COVID - 19

USE OF PERSONAL PROTECTIVE EQUIPMENTS DURING COVID-19 PANDEMIC IN RESOURCE LIMITED SETTINGS - THE BAREST MINIMUM NEEDED

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Abstract: *Personal Protective Equipment are protective gear designed to safeguard the health care workers by minimizing exposure to a biological agent. Personal protective equipment includes mask, gloves, face and eye protection (face shield, goggles), gowns and full body suits. Different types of masks are available for specific purposes. Masks are intended for protecting others from respiratory emissions of the wearer while respirator protects wearer from small particles like aerosols besides large droplets. Face shields provide a barrier for suddenly expelled aerosol of body fluids and are commonly used as an alternative to goggles. Isolation gowns may be adequate for medium risk while coveralls provide full protection. It is important to know and appropriately choose the gowns based on the fabric and reliability of manufacturer. All health care workers need to be taught the correct sequence of donning and doffing-PPE in order to avoid contamination. Though not ideal, the most effective methods of sterilizing and reusing N95 masks during scarcity may have to be adopted.*

Essential protective measures depend heavily on the location of patient contact, the role of the particular health care facility and the hazard vulnerability analysis. Hazards for the health care worker can be through air, surface, equipment and body secretions. Personal Protective Equipment reduces the risk of acquiring infection through any of these routes. This article deals with the selection of appropriate personal protective equipment for the health care workers managing suspected or proven COVID-19 infected persons.

Keywords: *Personal protective equipments, N 95, Masks.*

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Personal protective equipments PPE is important not only to protect Health Care Worker (HCW) but also prevent patient to patient transmission of infection. Examples of PPE include items such as mask, gloves, face and eye protection (faceshield, goggles), gowns, shoe covers and full body suits. Picture of a heath care worker wearing full PPE is shown in (Fig.1).[1]

Need for Personal Protective Equipment (PPE) considering transmission in hospital setting

In hospitals especially in areas where aerosols are generated, like intensive care units where droplet nuclei spread quite far.[2] Therefore wherever intubation and procedures like manual ventilation, suctioning, nebulization, cardiopulmonary resuscitation, bronchoscopy, throat examination, endoscopy and autopsy are done, special precautions meant for airborne spread are required.[3] A very important fact or that prevents extensive dissemination in hospitals is the presence of an adequate air exchange. Ideally a negative pressure room

Fig.1. A health care worker in full PPE and coverall

with at least six air changes per hour (minimum air changes recommended by WHO is 12 per hour) or natural ventilation (with airflow of at least 160 L/second is recommended as ideal air exchange). Another important variable to consider is the exhaled air dispersion distance during oxygen administration and ventilator support.

Masks

Various types of masks

Wearing a mask helps in preventing the aerosol spread of COVID-19. Droplet transmission begins two and half days before patients show any symptoms in COVID infection. Asymptomatic individuals were responsible for 66% of transmission.[4] In one interesting case report, an asymptomatic individual infected 5 out of 39 individuals when he was not wearing a mask but did not infect anyone when he wore a mask under the same circumstances.[5] Importance of wearing a mask by everyone in prevention of transmission was seen during the influenza epidemic.[6] Wearing a mask helps in preventing the aerosol spread of COVID-19. Health workers should not share the same room such as during meal time when masks cannot be worn.

Common (nonmedical) masks available to general population

a) **Dust mask** is a disposable, molded face mask made of paper pad. It does not offer any protection against airborne pathogen such as corona virus. It is worn for protection against non-toxic dust (Fig.2).

b) **Single layer face mask** which consists of a single layer of wood pulp tissue paper or non-woven fabric. It is also not recommended for protection against corona virus transmission. It is used commonly in the food processing industry. It should not be reused as it is a single use item and cannot be washed.

Fig.2. Dust mask

c) **Cloth mask** seems a practical option for usage by general public.[7] Cotton masks are available in the market and can even be made at home. A manual for making home made cloth masks has been released by Government of India recently.[8] This manual advises using 100% cotton like old T shirt, cotton vest, etc. Two to three layers of cloth is optimal as increasing layers can improve efficacy but makes breathing difficult.

Masks used in the health care settings

a) Three layered surgical mask

Surgical mask is the one which is most commonly worn in healthcare settings. It consists of three layers (Fig.3). The inner layer has absorbent property to absorb moisture from exhaled air. The middle layer acts as a filter and is made up of nonwoven mat of thin fiber or melt blown (The melt blown process is a nonwoven manufacturing system) material. The outer most layer repels liquid. These masks have pleats to increase the surface area in order to cover the chin and nose. These masks are disposable and they do not fit tightly around face and nose. Surgical mask prevents the release of respiratory emissions from the user into their immediate environment.[9] The main purpose of wearing these masks is to protect patients or people nearby from the person wearing it and not the other way around. Although not protective to wearer against airborne infection because of their loose fit, they do protect the wearer from direct spray or splashes of infectious body fluids or blood.[10] Surgical masks do not have safety rating but USFDA requires them to conform to certain quality standards. They should have bacterial filtration efficiency more than 98%.[11]

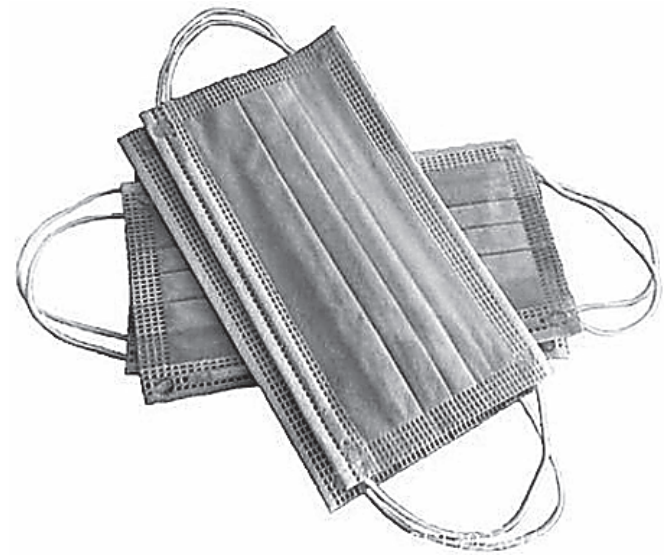

Fig.3. Triple layer surgical mask

Usefulness of surgical mask in preventing respiratory infection: Surgical masks are the most commonly used protective device but there is not much evidence in protective efficacy against airborne infection. Previously WHO recommended face masks for people with respiratory symptoms or care givers of symptomatic individuals[12] but in the present scenario where a high level of SARS-CoV2 shedding even in asymptomatic patients, some type of barrier or mask is recommended for everyone during interaction with people. Guidelines from China recommend wearing of surgical masks based on the risk of acquiring infection.[13]

Surgical mask for personal protection: Since main purpose of wearing a surgical mask is patient safety, most studies have focused on chances of wound contamination and not on protection for the person wearing it. During the influenza epidemic of 2008-9, this question was raised and at least two studies have documented that surgical masks were as effective as respirators for prevention of influenza among nurses providing care.[14-16]

b) Respirator mask

Respirators differ from surgical masks in their fit. Unlike loosely fitting surgical masks these are tight fitting. Respirators are designed to create a facial seal in order to protect the wearer from airborne particles. They provide two way protection by filtering both outflow as well as inflow of air. They are available as disposable device and also as full face or half face respirator device. These respirators are given ratings based on percentage of aerosol they can prevent from going through. Table I compares the surgical mask and respirator mask.

Working of respirators: Filters used in both surgical masks as well as respirators are fibrous in consistency. These filters are made from flat and nonwoven mats of thin fibers made of material like wool felt, fiberglass paper or polypropylene. Most importnat layer is melt blown layer for filtration. This layer is 100-1000 microns in thickness and composed of polypropylene mycrofiber with diamater in the range of 1-10 micron, the quality of mask depends on the quality of this layer and electro static charge over heat. Efficiency of the filter depends on the diameter of individual fibers, the ratio of open space to fibers termed porosity and overall thickness of the filter. In all these fibrous filters, there are four functional mechanisms which enable them to capture aerosol particles. These are interception, inertial impaction, diffusion and electrostatic attraction. First two mechanisms namely inertial impaction interception and electrostatic attraction are responsible for obstructing and filtering larger particles. Diffusion mechanism is responsible for collecting particles measuring 0.1 mm and smaller which have constant brownian motion leading them to collide with the filter fiber. Fourth one is electrostatic attraction which relies on attraction between the charged fibers and particles with opposite charge. This is very important for filter efficiency as it improves efficiency in particle collection without increasing resistance of breathing.[17]

Filtering efficacy of respirators: There are many types of respirators available in market which differ from each other in terms of their filtering capacity. Based on rating by different institutions such as CDC and European Committee for Standardization, masks are labelled. The mask with CDC 95 rating can collect at least 95% of the aerosol particles and doesn't allow them to pass through. Similarly CDC 99 rating means at least 99% aerosol particles get filtered out and there are even respirators with CDC100 rating which can filter almost 100% (practically up to 99.7%) of aerosol particles. Oil can impact the efficacy of the filter used in these masks as electrostatic charges in the filter media can change on contact with oil. Thus in industries where exposure to oil is common, respirators need to be made resistant to oil too. This gives rise to another rating based on permeability of oil. These are 'N ' meaning not resistant, 'R' meaning resistant but not absolute while 'P' meaning oil proof or strongly resistant. With these two properties-level of resistance to oil and percentage of particles filtered, these respirators can be divided into 9 categories in CDC standard. These CDC categories are N-95, N-99, N-100, R-95, R-99, R-100, P-95, P-99, and P-100. CDC has advised that N95 respirator should be considered as standard part of the PPE against Covid-19. European Committee for Standardization (CEN)

Table I. Comparison between respirator and mask

	Surgical mask	Respirator
Testing and approval	Cleared by the U.S. Food and Drug Administration (FDA)	Evaluated, tested and approved by National Institute of Occupational Safety and Health (NIOSH)
Intended use and purpose	Fluid resistant. Protects the wearer against splashes, large droplets or sprays of hazardous fluids. Protects others from respiratory emissions of the wearer	Protects wearer from small particles like aerosols besides large droplets Not resistant to oil (considered in industrial use)
Face seal fit	Loose-fit Air enters around the edge of mask with inspiration	Tight-fit Minimal leakage around edges when fitted properly
User seal check requirement	No	Yes Every time it is donned
Fit testing requirement	No	Yes
Filtration	Does NOT protect the wearer from inhaling smaller airborne particles	Provides respiratory protection by filtering out at least 95% of large as well as small airborne particles
When to discard	Disposable Ideally should be discarded after each patient encounter.	Ideally should be discarded after each patient encounter Even during shortage should be discarded if: after aerosol-generating procedures/becomes damaged or deformed/Ineffective seal around the face/gets wet or soiled/if breathing through respirator becomes difficult.

National Institute of Occupational Safety and Health - the United States federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness.

uses another system namely filtering face piece (FFP), with ratings of P1, P2 and P3 which depend on filtering capacity of 80%, 94% and 99.95% particles respectively. So the standard N95 of US FDA is equivalent to FFP2 of CEN.[18] Fig.4 shows some of the USFDA and CEN certified respirator masks.

c) Respirators with expiratory valve

There are many modifications done in the respirator to increase comfort. As the filtering capacity increases, passage of air through filter also becomes difficult. This makes it uncomfortable for the wearer to breathe through these respirators especially with N100 or FFP3 masks. In order to make them convenient to use, some respirators have expiratory valve included (Fig.5). This makes it easier to exhale and also less moisture build up inside the mask which can be very uncomfortable to

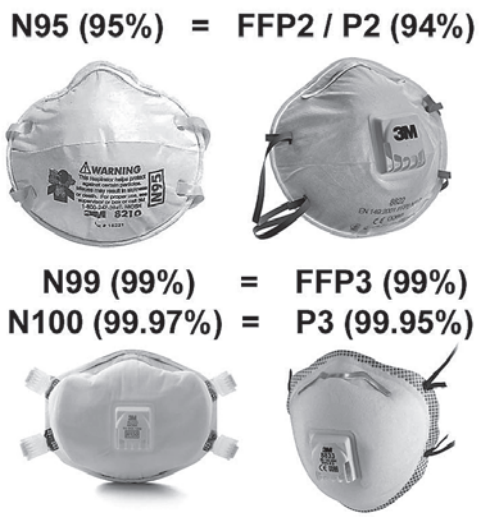

Fig.4. Comparison of N95, N99, and N100 with FFP2 and FFP3 respirator masks

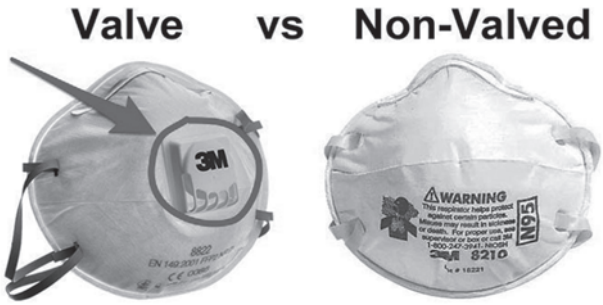

Fig.5. Valved vs non valved respirator

wearer after long duration.[19] However, as the exhaled air is not passing through the filter but getting out through the valve, it doesn't protect the environment if the person wearing this mask is already infected by a respiratory pathogen. When used, wearer should be instructed to wear surgical mask over respirator with expiratory valve.[19]

d) Powered air-purifying respirator (PAPR) is supposed to be more comfortable for the person wearing it as it reduces heat related stress.[20] A battery-powered fan is used in these respirators to make air flow through a filter and facilitate easier breathing. These respirators appear to be more protective than disposable N95 respirators but there is no clear evidence for this.[21] PAPRs are expensive, thus may not be an option in the current pandemic. Other limitations are difficulty in communication because of noise of the fan and risk of contamination during doffing. It is recommended that an expert staff should assist HCWs in the doffing process (Fig.6).[21]

Ensuring the safety of surgical masks and respirators available in the market

Surgical mask is expected to meet certain standards before it can be used. Because of sudden surge in demand, many fake surgical masks have come to the market all over the world. These counterfeit devices look like the real product and even use emblems, logos, and registration numbers of the real product. Unfortunately they do not offer adequate protection.[22] More than 12,000 fake N95 respirator masks were seized in Bengaluru recently.[23] To avoid this, dissect up one mask (cut open). One should be able to view three layers as mentioned above. Sometimes these similar looking masks contain only single ply or two ply instead of three ply which is recommended.

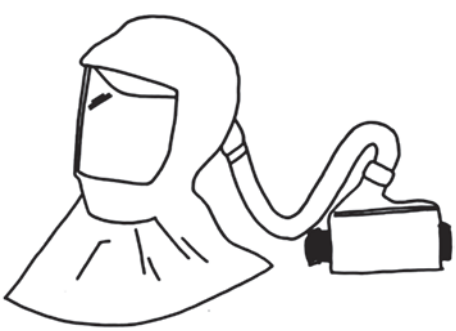

Fig.6. Example of a powered air purifying respirator (PAPR)

Identification of NIOSH certified respirator

National Institute for Occupational Safety and Health (NIOSH) approves all respirators used in healthcare settings to ensure standards of quality and performance. Only NIOSH authorized manufacturer can use the NIOSH logo or NIOSH name in block letters or on respirator. An established quality program to ensure respirator meeting the NIOSH requirements is expected from manufacturer. Markings of NIOSH logo or name may be on the front or on the straps. Counterfeit respirators with NIOSH name or logo are often sold in market and they may be available at lower prices. NIOSH website has a list of approved respirators and if NIOSH level is on the respirator but the name of manufacturer is not on the list, it may be a counterfeit product. There is also a TC number given by NIOSH and with the help of TC number, buyer can verify this at the website: - http://www.cdc.gov/niosh/npptl/topics/respirators/disp. TC number should be clearly marked on the packaging, on the respirator and also on the user instructions. Fig.7 shows markings on a N95 respirator.[24] If there is no TC number on any of these items, the respirator is not NIOSH-approved. NIOSH advises that even when the appropriate markings are present, any modification like how a strap is attached to main body, can compromise safety and should not be considered as NIOSH approved.[25] Before purchasing, mask should be verified physically.

Seal check of the respirator mask by wearer

The user must perform a seal check after wearing the respirator. This test can either be a positive or negative pressure check. To perform positive pressure seal check, person exhales gently after wearing the respirator and the face piece should become prominent and tense before elevated pressure causes leakage of the exhaled air. Similarly for a negative pressure check, face piece should collapse slightly when person inhales sharply. This procedure is called seal check and is different from a fit test. Fit test is performed by manufacturer before releasing respirator in market while seal check is performed by the user. Most of the wearers have a tendency to pull the respirator down to the chin intermittently especially during meal time. Every time the respirator is pulled down it is an episode of doffing. More than 5 doffings can lead

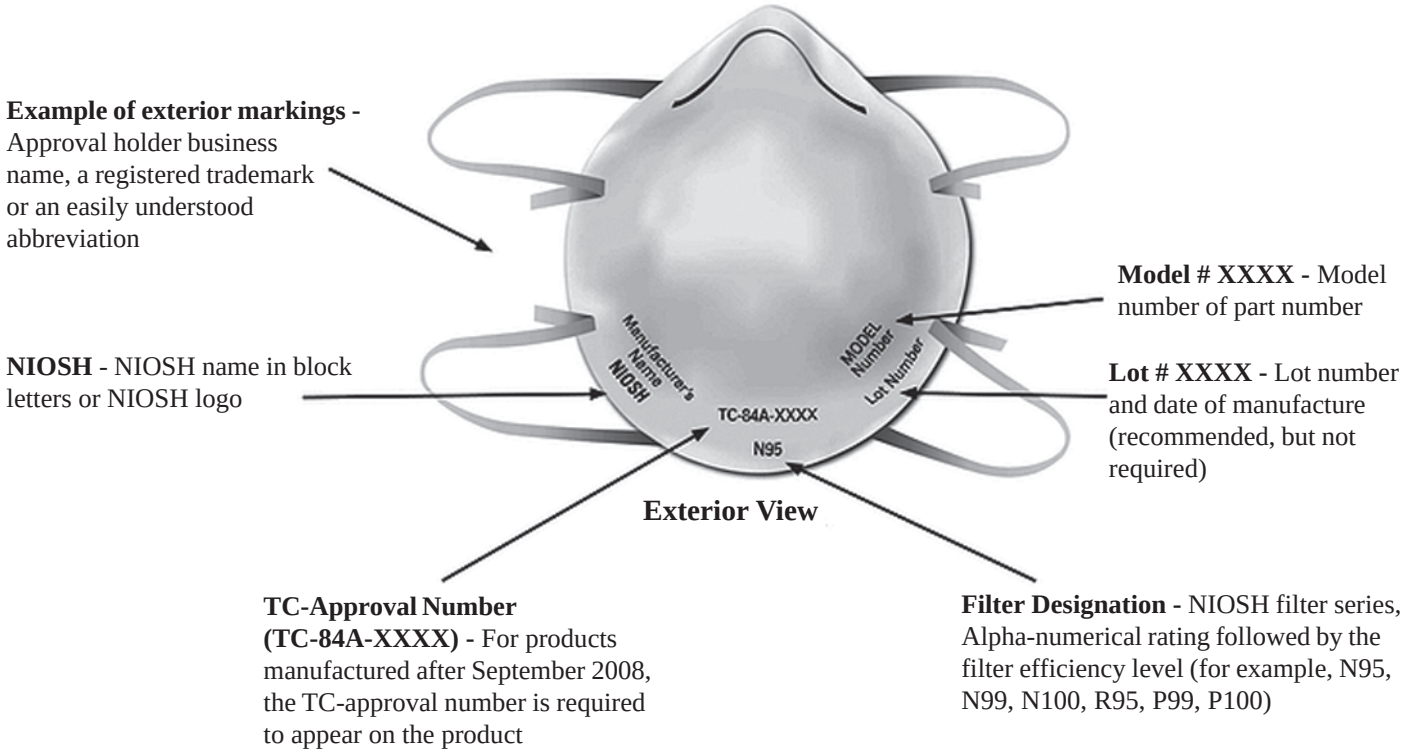

Fig.7. Example of exterior markings on NIOSH approved respirator

For more information about NIOSH-Approved respirators, to to: http://knowits.NIOSH.gov

to poor seal. If user ensures proper seal then respirator can be used till it is hard to breathe. After touching front of the respirator, hand hygiene should be performed.

Facial hair interfering with respirator seal

Ensuring proper seal is a vital part of effective respiratory protection. Facial hair such as sideburns, mustaches and beards, can interfere with the sealing area of a respirator. This may lead to failure of creating a tight seal to achieve maximum protection. Small particles in the air take the path of least resistance and through facial hair can bypass the filter of respirator. Hair is much larger in size and not dense enough to act as an effective filter.[26] Facial hair under the sealing area causes significant leakage when compared to a clean-shaven person. Even 2 days stubble can reduce protection. Generally, as per CDC, hair should not cross under the respirator sealing surface.

Alternatives to N95 NIOSH approved / FFP2 / FFP3 masks

These include other classes of filtering face piece respirators, elastomeric half-mask and full face piece air purifying respirators, powered air purifying respirators (PAPRs). All these alternatives will provide equivalent or higher protection than N95 respirators when properly worn.

e) Elastomeric respirators are half-facepiece, tight- fitting respirators that are made of synthetic or rubber material permitting them to be repeatedly disinfected, cleaned, and reused. They are equipped with replace able filter cartridges. Similar to N95 respirators, elastomeric respirators require annual fit testing. Elastomeric respirators should not be used without surgical mask over it due to concerns that air coming out of the exhalation valve may contaminate surrounding area.

Face Shield and goggles

Role of face shield as part of PPE

A face shield provides barrier protection to the facial area and the related mucous membranes (eyes, nose and lips). It provides a barrier to a bout of suddenly-expelled aerosol of body fluids and are commonly used as an alternative to goggles as they confer protection to a larger area of the face.[27] Combination of this face shield and an N95 filtering facepiece respirator (N95 FFR), protects the eyes, nares and mouth from contamination better than N95 combined with goggles.

Effectiveness of face shield for protection against droplets: For droplet size more than 5 micron, the efficacy is 96%

(for aerosol spread from distance of 45 cm). If the droplet size is reduced to less than 3.4 μm, the efficacy goes down to 23% upto 30 min following cough (during which time the larger aerosol particles settle out, droplet nuclei form and remain airborne so that flow occurs more easily around the edges of the face shield).[28]

Situations to wear face shield: Face shield should be worn during patient care activities where splashes and sprays are anticipated, typically aerosol generating procedures and during activities where prolonged face-to-face or close contact with a potentially infectious patient is unavoidable. Face shields should not be used while intubating because aerosols can flow behind the visor hence goggles should be worn. Face shield and goggles should not be used together as it does not offer additional protection and causes more discomfort and fogging affecting vision.[27]

Precautions while using face shield: Health care worker should take care not to touch their face shield. If they touch or adjust their face shield, they must immediately perform hand hygiene. If they need to remove their eye protection, they should leave patient care area. Face shield should be taken off as late as possible, preferably at the end of the procedure to prevent inadvertent exposure of the mucous membranes when other potentially contaminated PPE components are being removed.[27] Face shields with single Velcro or elastic straps tend to be easiest to don and doff. Doffing can be accomplished with a single hand. It should be discarded if damaged.

Components of a face shield: The major structural components of a face shield include a visor which is the transparent part of face shield. Ideally width should be sufficient to reach at least the point of the ear on both sides (Fig.8). The purpose is to lessen the chances of the splash reaching the eyes and oral cavity. In addition, visors should have crown and chin protection for improved infection control purposes. It is made of either polycarbonate propionate, acetate, polyvinyl chloride, and polyethylene terephthalate glycol. Visor is available in disposable, reusable, and replaceable models. Visors can be treated with advanced coatings to impart anti-glare, anti-static, and anti-fogging properties, ultraviolet light (UV) protection, and scratch resistance features to extend the life.

Choice and regulatory standards for face shields: Face shield should be made of clear plastic and it should provide good visibility to both the wearer and the patient. There should be an adjustable band to allow good fit around the head and snug fit against the forehead also to prevent slippage of the device. Visor should ideally be fog-resistant and should cover the sides and length of the face

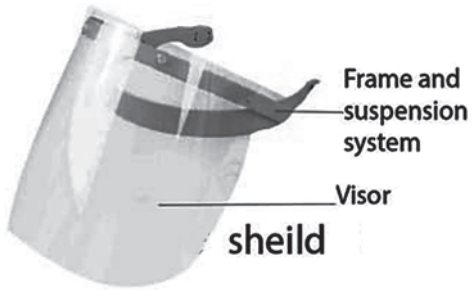

Fig.8. Face shield with visor, frame and suspension system

completely. Visors manufactured from acetate, propionate, and polycarbonate offer improved visual clarity and optical quality with the potential for less eye strain. Brow caps or forehead cushions should be of sufficient dimensions to ensure that there is adequate space between the wearer's face and the inner surface of the visor to allow for the use of ancillary equipment (medical/surgical mask, respirator, eyewear, etc.). There is currently no universal standards for face/eye protection from biological hazards. Face shields are marketed as class 1 medical devices exempt from FDA pre market notification.[27]

Selection of appropriate goggles: Goggles should have a good seal with the skin of the face. Frame should be flexible to easily fit all face contours without much pressure on the skin. It should cover the eyes and the surrounding areas (through the silicon rim) and accommodate the prescription glasses underneath. It should have a fog and scratch-resistant adjustable band that can be firmly secured and does not become loose during clinical activity. Goggles should have an indirect venting mechanism to reduce fogging. Goggles can be reusable (provided appropriate arrangements for decontamination are in place) or disposable.

Reuse of face shields and goggles: Face shields should be reused only if they are made of robust material like polycarbonate propionate or acetate. Though propionate has the best clarity acetate is most commonly used. Face shield should be dedicated to one HCP only. WHO recommends cleaning with soap/ detergent and water and disinfection with 70% alcohol or sodium hypochlorite 0.1%; finally rinsing with clean water. Isopropanol (IPA) 75%, 95% or 99% for 5 mins, ethanol 70% for 5 mins, sodium hypochlorite 1% for > 5mins or UV-C for 15 mins are the methods recommended for sterilising face shields and goggles. Autoclave, steam or ethanol > 80% are not recommended.

Medical gowns

Types of gowns

Several types of protective gowns are available as part

of PPE. These include a) aprons b) surgical gowns c) isolation gowns d) coveralls. Aprons cover only torso and they are used occasionally where limited contamination is anticipated. A surgical gown protects both the patient and health care worker from contamination. Front of the body from top of shoulder to knees and the arms from above elbow to the wrist cuff are the critical zones most prone for receiving splashes during procedures. These parts of surgical gown are provided with extra protection while other area is made of normal material. Isolation gown differs in that all areas of the gown except bindings, cuffs, and hems are considered critical zones and must meet the highest liquid barrier protection level. All seams must have the same liquid barrier protection as the rest of the gown (Fig.9). Isolation gowns are used when there is a medium to high risk of contamination. These gowns do not provide extended whole-body protection due to possible openings in the back or neck and coverage upto the mid- calf only as compared to cover all suits or Hazmat suits which provide 360 degree protection (Fig.2). Coveralls and gowns are deemed equally acceptable.

Quality check when ordering gown or coverall for PPE: Gowns should be made of light weight fabric and it should fully cover the torso, It should comfortably cover the body and should have long sleeves that fit snugly at the wrist. It is important to have sufficient overlap of the fabric so that it wraps around the body to cover the back ensuring that if the wearer squats or sits down, the gown still protects the back area of the body. Light colours are preferable over dark ones to better detect possible contamination. Coverall should be designed to have universal fit. It should have inbuilt hood cap. Zipper of the coverall should be covered with a flap to avoid accumulation of microbes. It should be ensured that the gown or coverall being procured meets or exceeds ISO 16603 class 3 exposure pressure.

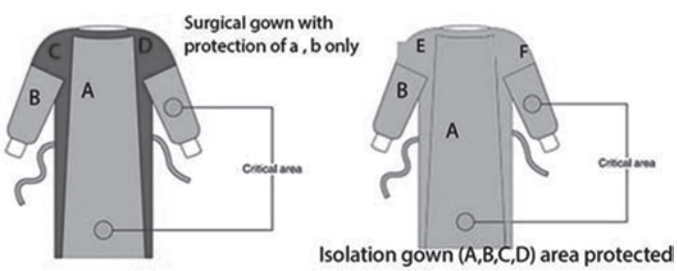

Fig.9. Surgical gown (left) gives extra protection to front and sleeves only whereas isolation gown (right) gives 100 percent protection (Unprotected area C, D; protected A,B,E,F)

Clothing material for gowns: Isolation gowns are made either of cotton or a spun synthetic material that decide whether they can be laundered and reused or must be disposed off. The clothing material should be impermeable to blood, body fluid and to COVID virus sized 0.11microns. Reusable gowns made of cotton are not impermeable to blood or fluid so they do not provide protection against transmission of pathogen.[29] Recently gowns made up of microfibers have been introduced in medical field as replacement for cotton gowns since they can be reused.

Of the materials used for making gowns, non woven fabric is criss cross and functions as filter against fluid, blood, bacteria and viruses and also impermiable. The three most commonly used non woven fabrics for surgical gowns and drapes are - i) Spunlace, ii) Spunbond-meltblown-spunbond (SMS) and iii) Wet-laid

Most popular amongst these is spunbond meltblown spunbond, known as SMS.

Recommendations on gowns

Government of India requires that all gowns should have following information printed by manufacturer.[30]

- Name of manufacturer
- South India Textile Research Association (SITRA)/ Defence Research and Development Establishment (DRDE) /Institute of Nuclear Medicine and Allied Sciences. (INMAS) Unique Certification Code (UCC)
- Test standard
- Date of manufacturing / batch number

The same UCC seal should be found on each gown. Manufacturer can be verified on sitra.org.in or DRDE website ISO/FDIS 16603 class 3 is the minimum requirement for COVID 19 isolation ward.

Another very important factor is the breathability which should be checked. This is very important for comfort of wearer. The breathability is tested by air permeability (AP) and water/moisture vapor transmission rate (WVTR/MVTR) of fabric. These tests should be done as per ambient temperature where the PPE will be used. Gown fabric must have the following range of AP and WVTR/MVTR:

a. Air permeability (L/M^2/minute):100-150

b. Water/moisture vapor transmissionrate-WVTR/ MVTR (g/M^2 /day): 400–500

Shortage of gowns during the pandemic: Extended use, reprocessing, or use of alternative gown can be considered temporary and should be avoided as much as possible when

caring for severe or critically ill COVID-19 patients. These alternatives should also be avoided when performing aerosol-generating procedures and constant contact for more than 30 minutes in same environment or close contact (within1meter) for more than 15 minutes.[31] If someone has an old gown without UCC stamp and wants to check for permeability, there is a crude method (not evidence based) to check gown fabric and seam. Pour 2 glasses of water over gown including seam. If no leak is found after 2 minutes especially over the seam, then it can be used for desired purpose. Same test can be used to assess the gowns which do not have this certificate (pushed in market as laminated products and are cheap). Clinician should always remember that these low cost, unapproved gowns may be used for low risk areas like outdoor patient services but should be avoided in isolation areas especially ICU or any aerosol generating areas. Many of these products are uncomfortable to wear as they are either too heavy (laminated cotton based) or non-breathable. Therefore before purchasing in bulk, user should try and test PPE for at least 3 hours in actual condition or run on treadmill for 15 minutes (2.5 miles/ hour). Look for the comfort, sweat and heat generated beneath fabric. Another weak point is the cuff. Ideally Gloves should overlap the cuff of gown so that no portion should be left exposed.

Precautions while wearing gowns for extended duration: Extended use means using the same gown, when providing care to a cohort of patients with COVID-19. This may increase risk of contamination with COVID-19 virus and may increase the risk of transmission of other pathogens between patients. Gown should be removed whenever it becomes wet, soiled, or damaged or exposed to splash of chemicals, infectious substances, or bodyfluids.[32]

Cotton re usable gowns for PPE: Cotton reusable gown is not impermeable to fluid hence, does not provide adequate protection. If due to circumstances cotton reusable gown is used, it should be combined with barrier polyester sheeting which is worn above gown, with a property of water-repellent chemical finish. Main problems are thermal discomfort as these are nonbreathable and lack of protection of arms and the back of the torso, which can be exposed to splashes.[33]

Washing and disinfection of cotton gowns: Washing by machine with warm water (60-90°C) and laundry detergent is recommended for reprocessing of the gown. If machine washing is not possible, linen can be soaked in hot water and soap in a large drum, using a stick to stir, avoiding splashing. It is then soaked in 0.05% chlorine (hypochlorite solution) for approximately 30 minutes. Finally, it is rinsed with clean water and sundried.

Donning and doffing PPE

Employers are required to train every employee who must use PPE about how to properly put on (Donning), take off (Doffing), adjust and wear the PPE. Everyone working in a health care facility must be trained to know about situations where PPE is necessary and also what kind of PPE to choose, its limitations and proper disposal after use.

Individuals are instructed first to perform hand hygiene and then the sequence of first gown followed by surgical mask, eye protection and gloves in the end. The order of doffing is gloves first followed by gown, eye protection and surgical mask in the end (Table.II).

N95 is a tight-fitting respirator, it is not effective when it is not properly fitted, It needs to create a tight seal. Seal test is performed by inhaling after respirator is worn.[34] If seal is good it should get puckered in slightly. It should be done every time a respirator is worn.[35] Practical tips to remember while donning and doffing PPE are shown in Table III.

Tips to remember when donning a mask or respirator ties of mask/respirator should be tiedup at middle of head and neck

Tackling the scarcity of PPE

Reuse of PPE

Conventionally disposable items are one time use only after which they need to be disposed. Reuse should be done by single person only and should never be shared between different persons. Recommendations have been issued for limited reuse or extended use of disposable respirators and masks. Reuse is not recommended if used for any procedure which may result in aerosol generation like suction, intubation, bronchoscopy etc.[36] Respirators should be discarded if seal is not adequate around mouth and nose or become moist from exhaled air or sweat or soiled or damaged (Table I).[37]

Practical methods of sterilizing and reusing N95 masks

Air drying: Drying for at least 72 hours kills the coronavirus. Drying the used respirator in a clean, dry place for 3 days is one practical way for reusing the mask.

AIIMS, Delhi protocol: Health care workers are issued 5 masks and 5 marked paper bags. They are supposed to use one mask a day and then keep it in the paper bag and use next mask for day 2 and so on for next 4 days till by

Correct sequence of wearing PPE (Fig.10)

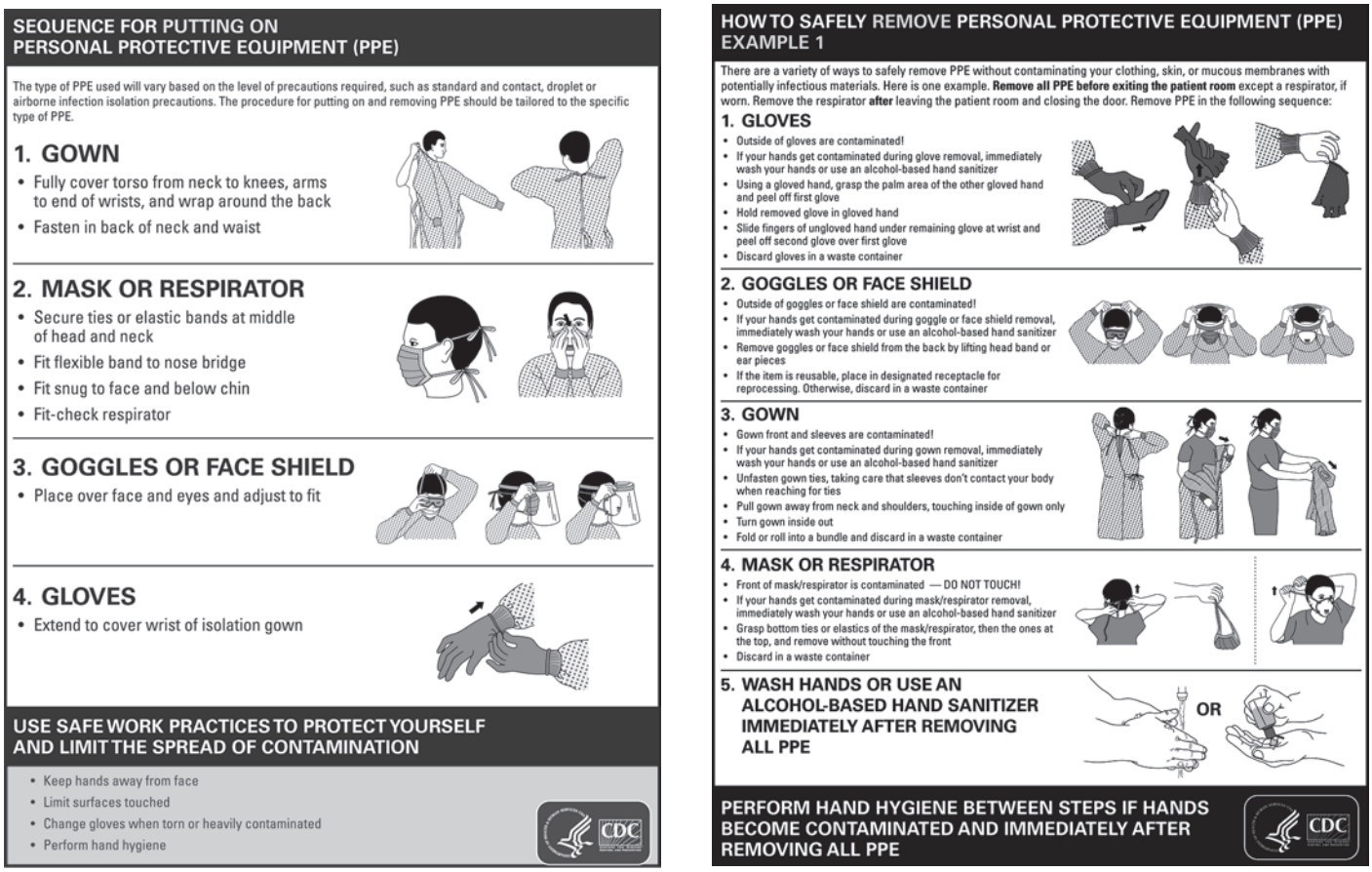

Fig.10. Sequence for putting on and safely removing PPE Source: CDC

All health care workers need to be taught the correct sequence of wearing (Donning) and taking off (Doffing) the PPE in order to avoid contamination.

rotation first worn respirator comes again. Maximum reuse of N 95 mask by a single user is 5 times.[38] Paper bag should be kept away from direct sunlight and ultraviolet rays. If the respirator becomes damaged, soiled or breathing becomes difficult, it is no longer fit to be used. Person wearing it should be familiar with method of removing and wearing it properly.

Heat in an oven

i) Heat the respirator at 70^{O}C for 30minutes after confirming that it is not inflammable and does not have a metal clip. Respirator can be hung in the oven using a wooden clip.[39]

ii) Microwave (one minute each side) can also be used.

Chemical sterilization

Vapor of hydrogen peroxide is used for sterilising used respirators.[40,41] During 2009 influenza epidemic, NIOSH had compared 5 methods of disinfection namely microwave

Table II. Suggested sequence of donning and Doffing PPE

Donning sequence	Doffing sequence
Hand hygiene	Outer gloves
Cap	Gown/ cover all
Shoe cover	Shoe cover
Hand hygiene	Goggles / face shield
Inner glove	Mask
Gown/ cover all	Cap
Mask (Surgical mask or N95 Respirator)	Inner glove
Goggles / face shield	Hand hygiene
Outer gloves	

Table III. Practical tips to remember when donning and doffing off mask, respirator and face shields

Tips to remember when donning a mask or respirator
Ties of mask/respirator should be tied up at middle of head and neck
Flexible band should be at the nose bridge.
It should fit snugly to face and below chin
Respirator should be tested every time it is worn by inhaling deeply after wearing and it should pucker in slightly.
Tips to remember when doffing a mask or respirator
Front of mask/respirator is contaminated and it should never be touched
If hands get contaminated during removal of mask/ respirator, immediate hand hygiene should be performed.
Mask should be removed by grasping bottom ties or elastics and then the ones at the top.
Mask/ respirator should be removed without touching the front
Disposable item should be discarded in a designated container
Tips to remember when doffing a face shield
Outside of face shield is contaminated and it should never be touched.
If hands get contaminated during removal of face shield, immediate hand hygiene should beperformed.
Face shield should be removed by lifting ear pieces or head band from the back.
Disposable face shields should be discarded in a designated receptacle
If reusable, face shield should be placed in designated container.

oven irradiation, bleach decontamination, ultraviolet germicidal irradiation (UVGI), ethylene oxide (EtO) and vaporized hydrogen peroxide (VHP). Out of these UVGI, EtO and VHP methods were found to be promising decontamination methods.[40,42] Cleaning the mask with soap, alcohol, bleach or isopropranolol have not been successful as they caused damage to the electrostatic charge thus significantly reducing the filtration capacity.[42] Successful regeneration is confirmed by sprinkling the mask with small scraps of paper-if the paper sticks, the electrostatic charge has been restored.

Storing the respirator or face mask during reuse

All respirators or facemask should be stored in a container made of material that allows breathing like paper bag. Name of user should be placed on the respirator or face mask as well as storing container in order to prevent reuse by another person. Name on mask can be written on the straps of respirators. Date and time should be writtenon the container bag to track duration of use.[43]

Choice of mask to be worn

With the ongoing pandemic it is now clear that if everyone wears a mask, chances of virus transmission significantly goes down.Triple layer surgical mask seems an ideal choice but it has to be disposed after getting soiled and may need frequent replacement even within a day. A washable three layered cotton cloth mask can be a more practical option for the general public. Irrespective of the type of mask worn, the person wearing it needs to know the proper way of wearing it and general precautions - hand hygiene before wearing and after removing, not to touch the mask while it is on the face of the user. Dust mask and single layer mask should not be used and surgical mask should not be washed or reused. The N95 respirator mask should not be used in the community as it is a precious commodity. Mask should be worn even inside the house if some one is having a respiratory infection. During this pandemic all HCWs should wear a respirator when sitting in the outpatient department (OPD), irrespective of nature of OPD. All patients and accompanying attendants must be made to wear a mask before entering OPD. During aerosol generating procedure N95 mask is mandatory. Doctors and nurses are at maximum risk of acquiring infection hence no compromise should be made with respect to wearing adequate PPE.[44]

Issues faced by HCW while using PPE

Danger of hypoxia and carbondioxide retention after extended use of respirator

Many clinicians feel claustrophobic after wearing tight fitting respirators, but significant hypoxemia or carbon dioxide retention of clinical significance has not been proven.

Common injuries on wearing respirators

Long hours of wearing the N-95 respirators or surgical masks and goggles can compress nose-bridge and cheeks, the mask strap can compress the ears, and face shield and

Table IV. Summary of quality standard for various components of PPE.

No	Equipment	Specifications	Quality Standard
1	Coverall suit / Surgical gowns	S-spunbound, M-meltdown • SMS (GSM >70) • SMMS (GSM >70) • SMMMS (GSM >70) • Single use only • Light colors GSM alone should not be the criterion to select cloth but all these fabrics and seams should be approved by SITRA or DRDO / INMAS. Each and every gown should have stamp on individual product.	1. Meets or exceeds ISO 16603 class 3 exposure pressure 2. UCC stamp from SITRA or DRDO
2	Gloves	• Nitrile • Non-sterile • Powder free	1. EU standard directive 93/42/EEC Class I, EN455 2. EU standard directive 89/686/EEC Category Ill, EN 374 3. ANSI/SEA 105-2011 4. ASTM D6319-10
3	Goggles	• Accommodates prescription glasses • Adjustable band • Indirect venting to reduce fogging • Disposable	1. EU standard directive 86/686/EEC 2. EN 166/2002 3. ANSI/SEA Z87.1-2010
4	Shoe cover	Made up of the same fabric as of coverall/gown	
5	N-95 Masks	1. NIOSH - approved N95 or 2. EN 149 & FFP2 or FFP3 3. Fluid Resistance - ASTM F1862, ISO22609, or equivalent”	Made in India masks either should be certified by NIOSH (CDC web site) or approved by SIRA or DRDO
6	Face Shield	• Made of clearplastic • Adjustable band • Fog resistant (preferable) • Disposable	1. EU standard directive 86/686/EEC, EN 166/2002 2. ANSI/SEA Z87.1-2010

surgical cap can compress the forehead, which might be the main cause of pressure injuries on multiple parts of the head and face. Following are the strategies to prevent and treat them.

1. Apply hydrogel and hydrocolloid dressings beneath N95 mask as a preventive measure
2. Adequate cleansing and applying moisturizers (coconut oil, over the counter moisturizers like Vaseline lotion or moisturizing cream) over pressure areas frequently will help.
3. If injury has occurred - for small sterile blisters, where the epidermis is intact, the blister fluid will be absorbed without intervention; for blisters with a large area or high tension, a sterile syringe is used to suction out the fluid from the bottom of the blister, topical antibiotic ointment is applied and epidermal loss should be avoided.

Precautions during aerosol-generating procedures

Aerosol-generating procedures are nebulization, HFNC, endotracheal intubation, airway suction, tracheostomy procedures and UGI endoscopy, tracheostomy, bronchoscopy and cardiopulmonary resuscitation. Non invasive ventilation is also an aerosol

Table V. Strategies to optimize PPE and Equipment during pandemic

	N95 Respirators	Facemasks	Eye Protection
Conventional Capacity	Recommended only for use by HCW for protection from airborne as well as fluid hazards.	Use based on local guidelines	Based on local guidelines
Contingency Capacity	Use beyond the manufacturer-designated shelf life for training and fit testing. Extended use and Limited re-use for tuberculosis and non Covid cases	Restriction on use of facemasks only by HCP. Do not keep facemasks in public areas for visitors extended use.	goggles and reusable face shields to be preferred over disposable onesImplement extended
Crisis Capacity	Use beyond the manufacturer - designated shelf life also for health care limited re-use COVID-19 patients. Prioritize the use of respirators based on type activity. Use of respirators other than standard N95 (should be considered equivalent in standards prevalent in other countries)	Use beyond the manufacturer-designated shelf life limited re-use. Prioritization for selected activities.	Use beyond the manufacturer - designated shelf life limited re-use Prioritization for selected activities.
No PPE available	Non-NIOSH approved masks or even home made masks.	A face shield that covers the entire face extending to the chin or below and sides of the face with no face mask.	

generating procedure.[46] Ideally these procedures should be done in rooms with negative pressure and atleast 12 air changes per hour or room with natural ventilation with airflow 160 L per second per patient.[47] PPE for HCW performing any of the procedures discussed above should include double gloves, impervious gown with long-sleeves, eye protection with goggles and face shield and a N95 respirator mask.

Behavior and compliance issues related to PPE

Since wearing the PPE for long time can be uncomfortable with difficulty in breathing, compliance may not be optimal. Compliance for wearing gloves is high while compliance for wearing eye protection was lowest in one questionnaire based survey.[48] In another survey, availability of PPE, safety culture of unit and training of HCWs were found to be determinants of improving compliance among HCWs.[49] Everyone working in a health care facility must be trained to know about situations and type of PPE necessary. They should be taught about how to properly put on, take off, adjust and wear the PPE. They should be aware of limitations of the PPE and about proper disposal of PPE. Quality standards acceptable for PPE have been shown in Table IV.

Checklist for PPE kits required for HCWs is available as guidelines issued by MOHFW, GOI and WHO (Table V).

In view of constantly changing epidemiology (especially increase in asymptomatic spread) guidelines can be modified as per resources available.

Selection of PPE in specific situations

In non COVID / suspect COVID cases (Awaiting report)

In ICU / Emergency - Above full set of PPE is essential (preferably single use)

In ICU / Emergency (limited resources) - Above PPE (Reprocessed)

Non critical areas (wards with Covid negative cases, areas without aerosol generating procedure) - head cap, reusable gown, face shield, goggles, gloves. Three ply surgical mask or N95 mask.

If suspected case turns positive - Full set of PPE is essential to the health care workers handling (Single use).

If resource limited reprocessed full set of PPE can be used.

In ICU and Emergency ward - Health care workers to be in the full PPE with all elements (based on availability) considering all cases to be as suspected COVID.

Aerosol generating areas - Fluid resistant isolation gown, face shield and goggles / Gloves / N95 mask should be used.

Points to Remember

- ***Health Care Workers should wear appropriate Personal Protective Eqipment - not only to protect himself from suspected COVID patient but also to prevent patient to patient infection.***
- ***Mask helps in preventing the aerosol spread and N95 respirators are recommended to be used by healthcare workers when caring for COVID-19 positive or suspect.***
- ***Face shields provide a barrier to a bout of suddenly-expelled aerosol of body fluids and are commonly used as an alternative to goggles.***
- ***Isolation gowns including coveralls provide higher level of protection as they cover larger critical zones than traditional surgical gown.***

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CLIPPINGS

Contact tracing assessment of COVID-19 transmission dynamics in Taiwan and risk at different exposure periods before and after symptom onset.

This prospective case-ascertained study in Taiwan included laboratory-confirmed cases of COVID-19 and their contacts, from January 15 to March 18, 2020. All close contacts were quarantined at home for 14 days after their last exposure to the index case. During the quarantine period, any relevant symptoms (fever, cough or other respiratory symptoms) of contacts triggered a COVID-19 test. Secondary clinical attack rate (considering symptomatic cases only) for different exposure time windows of the index cases and for different exposure settings (such as household, family and health care) were analysed . Here 100 confirmed patients were enrolled, with a median age of 44 years. Among their 2761 close contacts, there were 22 paired index-secondary cases. The overall secondary clinical attack rate was 0.7% (95% CI, 0.4%-1.0%). The attack rate was higher among the 1818 contacts whose exposure to index cases started within 5 days of symptom onset [1.0% (95% CI, 0.6%-1.6%)] compared with those who were exposed later (0 cases from 852 contacts; 95% CI, 0%-0.4%). The 299 contacts with exclusive presymptomatic exposures were also at risk (attack rate, 0.7% [95% (CI, 0.2%-2.4%)]. The attack rate was higher among household (4.6% [95% CI, 2.3%-9.3%]) and non household ({5.3% [95% (CI, 2.1%-12.8%)}) family contacts than that in health care or other settings. The attack rates were higher among those aged 40 to 59 years (1.1% [95% CI, 0.6%-2.1%]) and those aged 60 years and older [0.9% (95% CI, 0.3%-2.6%)]

Conclusions: High transmissibility of COVID-19 before and immediately after symptom onset suggests that finding and isolating symptomatic patients alone may not suffice to contain the epidemic and more generalized measures may be required, such as social distancing.

Cheng HY, Jian WS, Liu DP, Ng TC, Lin HH. Contact tracing assessment of COVID-19 transmission dynamics in Taiwan and risk at different exposure periods before and after symptom onset. JAMA Internal Medicine / Original Investigation. JAMA Intern Med. doi:10.1001/jamainternmed.2020.2020. Published online May 1, 2020.

Reactive lymphocytes in patients with COVID-19.

The peripheral blood films of 32 patients out of 96 COVID-19 cases confirmed in Singapore by RTPCR were examined and reactive lymphocytes were found in 23 cases (72%). The most common subtype seen in this cohort displayed a distinctive abundant pale blue cytoplasm that often abuts adjacent red blood cells. This type of reactive lymphocytes were not seen in 185 SARS cases in Singapore during the 2003 outbreak and were seen in only 15.2% of 138 cases in Hong Kong. Lymphoplasmacytoid lymphocytes were present in 16 out of 23 patients. These are small mature lymphocytes with condensed chromatin and an eccentric nucleus. Both types of cells can coexist. The latter cells are also seen in dengue and B-NHL. This is an observation seen in the peripheral smears of COVID-19 patients, significance is not known at present.

Vanessa CL Chong, Kian Guan Eric Lim, Bingwen Eugene Fan, Stephrene SW Chan, Kiat H Ong, Ponnudurai Kuperan. Reactive lymphocytes in patients with COVID-19. British Journal of Haematology 2020;189(5) 844.