persons wearing the mask and the environment (i.e., source control). Only few studies have proved the use of universal masking for preventing transmission of infection in health care settings.

Considerations for Release of Stockpiled N95s Beyond the Manufacturer-Designated Shelf Life[20,79]

During covid -19 pandemic, where there is increased demand and decreased supply it was decided by NIOSH that the N95 respirators, which are actually fit can be considered to use after their the expiry, or beyond shelf life. There are certain N95 respirators which were evaluated by the NIOSH and were found protective. It is recommended by CDC recommends that N95s which exceeded their shelf life should be used only when the supply chain of N95 decreases. However there are few precautionary measures which should be taken before using the respirators. These include visual inspection of the integrity of N95, degradation of material of various components like straps, nose bridge, and nose foam. Degradation can affect quality of the fit and seal of the respirator. In case of non-compliance the respirator is discarded.

Strategies for continuous supply/Conservation strategies during pandemic[80]

There are various strategies which can be implemented during pandemic

- Engineering control- Airborne isolation, physical barriers, ventilation
- Triaging at the entrance with judicious use of PPE, reserve PPE for HCW and replace PPE normally used for source control, prioritizing PPE
- Administration control must include telemedicine, cohorting, and teams of HCW, rational use of PPE in conventional setting with reuse or extended use during crisis, limited visitor's entry exit, less staffing.
- All elective and non-urgent procedures to be cancelled.
- Use of re-usable PPE that can be reprocessed or extended used.

Continued preparedness post lockdown

The only way to prepare ourselves is to know this virus, its virulence and infectivity and perform research on finding its treatment and prevention (vaccine) by epidemiological, microbiological and clinical Data. We should have more of evidence based analysis in form of RCT or prospective study rather than laboratory studies or anecdotal studies with respect to reuse of gloves and use of cotton fabric gowns and risk of transmission during Covid-19 patient care.

Table 1: Showing Aerosol Generating Procedures

	CDC [17]	WHO [18]	Public Health England [19]
Procedures	open suctioning of respiratory tract, sputum induction, cardiopulmonary resuscitation endotracheal intubation, extubation non-invasive ventilation (e.g., BiPAP, CPAP) bronchoscopy manual ventilation nebulization	Tracheal intubation, non-invasive ventilation, tracheostomy, cardiopulmonary resuscitation, manual ventilation and bronchoscopy	intubation, extubation, ventilation procedure, open suctioning of the respiratory tract tracheostomy, bronchoscopy, upper respiratory, upper gastro-intestinal endoscopy, surgery and post mortem procedures, involving high-speed devices some dental procedures, non-invasive ventilation (NIV); Bi-level Positive Airway Pressure Ventilation (BiPAP) Continuous Positive Airway Pressure Ventilation (CPAP) High Frequency Oscillatory Ventilation (HFV) induction of sputum high flow nasal oxygen

Table 2: Risk of transmission to HCWs exposed and not exposed to aerosol-generating procedures

S. No.	Type of aerosol-generating procedures	OR	95% CI	References	Country
1	Tracheal intubation	3.0	1.4-6.7	21	Canada
2	Defibrillation	0.5	0.0-12.2	22	Canada
3	Administration of oxygen	1.0	0.3- 2.8	23	Singapore
4	High-flow oxygen	0.4	0.1-1.7	21	Canada
5	Manipulation of oxygen mask	2.2	0.9-4.9	21	Canada
6	Intubation, tracheotomy, airway care, and cardiac resuscitation	6.2	2.2- 18.1	24	China
7	Chest physiotherapy	1.3	0.2-8.3	22	Canada
8	High-frequency oscillatory ventilation	0.7	0.1- 5.5	25	Canada
9	Chest compression	4.5	1.5-13.8	26	China

SARS= Severe acute respiratory syndrome; HCWs= Health care workers; OR= Odds ratio; CI = Confidence interval

Table 3: Showing Filtering efficiency of various categories of mask

Test	FFP1	FFP2	FFP3
Concentration of harmful substances	Till 4 × NDS	Till 10 × NDS	Till 30 × NDS
Leakage	<22%	<8%	<2%
Penetration	<20%	<6%	<1%
Initial expiration resistance at 95 L/min	<210 Pa	<240 Pa	<300 Pa

Filtration Efficiency for Each Class of Masks

Abbreviations: FFP1, filtering face piece 1; FFP2, filtering face piece 2; FFP3, filtering face piece 3; NDS, the highest acceptable concentration of the harmful factor

Table 4: Characteristics of the studies included in meta-analysis

S No	Author & Year	Country	No. of Sample	Setting	Participants	Interventions	Result/ Outcome
1	Radonovich et al. 2019 [34]	United States of America	2862	137 study sites ;comprised of varying outpatient settings: primary care facilities, dental clinics, adult and pediatric clinics, dialysis units, urgent care facilities and emergency departments, and emergency transport services; across 7 medical centers; USA	Healthcare personnel; clusterrandomized study during 4 viral respiratory seasons (2011/12 to 2014/15); 60% at occupational high risk.	Medical masks, targeted N95 (when 2m from confirmed respiratory infection) in Outpatient setting.	Primary: laboratory-confirmed influenza infection; Secondary: laboratoryconfirmed viral respiratory infection; influenza-like illness; clinical respiratory illness. No significant difference between Masks and targeted N95.
2	Leung et al. 2020[37]	China	246	Tertiary care center	Experimental study of coronaviruses, influenza viruses and rhinoviruses, by quantifying the amount of respiratory virus in exhaled breath	Randomisedstudy: surgical mask vs No mask.	111 (90%) were infected by human (seasonal) coronavirus. Coronavirus found in exhaled breath of no-mask subjects but not in Mask wearers. More virus were found in fine aerosols than large droplets.
3	MacIntyre et al. 2016 [38]	China	842	6 major hospitals in 2 districts of Beijing, China	Index cases and household contacts.	Medical mask worn by sick. Case control (no mask) Household contacts followed for infection.	Mask protective if worn.

4	MacIntyre et al. 2015 [39]	Vietnam	1062	14 secondary-level/tertiary-level hospitals in Hanoi, Vietnam.	1607 hospital HCWs aged ≥ 18 years working full-time in selected high-risk wards.	Hospital wards randomised to: medical masks; cloth masks; control group (usual practice, which included mask). Participants used the mask on every shift for 4 consecutive weeks.	Medical masks protective or Cloth masks increase risk of infection.	
5	Barasheed et al. 2014 [40]	Australia	164	Hajj Setting. 22 tents were randomised to 'mask' (n=12) or 'control' (n=10) 75 pilgrims in 'mask' and 89 control.	During the Hajj week in Mina, Saudi Arabia.	Pilgrims Hajj.	Mask and control.	Less ILI among the contacts of mask users compared to the control tents (31% versus 53%, p= 0.04). Laboratory results did not show any difference between the two groups.
6	MacIntyre et al. 2013 [41]	China	1669	19 hospitals in Beijing: emergency departments and respiratory wards.	1669 nurses, doctors and ward clerks; cluster randomization by ward	Intervention 1: continual use, fit-tested N95 respirator • Intervention 2: continual use, non-fit-tested N95 respirator • Control: continual use, surgical mask	Laboratory-confirmed respiratory infection, influenza-like illness • 5-week follow-up Detection of influenza A and B, respiratory syncytial virus metapneumovirus, parainfluenza virus, rhinovirus- enterovirus, coronavirus, adenovirus, S. pneumoniae, B. pertussis, C. pneumoniae, M. pneumoniae and H. influenzae type B Continuous N95 protective. No difference between targeted N95 and medical mask.	
7	Suess et al. 2012 [42]	Germany	302	Tertiary care hospital	index cases and household contacts	Masks + hand hygiene, Control	Both intervention groups protective in compliant users together protective compared to control if used within 36 hours	
8	Aiello et al. 2012 [43]	United States of America	1178	University of Michigan	college students	Masks + hand hygiene Control	Hand hygiene alone not protective	
9	MacIntyre et al. 2011 [44]	China	1441	15 hospitals in Beijing: emergency departments and respiratory wards	nurses, doctors and ward clerks; cluster randomization by hospital	Masks, N95 respirators, fit tested N95 respirators, non-fit tested Control	Laboratory-confirmed respiratory infection, influenza-like illness • 5-week follow-up Primary: laboratory-confirmed viral respiratory infection; influenza infection; influenzalike illness; clinical respiratory illness. Medical mask better than cotton mask.	
10	Simmerman et al. 2011 [45]	Thailand	465	nurses conducted home visits within 24 hours enrolled cases	index patients and their families Households were randomized to control	Hand hygiene Masks, hand hygiene Control	No significant difference in confirmed influenza	
10	Aiello et al. 2010 [46]	United States of America	1437	College students	Households	Health education (HE) HE + sanitizer. HE + sanitizer +	HE + sanitizer + masks protective .Hand hygiene alone not protective	

						masks	
11	Larson et al. 2010 [47]	United States of America	617	Upper Manhattan Neighbourhood	households	Health education (HE) Hand hygiene , HE Masks , hand hygiene +HE	Masks + hand hygiene protective ,Hand hygiene or HE alone not protective
12	MacIntyre et al. 2009 [48]	Australia	143	Initial home visit	Households	Medical masks , P2 masks Control	Masks/P2 protective if adherent
13	Cowling et al. 2009 [49]	Hong Kong	143	Pediatric Primary care Practice	Households	Hand hygiene, Masks , hand hygiene Control	Masks plus hand hygiene protective, Hand hygiene alone not protective
14	Cowling et al 2008 [50]	Hong Kong	198	Home visit	Households	Medical masks; Hand washing Control	NS – this was a preliminary report of 2009 trial.
15	Loeb et al., 2003 [22]	Canada	43	2 hospitals in Ontario: coronary care units and ICUs with SARS patients	Nurses	Intervention: N95 respirator • Control: surgical mask	Laboratory-confirmed respiratory infection • Retrospective study • Only 20 nurses reported exposures and consistent use of facial protective equipment • Detection of SARS
16	Seto et al 2003 [51]	China	N=254 ; 13 Infected 241 Non Infected	5 hospitals in Hong Kong: emergency departments and medicine units	13 infected (cases) and 241 noninfected (controls) nurses, doctors, health care assistants and domestic staff	• N95 respirator • Surgical mask • Cloth mask	Primary: laboratory-confirmed viral respiratory infection; laboratory-confirmed influenza infection; influenzalike illness, clinical respiratory illness.

Table 5: Shows various decontamination process

Method	Fit testing	Filteration testing	Microbial decontamination	Reference	Summary
IUSS	Passed	Passed	Not performed	[52]	Sample size was less.
Ultraviolet germicidal irradiation(UVGI)	Passed till 2 testing	Passed till 20 cycles	Yes	[53,54]	These data suggest that FFPR decontamination and reuse using UVGI can be an effective method but it requires
Vaporised Hydrogen peroxide	50 cycles	50 cycles	Yes. 6 log reduction.	[55,56]	This project was comprehensive pilot-scale study that evaluated the efficacy of hydrogen peroxide vapor (HPV) for decontamination of N95 respirators against a single
Liquid hydrogen peroxide	NE	Passed till 3 cycles	NE	[57]	1 sec to 30 min (range: 3–6%)
Dry Heat	Passed till 2 cycles	Passes	NE	[58,59]	temperatures of 70-80 °C
Moist heat incubation	Passed	Passed till 3 cycles	99.99% reduction. Varies with micro organisms	[60,61]	consisting of 60°C and 80% relative humidity
Microwave generated steam	Passed	Passed till 20 cycles	99.9%	[60-62]	1100 W, 90 sec (bags filled with 60 mL tap water)

NE: not evaluated.

Table 6: Showing location-wise use of PPE

Location	Activity	PPE
Screening, Thermal screening/Triage	Provide triple layer mask to patient	N95 Gloves
Out Patient Department	Patient history taking and examination	N95 Gloves
Isolation room	Patient stable and masked	N95 Gloves
Intensive care unit		Full PPE
Emergency Room	Non Covid Patients Covid Patients	N95 mask and gloves Full PPE
Housekeeping and sanitation		N95 gloves
Laboratory	Non Covid samples Covid Lab	As per hospital policy Full PPE
Transportation	-	N95 Gloves
Dead body packing and autopsy	-	N95 gloves

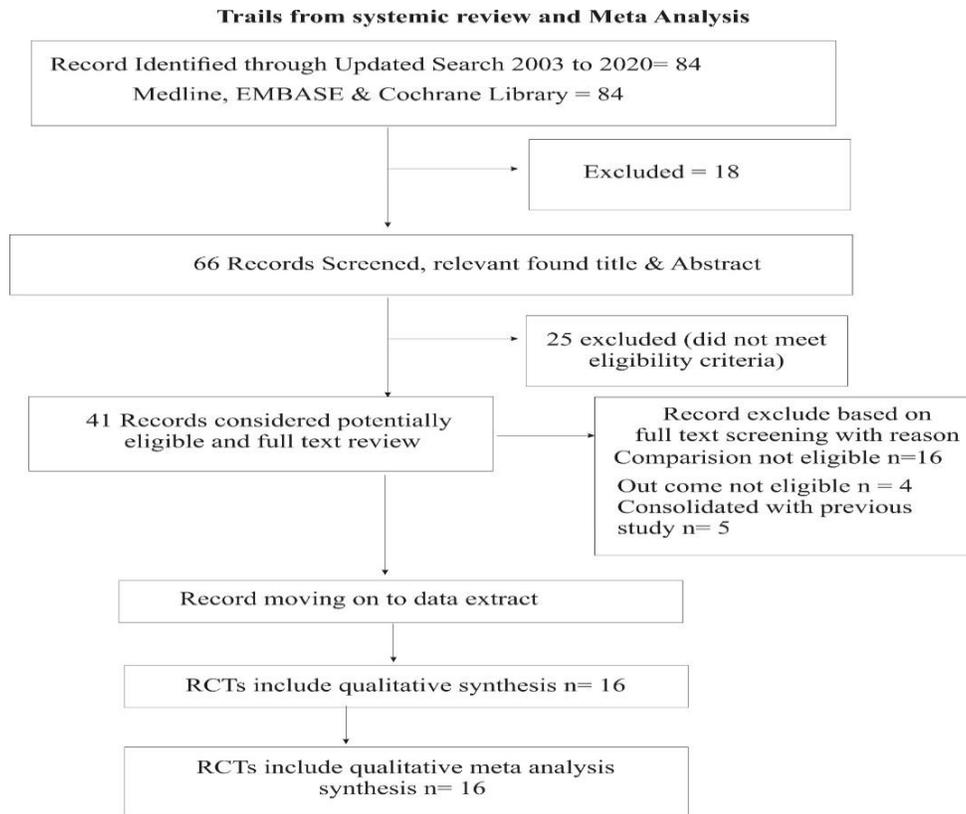


Fig. 1: Flowchart of study selection for the present study

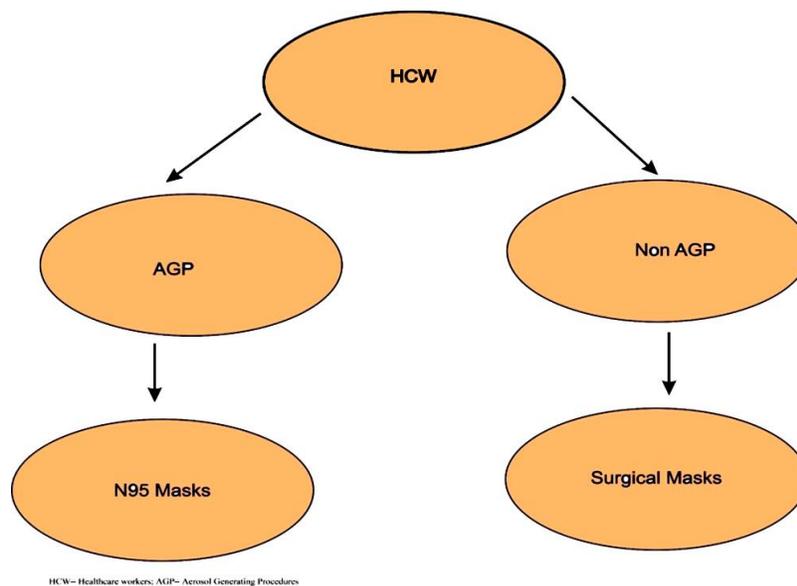


Fig. 2: Shows diagrammatic representation of use of respirators among HCWs

Conclusion

From the above review it is clear that PPEs to be used reasonably and sensibly. They must be used as per national guidelines. Following are the considerations made after analysis: Firstly for masks and N95 respirators it is said not to reuse, CDC recommends to reuse to no more than five times per device. Direct evidence to reuse or reprocessing is lacking. Various methods (UV radiation, heat, 70% ethanol and vaporized hydrogen peroxide (VHP)) have come up but researches are the need of the hour. We must perform studies related to decontamination with respect to efficacy and fit of the respirator as well. A study can also be performed related to these procedures and their risk of transmission of infection among healthcare workers and skin damage related to it. Secondly strategies for extended use N95 mask using surgical mask and facemask lack evidence based data on infection rates among health care worker (HCW). These studies can guide us in future and we will be better prepared with more knowledge and experience and confidence. These recommendations need more of research work with more data and evidence.

Thirdly it is recommended that AGPs require wearing of N95 mask or higher level respirators. Studies are required for understanding respiratory transmission characteristics of SARS-CoV-2 in the healthcare settings. Various types of procedures need different level of respiratory protection can be proved by performing studies. Fourthly, regarding shoe cover and double gloving more RCT and prospective studies should be performed. These studies once performed and analysis done will later in future make us more confident and prepared for any outbreak and unforeseen circumstances.

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