


REVIEW

Review of Coveralls, Gowns, and their Use as Part of Personal Protective Equipment (PPE KIT) for Effective Protection of Healthcare Workers in India in COVID-19

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ABSTRACT

Healthcare Workers (HCWs) and public health professionals are playing a pivotal role in containing COVID-19. Personal Protective Equipment (PPEs) are a critical component in the hierarchy of primary infection controls to ‘break the chain of infection’ to protect patients, HCW’s, and public. As SARS-CoV-2 is highly contagious, and vaccine and prophylactics not yet available, understanding correct PPE usage is imperative. This study aims to: understand purpose, use, and quality standards of body-coveralls and gowns and how to use PPE’s for effective protection in COVID 19 in India. Types of PPE’s in healthcare, their purposes, materials used, and properties were reviewed. Gowns and Body-coveralls classification and standards in Europe, USA and India were studied. While current stipulated test standards for coveralls in India are lower, as routine use of reusable gowns made of woven fabrics is more common in India, one could hypothesize that these coveralls provide a higher level of protection. As per current understanding of mode(s) of transmission of SARS-CoV-2 a properly fitted N95 respirator; goggles and splash resistant face shield; gloves; and single-use full body-coverall/gown preferably resistant to Synthetic Blood Penetration under pressure and made of non-woven Laminated SMS (Spunbond-Meltblown-Spunbond) or Non Laminated SSMMS fabrics are advisable depending upon anticipated level of exposure. HCW’s should be educated about transmission risks, correct principles of infection control, functional purpose of PPE’s and must be conscious that PPE’s alone will not protect them. They must follow good practices of how to wear (don) and how to remove (doff) and ensure that they do not inadvertently contaminate their clothing/skin and self-inoculate.

KEYWORDS: Personal Protective Equipment (PPEs), COVID-19, Healthcare Workers (HCWs)

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INTRODUCTION

Personal Protective Equipment (PPEs) have become important during COVID-19 pandemic due to the highly contagious nature and virulence of the virus and insufficient treatment modalities. PPE’s are used in many settings - in industry, against pollutants, in sports, and in healthcare. PPEs have been used time and again during epidemics and pandemics, and are in routine use as a critical component in the hierarchy of controls as part of infection control to protect healthcare workers (HCW’s), patients and others from health-related risks, and exposure to infections. The earliest forms of PPEs were used for the Black Death epidemic in the 14th Century, though we now know that they were ineffective.

HCW’s are in the combat zone when treating communicable diseases and risk getting infections ^{[1][2]}

and various infection control strategies are used for protection. The rapid spread of COVID-19, and reports of many HCW’s including doctors and nurses getting infected while treating patients, led to the realization that the routine PPE’s and practices are not sufficient. There were reports of HCW’s getting infected despite using PPE’s specifically for COVID-19, and discomfort of PPE’s hindering ability to work, leading to non-compliance ^{[3][4]}.

As countless HCW’s were affected there developed need for suitable PPEs in large quantities. Hospitals and governments did not have much prior knowledge/experience of the types of suitable PPEs, nor stocks/supply-chains ^[5]. This research is important as need for suitable PPE’s in large numbers continues and though

production has increased there are doubts about quality/efficacy. Globally many manufacturers repurposed facilities to produce PPEs. However, they lacked proper knowledge of the design, materials to be used, quality standards and regulations. India lacked organized PPE production before February/March 2020^[6], and not enough knowledge or understanding about them. Due to the huge demand and Government's encouragement, several producers started manufacturing or supply of PPE's. However, there are many questions on what PPE's are, which are suitable, are they safe, can they be reused, be made more comfortable and cost-effective, and what is the impact on the environment?

Research was undertaken on PPE's used in healthcare and their utility. To understand the type of PPE's required for protection against the SARS-CoV-2 – the virus causing COVID-19, research was done to understand mode of spread. Type of materials used for making PPE suitable to protect against COVID-19, and knowhow of manufacturing details of the body-coverall was researched. Study on the quality standards, testing methods, and Governmental guidelines were done. Materials used for making were collected, some tests performed on them and on the body-coverall. A survey was undertaken to collect feedback from healthcare and other frontline workers, to help understand type of PPE's used, difficulties faced, and preferences or needs of the frontline workers.

Governments and manufactures are gaining better understanding from research previously conducted, and from standards already in place in the USA/EU. The Indian government and industry are establishing quality standards and innovating to find suitable, cost-effective solutions for use in India. By collecting information from various reliable sources, information will be provided to aid government and industry in producing appropriate cost-effective PPEs for use in India and elsewhere

The results from this study will prepare the HCWs and Healthcare administrators protect themselves while taking care of those infected, or suspected to be infected by SARS-CoV-2. It may help manufacturers produce comfortable cost-effective body-coverall or gowns meeting required quality standards.

MATERIALS AND METHODS

Study design

Strategy for Search

Online search for articles and papers on 'PPE's used in Healthcare' 'quality standards and testing of gowns and coveralls', 'mode of spread of SARS-CoV-2' 'Government guidelines for PPE' 'materials used for gowns / coveralls' was done. Articles, papers, notifications from sites such as CDC, FDA, Ministry of Health and Family Welfare and other reliable sources were shortlisted.

Study Selection

Epidemiological, Clinical, and laboratory-based studies done globally have been included in the review. The emphasis of this methodical review was regarding use of PPE for prevention of infectious diseases. Consequently, we specifically involved reports that examined use of overalls, facemask, and respirator for HCW's, with or without other PPE. We have considered only those studies relevant to PPE for review in this article. To better understand PPE's, their uses, and the suitable types to be

used in the COVID-19 pandemic, an analysis of articles and scientific papers was undertaken. Latest understanding of modes of spread of SARS-CoV-2 was researched. Information was collated from a variety of sources and inferences were made. Also, professionals involved in the field of production or study of PPEs were interviewed to understand the types of PPEs used in healthcare, need for PPE's during COVID-19 pandemic, and types of PPEs required to protect from the virus. Research was undertaken to gain knowledge about the different materials used for making PPEs, specifically Body-coveralls. Research on the quality standards was carried out to understand the required level of protection against SARS-CoV-2 and other viruses. A study of some of the tests prescribed to achieve the quality standards was also done. A detailed study of guidelines and notifications issued by the Government of India was done.

Experimentation

Samples of different materials were collected and visit to a factory producing Body-coveralls organized. A thorough evaluation of the step-by-step procedure, functioning of testing machines was conducted. Raw material (fabric) samples, and samples taken from manufactured Body-coverall^[7] were tested. Thickness, GSM, hydrophobic property, hydrostatic pressure resistance and synthetic blood penetration were tested using various equipment- Vernier Caliper, GSM Cutter, weighing scale, hydrostatic pressure tester, Synthetic Blood Penetration Tester, and synthetic blood.

The Test Procedure under IS 16546- Synthetic Blood Penetration Test (Procedure C) (Same as ISO 16603:2003 Level 3) was done.

The body-coverall (or material) was kept for conditioning at a temperature of 21°C (+5) and RH 60(+10) for 24 hours. Initially, the body-coverall was inspected particularly at the folds to check that tape covering the seam was intact/adherent. Samples were cut from 6 places of the coverall- three from the body fabric and three from the seams, one each from a straight seam, curvature and the cross seam and then subjected to the Synthetic Blood Penetration Test by fixing to the Penetration Test Cell. Synthetic blood was poured into the chamber and pressure was gradually increased and through the following six stages: i) 0 kPa for 5 minutes, ii) 1.75 kPa for 5 minutes, iii) 3.5 kPa for 5 minutes, iv) 7 kPa for 5 minutes, v) 14 kPa for 5 minutes vi) 20 kPa for 5 minutes. (No leakage up to Level 3 (3.5kPa) is Pass).

RESULTS & DISCUSSION

There is paucity of data and lack of stringent guidelines along with Standard Operating Procedures (SOPs) regarding PPE issued in most of the hospitals or laboratories or recovery centres. Transmission of infectious agents in healthcare settings require three elements: a source of infectious agents, susceptible host with a portal of entry receptive to the agent, and mode of transmission. Transmission can be- HCW to patients; patients to HCW and environment or equipment; and environment/equipment to patients or HCW. The Centre for Disease Control and Prevention (CDC) categorizes three primary routes of contact between people and microorganisms in healthcare settings: (i) contact (direct/indirect), (ii) respiratory droplets (iii) airborne droplet nuclei^[8]. PPE's are used in healthcare to "break

the chain” of transfer of infection to protect patients and HCW’s from infection. Some protect patients, most serve dual purpose, some primarily protect the HCW’s where there is a higher risk of exposure- these PPE’s are made to meet higher protection standards.

SARS-CoV-2 is highly contagious with modes of transmission not fully understood; highly virulent, debilitating, often fatal; treatment modalities remain uncertain. no vaccine at present nor confirmed prophylactics . As HCW’s treating either confirmed or suspected cases are at high risk- understanding of a suitable PPE’s and their correct usage is critical to protect them becoming infected, carriers, or inadvertently spreading the infection.

PPE constitute any specialized clothing, device, or appliance that is designed to be worn or held by an individual for protection against one or more health or safety hazards ^{[9][10]}. PPE’s used in occupational safety, sports, adventure sports, car racing, etc. include helmets, masks, aprons, hazmat suits, gloves, boots, shin-guards, cricket-pads, elbow or knee protectors etc. For particulate air pollution people use suitable face masks with filters. Historically, prevention of spread of infection in healthcare is focused on preventing infection of the patients from the HCW’s and environment, starting with practice of washing hands in chlorinated water in 1846, introduced by Ignaz Semmelweis, a Hungarian physician who focused on antiseptic procedures ^[11]; introduction of asepsis by Joseph Lister in 1880’s; masks first used in surgery by Johann Mikulicz, (University of Breslau) who worked with bacteriologist Carl Flüggé ^[12]. Adoption of isolation precautions and principles of asepsis by Grancher in a children’s hospital in Paris in 1890 to prevent cross infections, eventually led to use of ‘Isolation Gowns’ to protect HCW’s and later as part of Contact Precautions when working with patients known to be infected with pathogens that spread through direct/indirect contact. In World War II US military developed a high-density woven fabric with less than 5 microns between each yarn, coated with a hydrophobic chemical making it water repellent ^{[13][14]}. Such gown created a field of ‘isolation’ and gave protection. However, it had low penetration resistance, water pressure resistance, poor air permeability and deteriorated with washing.

Development of nonwoven fabrics made of extruded fibers of polypropylene, or such material, layered to form a fine mesh-web found application in hygiene, health care and other areas. Random orientation of the fibers reduces liquid transmission by (i) providing filtering media (ii) reducing the capillary formation ^[15]. Two varieties are Meltblown and Spunbond. In 1976 technology developed to merge/ bond spunbond with meltblown leading to development of a triple-layered fabric of meltblown sandwiched between layers of spunbond with good strength, breathability, and filtration properties against pathogenic bacteria to some extent. Another technology was the development of PTFE (polytetrafluoroethylene) microporous film applied to the outer layer with pores of 0.3 microns allowing breathability but block passage of blood ^[16].

Gowns and Body-Coveralls

Gowns are the second-most-used PPE in healthcare, following gloves. HCW’s often get exposed to

microorganisms carried through biological fluids like blood, body-fluids, and other potentially infectious materials (OPIM) through direct/indirect contact of contaminated body-fluids with non-intact skin, and mucous membranes. Use of appropriate protective clothing creates a barrier to eliminate, reduce contact and droplet exposure- preventing the transfer of microorganisms between patients and HCWs. In healthcare, many types of gowns are used for different purposes, with different materials, design & protective properties. Not every type offers the level of protection that a HCW needs in a particular level of exposure.

In USA the FDA adopted a standard ANSI/AAMI PB70:2003 for gowns and protective clothing based on barrier protection levels and risk during intended use- Level 1 (for Minimal Risk) Level 2 (Low Risk), Level 3 (Moderate Risk) and Level 4 (high risk) based on tests and performance levels. FDA classifies medical gowns as Surgical Gowns, Surgical Isolation Gowns and Non-Surgical gowns based on design/coverage areas and risk level of intended use. Aprons or gowns not fully covering the back with sufficient overlap do not come into these categories. In surgical gowns based on expected area of exposure only the front panel and lower sleeves are considered critical- level of the gown in as per the performance standard of the lower of the two. Other parts of the gown may not have the same level of barrier protection. In Surgical Isolation gowns and Non-surgical gowns all parts of the gown including the seams, except cuff, hems and binding must have the barrier properties of the Level. Non-surgical gowns are used in Minimal or Low Risk of patient isolation situations and Surgical Gowns for moderate to high risk of contamination. While all gowns will offer some level of protection because of the nature of the material, Level 1 to 3 are tested against Liquid challenge using water (AATCC 42 and AATCC 127), Level 4 is tested against Synthetic Blood Penetration and Viral Penetration under pressure (ASTM 1670/1671 tested up to 2psi (13.8 kPa)). Surgical Gown Level 4 provides the best protection amongst gowns. NFPA 1999 standard based on resistance to viral penetration under pressure amongst other requirements applies to body-coveralls/other multi-piece/partial clothing used for emergency use.

In Europe surgical gowns are classified as ‘Standard Performance’ or “High Performance’ under EN 13795 based on resistance to liquid penetration and resistance to microbial penetration aimed to protect patients. Gowns are not tested for resistance to Synthetic Blood Penetration or Viral Penetration. As PPE (typically coveralls) protect against infectious agents the standard is EN 14126 based on fabric resistance to penetration by synthetic blood and viral penetration under pressure ISO 16603 and ISO 16604 (ranked Class 1 to 6 based on pressure from 0 kPa to 20 kPa)

In India, the Bureau of Indian Standards (BIS) classifies Surgical Gowns in 4 levels from Level 0 to 3 under IS 17334:2019. Body-coveralls come under IS 17423:2020 based IS 16546- Synthetic Blood Penetration Test (Procedure C) (Same as ISO 16603:2003 Level / Class 3 (3.5 kPa)). Both fabric and seams are tested. However, at present there is no mandatory test for Viral penetration.

Table 1 Summarizes groups of PPE

Types of PPE	Purpose	Material/Properties
Gloves:	Protect Hands/protect the patient in case of surgery/open wounds	Nitrile, Latex, Vinyl
Gowns/Aprons Coveralls	Protect skin/clothing	Natural or manmade fiber/fabric. Thickness depends on Grams per square meter GSM
i) Patient Gowns	To examine and treat patients	
ii) Cover gown for visitors	Prevent infection to be carried to patient/room through clothes of visitors	
ii) Isolation Gowns (Also called Non-Surgical Gowns/Procedural Gowns)	Barrier to spread of infection both ways – to the healthcare worker from the patient or <i>vice versa</i>	Depending upon risk of exposure to fluids they are required to meet different Liquid Barrier Protection standards and are classified as AAMI Level 1 to 4 Level 4 Resistant to Synthetic Blood Penetration and Viral Penetration.
iv)Surgical gowns/Surgical Isolation gowns	Sterilized to prevent passage of infection to patient. Isolation Gowns has liquid barrier protection	
Protective Gowns/Suits/Coveralls	Protect the Healthcare Worker when exposed to Class A infections like SARS, Ebola, MERS Provides a higher degree of protection than the gown	Hooded top and trouser. Can be a one-piece structure or separate. Trouser legs and cuffs are tightened
Surgical Masks	Protect mouth and nose (Should fully cover nose and mouth and prevent fluid penetration)	Has Liquid Barrier property
Respirators (Other versions can be Particulate respirators and half or full-face elastomeric respirators)	Protect respiratory tract from airborne infections agents	Different types of filtration materials depending upon usage conditions
Powered air purifying respirators (PAPR)	Protect HCW from aerosol/airborne infection	Air pumped through a HEPA filter into a suit or head-cover.
Goggles	Protect Eyes (Normal glasses/goggles do not protect)	Should Fit snugly over and around eyes. Preferably anti fog feature.
Face Shield	Protect face, mouth, nose, and eyes	Should cover forehead, extend below chin, and wrap around face
Head Covers Bouffant caps/Surgical Caps/Other hair covers	Covers Head to Neck These are used to prevent any hair or infection from falling onto the patient during surgery, wound dressing and to protect healthcare workers head/hair to carry any infected material out	Allows vapor to pass through but stops air and bacteria
Shoe Covers	Prevent outside contaminants to come into clean areas and Prevent infection being carried out from areas where floor may have been contaminated	Natural or manmade fiber fabric, or plastic

Table 2: Comparison between body-coveralls and gowns

BODY-COVERALLS	GOWNS
Typically provide 360° protection including back, lower leg, and sometimes head and shoes as well	Do not provide continuous whole-body protection as possible opening as back and coverage to mid-calf only. Does not cover head and shoes.
Front zipper closure could compromise barrier protection if suitable zipper not used and covered with a flap.	Gives better front chest protection.
Not used routinely by HCW	More frequently used by HCW
More difficult to wear/take off	Easier to wear/take off
Heat stress to wearer more	Less heat stress to wearer
Less likelihood of compliance and more risk of contamination while doffing if not trained and done suitably.	More likelihood of compliance and proper doffing

Table 3: Fabrics Tested

Sample	GSM	Thickness	Synthetic Blood Penetration Test IS 16546 (Procedure C)
Laminated SMS	54	0.2 mm	Passed at 3.5 kPa
Non-laminated SMS	80	0.32 mm	Failed at .75 kPa
Laminated SMS	70	0.34 mm	Passed at 14 kPa
Laminated SMS	80	0.38 mm	Failed at 3.5 kPa in some swatches.
Non-laminated SMMSS (Breathable)	60	0.32 mm	Passed 3.5 kPa Failed 14 kPa
Laminated SSMSS	75	0.35 mm	Passed upto 20kPa

It can be seen that resistance to Synthetic Blood Penetration does not depend purely upon GSM / thickness or lamination of fabrics. Each fabric type and lot should be tested. Hot Seal of seams provides better resistance but is not guaranteed.

Table 4: Seam Tested

SEAM PORTION	TYPE OF TAPE	Synthetic Blood Penetration Test IS 16546 (Procedure C)
Sample A		
Straight	Cold Adhesive	Pass
Curved	Cold Adhesive	Fail
Cross	Cold Adhesive	Fail
Sample B		
Straight	Hot Seal	Pass
Curved	Hot Seal	Pass
Cross	Hot Seal	Pass
Sample C		
Straight	Hot Seal	Pass
Curved	Hot Seal	Pass
Cross	Hot Seal	Fail

COVID-19 is a disease in humans caused by an RNA virus named SARS-CoV-2 (SARS– Severe Acute Respiratory Syndrome), previously unknown beta-coronavirus which is part of a group of viruses called Coronaviruses (CoVs) [17]. Most Coronaviruses are zoonotic (prevalent in some animals like bats) and few have affected humans in the past [18]. Researchers believe that the virus mutated from a previous zoonotic variety and recombined with a human strain, spreading from human to human [19].

The illness can be very severe in some individuals, especially those above 60, or those with other pre-existing diseases, however, it affects all ages. It is fatal in a certain percentage of patients because of its complications. The disease is very debilitating in many cases and severe symptoms can persist for long time [20].

The dominant mode of transmission is close person-to-person contact with infected individuals *via* droplets from the respiratory tract. Respiratory droplets spread through nasal discharge, coughing, sneezing, speaking or singing loudly etc. Infection happens by the virion entering through nose or mouth, or the eyes as the lachrymal fluid (tears) drain into the nasal passage. It also spreads indirectly as a person may self-inoculate by touching fomites on contaminated surfaces either by touching droplets from an infected person- and then touching one's own face, mouth or nose. Aerosols (fine droplets) generated in certain hospital procedures stay in the air and cause airborne transmission. Infection through contaminated utensils is also possible [21].

It can affect the gastrointestinal tract and spread through fecal-oral route. It could spread through an infected person's body fluid like saliva, vomit, blood etc. The SARS Cov-2 virion is estimated to be between 60-140 nm (nanometers) in size. Each respiratory droplet is 5-10 micrometers length potentially containing hundreds or thousands of virus particles [22]. The virion is very stable and stay stable on copper- 4 hours, cardboard 24 hours and plastic or steel surfaces for nearly 3 days [23]. It is destroyed by using soap and water while iso-propyl alcohol helps sanitize the surfaces.

It is highly contagious and has a reproduction number (R_0) between 2.0 and 3.0 [24]. As it is a novel virus, humans have no previous exposure to this or anything similar, hence no inbuilt immunity. As it spreads from one human to another even before a person becomes symptomatic (during the incubation phase), and as 30% persons infected are themselves asymptomatic, but capable of spreading the disease, it has spread extremely fast. There is no vaccine to protect against the infection, nor any confirmed medication to use prophylactically (to prevent infection). Till a vaccine or suitable prophylactic treatment is found, epidemiological control, containment of the spread, detection, and protection of every person, especially those directly exposed to known or suspected cases is important. Therefore, the role of Personal Protective Equipment and other precautions is essential to the eradication of COVID-19.

In India disposable gowns are used usually when the patients are known to be Hep B, C or HIV positive, or in tertiary hospitals in specialized surgeries. Mostly reusable gowns made of woven fabrics are used. Due to frequent washing and autoclaving the fabric deteriorates and these gowns may not protect against liquids or body fluids; in fact, they could soak liquids or other body fluids more easily.

With COVID-19 spreading through droplets and not much known about how long the virus remains viable in the environment, protective clothing made of nonwoven fabrics which have repellency to water offer better protection. Resistance to liquids under pressure, and to Penetration of Synthetic Blood under pressure offers better protection. The stipulated standard IS 17423:2020 is lower than standards in USA/Europe, and resistance to Viral Penetration under pressure is not yet mandated.

As there are no such studies, one presumes that the body-coverall's design and quality standards under BIS standard IS 17423:2020 offers better protection than a reusable woven-fabric gown where risk of exposure is high; for example in HCW's working with COVID positive or

suspected patients. It would also be suitable at emergency services and primary health services level.

Users should be made aware that the coverall standard in India does not include testing for viral penetration, hence may not offer the requisite protection against liquids along with high pressure due to leaning, kneeling etc. and should exercise caution even with PPE use.

We want to draw upon the 'Protection Strategy Pyramid' based on US Army CBRN Defence Strategy (Chemical, Biological, Radiological, Nuclear hazards) shared by Dr. Sheshadri R. in an article to suggest suitable protection strategy^[25] in the SARS-CoV-2 pandemic

It envisages Sense (threat) based on the increasing number of positive cases of COVID-19. Lab technicians, Doctors other HCWs and other associated frontline workers essentially fall in the category of higher risk as they are directly exposed to persons suspected or confirmed to be infected. Accordingly, HCWs exhibit higher incidence as compared to general population. HCWs could also become source of infection to others and could inadvertently become carriers and spread infection to other patients/HCWs in their facility or even to their families.

Second aspect of the pyramid is Shape i.e., understanding the threat. The dominant mode of spread of SARS-CoV-2 via the respiratory droplets expelled/dispersed into the environment through nasal discharge, coughing, sneezing, speaking loudly. Infection happens through virions that come in contact with the mucous membrane of the nose, mouth, or eyes. It spreads directly through the air, or indirectly as a person may self-inoculate by touching fomites/surfaces/clothes contaminated by droplets from an infected person. Aerosols (fine droplets) generated in certain hospital procedures in the air could cause airborne transmission through the air.

Third part is Shield i.e., protection from threat. Face covers reduce droplet dispersal and give limited protection. Surgical Masks reduce droplet dispersal and give limited protection. Properly fitted Respirators (N95, equivalent or above) offer protection. Goggles give eye protection Face Shields give added protection but not a substitute for mask. Gloves protect hands, but gloves will be the most contaminated and should be frequently washed/sanitized or changed. Body-coverall or combinations of Gowns, Head-Cover, Shoe-Covers, additional Aprons where required will protect one's exposed skin/hair and clothes, to prevent contamination. PAPR provide additional protection in areas where there is risk of aerosol/airborne transmission. PPE's should be donned in the correct sequence before entering the area with exposure risk. Where patients with COVID-19 are (cohorted) grouped, gloves should be changed between examining patients. When exposed to patients with confirmed/ suspected SARS-CoV-2 infection, PPE which could have got contaminated should be removed and disposed off/suitably disinfected before moving out of the area/coming in contact with others to avoid passing infection to others. Sustain or rather contain the threat is emphasized as an important aspect of the pyramid. Separate COVID areas for suspected cases and confirmed in-patients for isolation; masks for patients where possible; HCWs in COVID wards/COVID designated areas should be restricted from working in non-COVID areas and take all possible precautions not to carry infection to others. Regular testing and screening of HCWs is a must.

Effective Use of PPE's

Comfort is one of the important characteristics for PPE compliance. The features most likely to impact compliance are movement restriction, time and ease to use or remove, thermal comfort (breathability) and gown fit, besides relating to large-sized users, neck designs and tie closures. PPE's should be designed to be comfortable (thermally and physically)^[26] as far as possible without compromising function to ensure better compliance and better protection and should be available across all sizes. Body-coveralls made with fabric that allows water vapor transmission should be preferred, however cost would be higher.

As both gowns and body-coveralls offer contact protection against liquids, administration and HCW's can assess the level of exposure risk in patient interaction and appropriately use single use liquid-resistant gowns of suitable level or body-coveralls as required.

Just having suitable quality PPE's does not guarantee protection. HCW's should be made aware of the modes and risks of transmission, the functional purpose of the PPE, and should be instructed on how to wear (don) and how to remove (doff) to ensure that they do not inadvertently contaminate their clothing or skin and self-inoculate themselves.

When wearing full PPE, care should be taken to ensure that there are no risk of leakage (strike-through) at the interface of the different components of the PPE kit– like the cuffs and the gloves (sleeve should have a thumb loop to ensure the sleeve is not pulled up) and gloves should be worn over the cuff. Due care should be taken to ensure the mask fits properly. The face shield should cover the opening of the face.



Fig 1. Early Mask

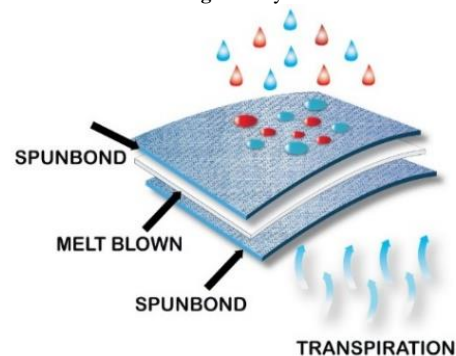


Fig 2. SMS (Spunbond Meltblown Spunbond) Fabric

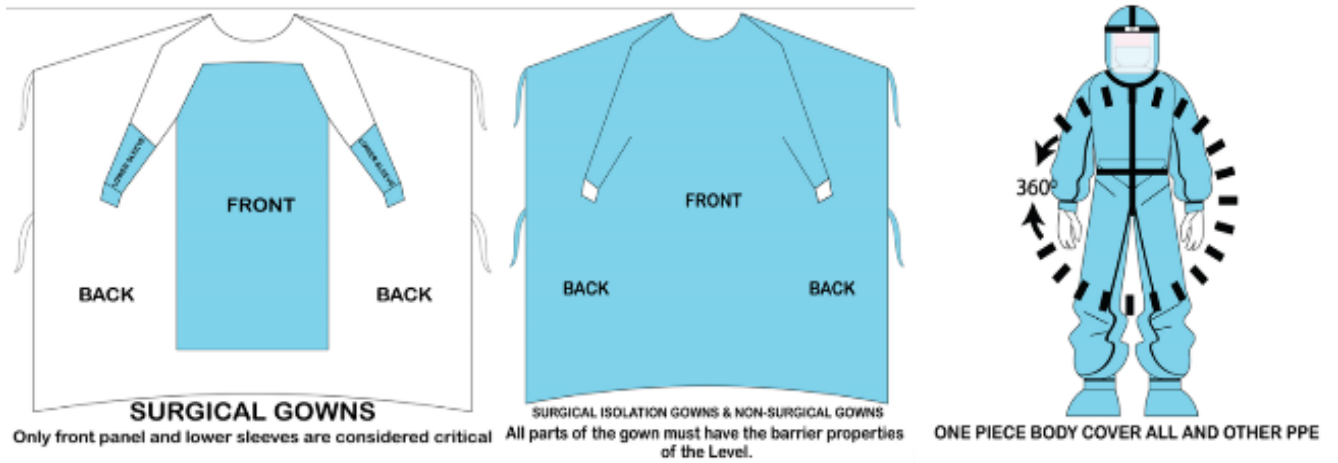


Fig 3. i) Surgical Gowns, ii) Surgical Isolation Gowns, iii) One-piece Body Coverall



Fig 4. Testing of materials and Full Body-coverall a) Thickness b) GSM c) Hydrostatic d) Hydrostatic Pressure e) Synthetic Blood Penetration Test f) Showing Leakage of Synthetic Blood under pressure

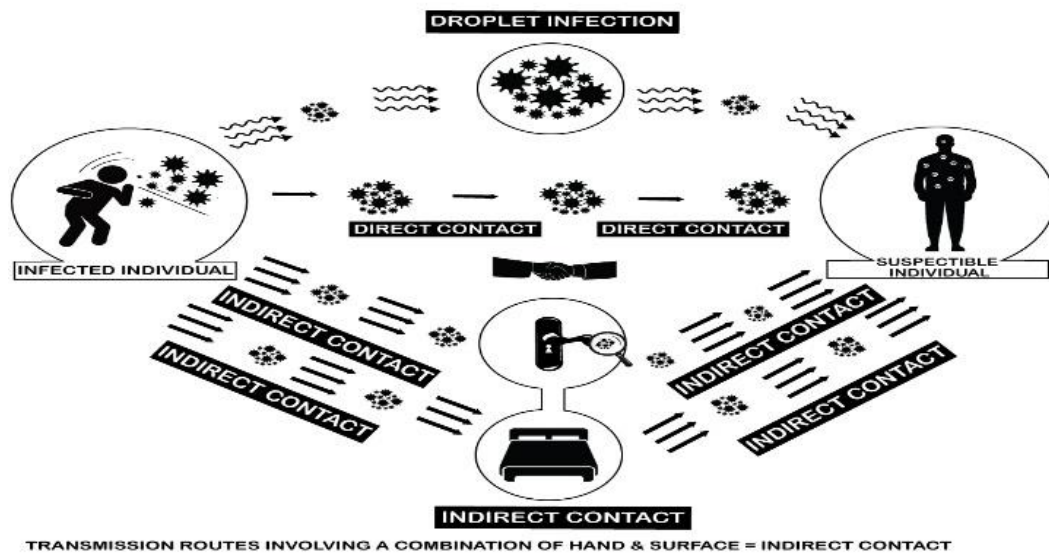


Fig 5. Modes of Transmission of SARS-CoV2

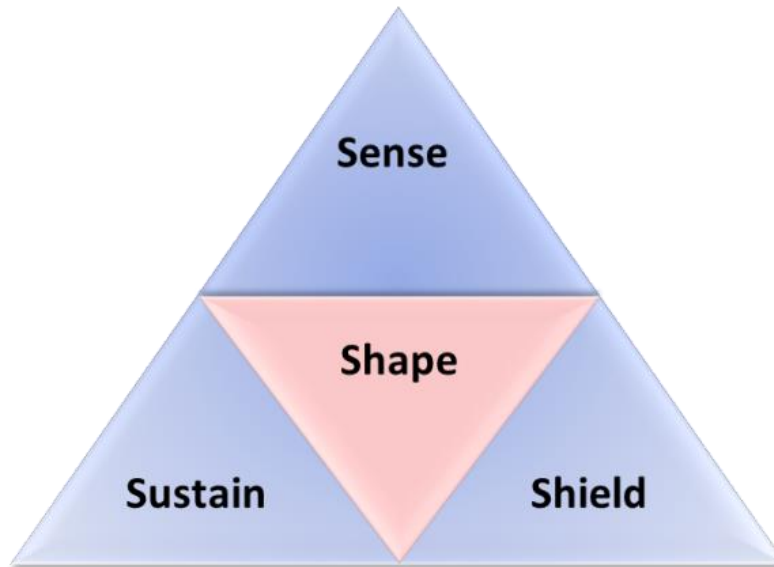


Fig 6. Protection Strategy Pyramid

Donning and Doffing should be done in a designated area.

DONNING PPE (Putting On)	DOFFING PPE (Taking Off)
<ol style="list-style-type: none"> 1. Take meal, use washroom, drink water. 2. Perform Hand Hygiene. 3. Put on Protective Suit/Gown. 4. Put on Shoe Covers. 5. Put on Mask/Respirator, ensure fit. 6. Put on Hood. 7. Put on Eye Protector/Face Shield, ensure fit. 8. Put on Gloves 	<ol style="list-style-type: none"> 1. Perform Hand Hygiene at each step. 2. Disinfect Gloves. 3. Remove Shoe Covers and dispose. 4. Remove Gloves. 5. Remove Face Shield/Goggles and dispose. 6. Remove Hood and Coveralls and dispose. 7. Remove Mask/Respirator and dispose. 8. Perform Hand Hygiene.
<p>Dispose in Bio Medical Waste Bag/Bin.</p>	

Fig 7. Directions for Donning and Doffing of PPEs

CONCLUSION

Effective use of suitable PPE's may significantly protect HCWs from getting infected during their work. Different combinations of PPE's are required depending upon the nature of duties or level of exposure expected. HCWs must be made aware of the risk of contracting infections; importance, purpose and function of PPE's; just PPE's will not protect them; but the method to use it that will ensure; how, when and in what sequence PPE's have to be worn (Donning); precautions of removing PPE's (Doffing); and how the used PPE's have to be handled and disposed of after use. HCWs should also be made aware of how they could get infected even if they are wearing PPE's; what precautions they should take to prevent inadvertent self-inoculation. Suitable PPE coupled with Awareness based on correct information/ principles of infection control and disciplined Good Practices are the key to desired protection. For HCWs working with known/ suspected positive cases, PPE's should be of single-use, and suitably discarded after exposure before coming in contact with others. Even though not yet required by Indian Government's current quality standards, fabric and body-coverall manufacturers should have their products tested for Resistance to Penetration by Blood-Borne Pathogens/Viral Penetration Resistance (IS 16545 or equivalent). Though it would be desirable to have products used in India to be of international standards, current standards set for body-coveralls could offer better protection than standard woven-fabric reusable gown. Users should be aware that India's coverall standard does not include testing for viral penetration, and material may not offer protection against liquids along with high pressure due to leaning, kneeling etc. and should exercise caution even with use of PPE. Body-coverall can be made more comfortable using fabrics that have the necessary levels of protection but better Water Vapor Transmission

rate for better compliance. This could make the product more expensive and as these would be of single use. A balance of comfort and cost will depend upon healthcare facility. Depending upon level of risk, substitutes of conjoint (one-piece) body-coveralls like the 'Nav-Rakshak' designed by the Indian Navy, or bodysuits made of separate structures can be used to provide comfort. Depending upon the risk of exposure, single-use gowns made of suitable material offering liquid barrier protection could be used.

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COMPETING INTERESTS

The authors declare no competing interests with this case.

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