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Pandemic Protective Wear for Healthcare Personnel

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Abstract:- The protective wear for the healthcare persons is their life-saving equipment as they are the one who is working on the frontline delivering care to the patients during the time of influenza pandemic. Globally the pandemic influenza affect number of people, in which the most important consideration is made for protecting the health of the health care personnel. The vital aspect of planning to prevent and control the pandemic influenza being affecting the health care personnel are by the use of Personal Protective Equipment (PPE) which consist of the coverall/gowns (with or without aprons), mask, gloves, goggles, face-shield, headcover and shoe cover that will be used by the healthcare personnel in their day to day patient care duties. In this paper, a review has been made on understanding the risk on the healthcare workers, as they have a high risk of getting transmitted of the virus through various mode of transmission. The paper discusses views for design and engineering the effective PPE which includes the different components of PPE used by healthcare workers, and its characteristics which enhance the safety of the healthcare personnel.

I. INTRODUCTION

The health care workers are the one who stands on the front line providing treatment to the patients during the time of influenza pandemic and inhibiting further spread of disease. As the world prepares to face the pandemic influenza, many research are being made for protecting the health of the health care personnel by providing the proper Personal Protective Equipment (PPE) which consist of the coverall/gowns (with or without aprons), mask, gloves, goggles, face-shield, headcover and shoe cover that will provide proper prevention for the healthcare workers in their day to day patient care responsibilities [1]. Also, it is more important to have proper training and equipping the health care workers with the personal protective equipment to protect the healthcare workers from infecting their families and patient. The droplet and contact routes are the major source of transmission of the virus in a pandemic. When smaller respiratory particles circulate in the air for prolonged periods (generally <5 μm) the airborne transmission occurs [2]. The outbreaks of the serious pandemic like COVID 19 which is the most current dangerous disaster globally, have highlighted the prominence of protecting healthcare workers from infectious agents. During the pandemic, if the healthcare workers are themselves ill or being absent due to the concern about the efficiency of PPE, it is difficult to face pandemic situation to reduce death rate. The increased importance on healthcare PPE and the related challenges predicted during an influenza pandemic requires early attention to ensuring the safety and efficiency of PPE products and their use [4].

Several organisations have provided proper guidance on PPE which includes The World Health Organization, Public Health England, The European Society of Intensive Care Medicine and Society of Critical Care Medicine and The European Centre for Disease Control [1]. These organisations states that, the airborne precautions contains fit-tested and fit checked high filtration long-sleeved fluid-repellent gown, mask, gloves and goggles or visor.

II. UNDERSTANDING THE RISK OF PANDMIC INFLUENZA TO HEALTHCARE PERSONNEL

The World Health Organization have been warning that severe and mounting troubles the global supply of personal protective equipment (PPE) causes through panic buying, rising demand, misuse and putting lives at risk from a various disease like the new coronavirus and other infectious diseases [2,4]. Healthcare workers should make sure of on their personal protective equipment to safeguard themselves from being infected and infecting others [1]. The fluids can transmit the virus that causes infection or colonization which include multi-drug resistant organisms(MDROs) such as Enterobacteriaceae, Methicillin-resistant Staphylococcus aureus (MRSA) and Acinetobacterspp; also the risk of transmission includes bloodborne viruses, noroviruses and respiratory viruses [13]. Healthcare workers should be more aware of risk of a new pandemic, especially in the recent outbreaks and the fact that many of the healthcare workers are being affected day to day facing many difficulties physically and mentally working in a stressful conditions in saving lives of many people [14]. A study has been reported that about 2-15% of the healthcare workers are colonized or been infected with MRSA which shows the risk of healthcare workers acquiring micro-organism because of workplace exposures [15].

There are four possible modes of virus transmission which are; Direct contact, Indirect contact, Droplet, Airborne explained in fig. 1.

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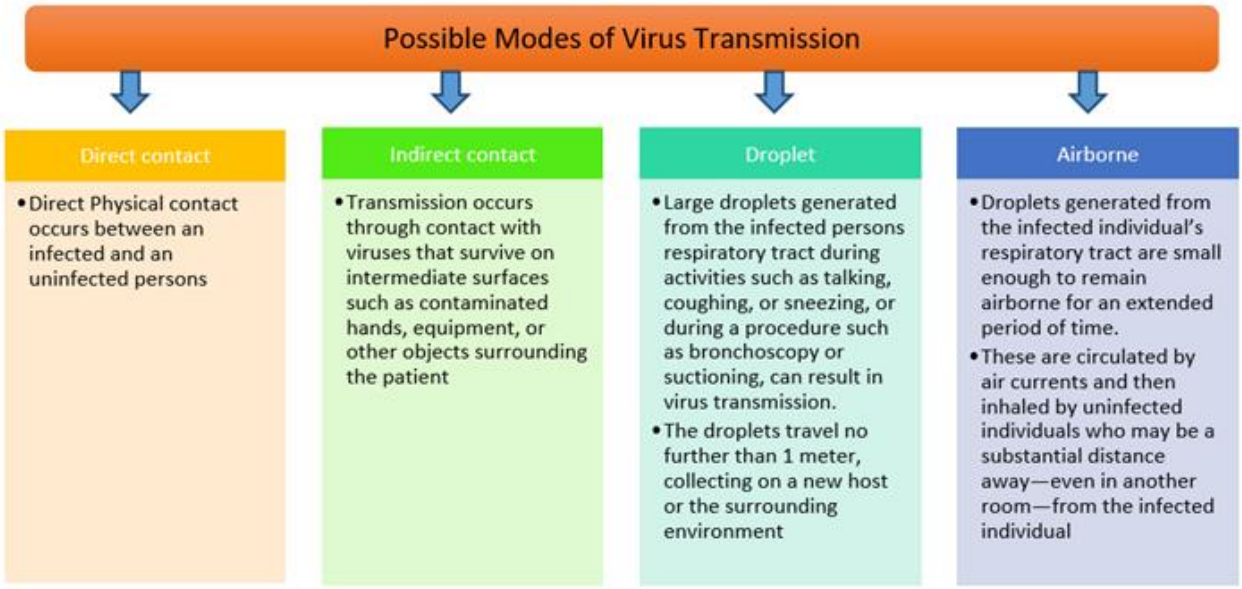

Fig 1:- Possible modes of virus transmission

In the resent pandemic of COVID 19, Italy has reported the death of health care workers by category. The report has the data available for 16179 out of 16991 healthcare workers confirmed positive for the virus [16]. The statistical data report is shown below in fig 2.

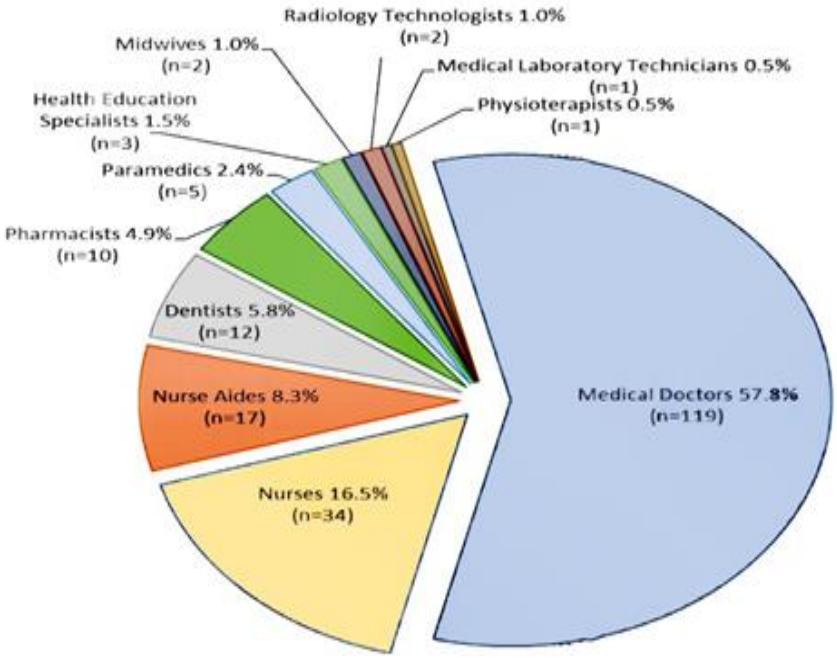

Fig 2:- Statistical report on HCW died in Nation of Italy during COVID 19 pandemic

In order to protect the health care workers from infecting, PPE act as the barrier between infectious particles such as bacterial and viral contaminations passing through the skin, mouth, nose, or eyes (mucous membranes) [15]. The barriers have the capability to block transmission of contaminants from blood, body fluid, or respiratory secretion and prevent the doctors and other frontline healthcare personnel being affected by these deadly diseases.

III. DESIGNING AND ENGINEERING EFFECTIVE PPE

The methodology used for design and development of PPE generally incorporates three phases which are associated with the product life cycle of PPE are the analysis of user requirement; understanding the design; and user evaluation and standardization [1]. The four main key factors such as degree of production, comfort, regulation and cost, mainly influence the design and development of PPE.

The polyethylene film enhance the degree of protection required for the protective clothing, such as surgical gown, without substantial additional expense, but at a significant loss of comfort for the user. On the other hand, a high degree of protection and comfort can be achieved by using a breathable, impervious, nonwoven material with much higher cost [2]. Due to exist of different manufacturing technologies and materials in this generation we can change any of the design factor, and develop the product to achieve ultimately the requirements of the end-user. The effectiveness of design and developments of different components of personal protective equipment are explained briefly;

A. Effective Design and materials used for an isolated Coverall/ Gowns

Coverall/gowns are usually designed to prevent the torso of healthcare workers from exposure to the pandemic virus. Coveralls which typically provide all-round protection over 360-degree of the human body. They were designed in such a way to cover the whole body, from head to feet, but sometimes the design of these medical or isolation gowns may failed to provide a continuous whole-body protection as they may have possible openings in the backside or coverage only upto mid-calf only [5]. So that it is necessary to use appropriate protective clothing with proper fastness provided to wear, elastic fittings in waist and ankle and ample crotch which provide complete close fittings and create a barrier to eliminate the droplet transmitted that are capable to spread the disease, thus protecting healthcare workers working nearby (within 1 meter) [25].

The nonwoven material are used to construct the disposable isolation gowns which are discarded after a single use. They are also made with the combination of material that offers high protection to liquid barrier, such as plastic films [4]. The technologies used to produce the nonwoven fabric which includes thermal bonding, chemical bonding, or mechanical bonding to provide better integrity and strength. The various forms of synthetic fibers are used as the basic raw material for manufacturing of disposable isolation gowns. Polypropylene (PP) spun-bond fabric, Spun bond melt-blown fabric and spun lace fabric are mostly used in manufacturing of disposable drapes, gowns and covers [3]. The weight of the fabric for gowns ranges 35-50 GSM fabric, for Caps it range from 12-25 GSM, for masks it is in the range of 25-40 GSM and for spun-bond fabric the weight of the fabric is typically 25-40 GSM is used. By using particular fibre types, bonding process and fabric finishes either by chemical or physical treatments, the desired properties of the fabric used can be achieved. Reusable (multi-use) gowns can be tumble washed after each use. These reusable coverall/ gowns are usually made of 100% cotton, 100% polyester, or polyester/cotton blend fabrics. The fabrics structure used are mostly woven plain weave structure with lighter weight fabric, which are chemically finished and pressed through rollers to create the liquid barrier properties to the fabric. The durability of the reusable garments generally can be for 50 or more washing and drying cycles. Surgical Gown features like blood-resistant, water-resistant, alcohol-resistant, liquid filter abilities, and anti-static, breathable. This high-quality surgical gown which is sterilized provides reliable and selective blood or any other liquid. Cotton cuff gives doctors comfort during operation [9].

A study has been done to determine if the laboratory gown for healthcare workers maintained infectivity on the surface of PPE, where they deposited the influenza virus over the surface of the coverall for three samples and left for 1h,8h and 24h, and hemagglutination (HA) and 50% tissue culture infective dose ($TCID_{50}$)/mL were measured. The result shows that the HA titer of this influenza virus did not decrease in any of the material tested even after 24h. This indicates that the PPE used by the healthcare workers in case of exposure to secretion and droplets containing viruses spread by patients can prevent cross infection [8].

Fig 3:- Design of PPE Coverall

B. Effective Design for developing PPE Masks

Respiratory viruses that affect mainly the upper and lower respiratory tracts of human beings, so that protecting the airway transmission of droplets and aerosols is important prevents human infection. Contamination of mucous membranes of mouth and nose present in the infective droplets or through a contaminated hand also allows the virus to enter the host [15]. Hence the airborne and droplet precautions using masks are most essential for healthcare workers while treating the patient. Generally two types of masks were recommended for healthcare personnel working in hospital or community settings, liable to their work environment are N-95 Respirator mask and Triple layer medical mask, where N-95 respirator mask are only preferable for the frontline healthcare works who are treating the patients very closely [12].

An N95 mask or N95 respirator is a particulate filtering respirator that is standardized by the National Institute for Occupational Safety and Health (NIOSH), means that it filters at least 95% of airborne particles. The N95 respirator mask is a flat folded, convex-shaped mask with elastic head-loops made up of polyamide/spandex to secure the mask firmly to the user. A flexible aluminium strip is fixed to the mask above the nose part to seal tightly around the nose and the face. N-95 respirator mask is a 4 layer mask consist of an outer layer of spun-bond polypropylene nonwoven material, second layer of cellulose or polyester, third layer of melt-blown polypropylene which act as a filtering material and an innermost (fourth) layer of spun-bound polypropylene nonwoven material [18].

Also, in N-95 mask a hydrophilic plastic substance is coated to the active outer layer whereas, copper and zinc are coated in the second inner layer. These two layers make the influenza virus to get inactivate using different mechanisms of action which creates a negatively charged particle so that when the particle tries to attack it creates a negative charge and destroy it which is the mechanism behind N95 respirators [18].

A study has been made to evaluate the value of the surgical mask used by the frontline workers were three lower-level studies has reported that a surgical mask can protect the workers from the occupational acquisition of respiratory infections when combined with the hand hygiene [10]. In another study concluded that the surgical mask for the visitors controls the concurrent infections in the workplace [11].

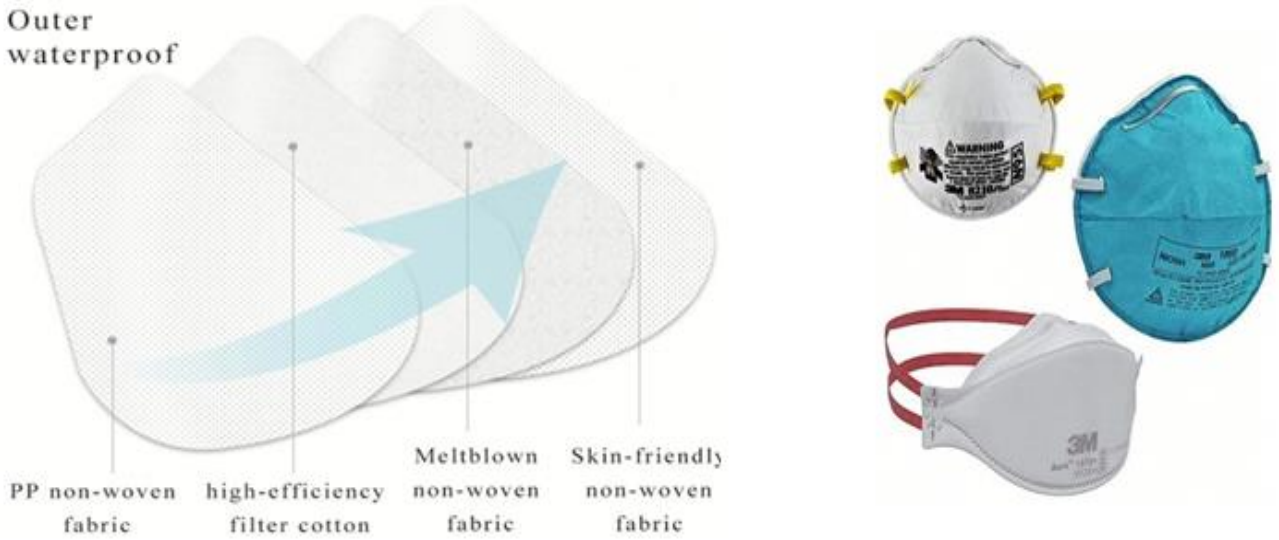

Fig 4:- Layers of N95 mask and different designs of N95 mask

C. Effective Design and material for PPE Gloves

The medical gloves used by health care workers helps to protect them from cross infections while they are treating the patients. Mostly medical gloves are made from copolymers and rubber material which are latex, nitrile, polyvinyl chloride and neoprene. They may be non-powdered, or powdered with corn starch to lubricate the gloves, and making it easier to put on hands. A study has been made to compare the efficiency of prevention of these types of gloves. On a total of 200 gloves tested, it is evaluated that latex and nitrile gloves provides good barrier characteristics whereas vinyl exhibited higher in use leakage rates associated with a decrease in durability [17].

Moreover, the guidelines provided by the healthcare sectors mentioned that they prefers nitrile gloves over latex gloves because they resist chemicals which includes certain disinfectants agents like chlorine. Also, latex has high rate of allergies and cause contact allergies dermatitis among healthcare workers. However, in unavailability of nitrile gloves latex gloves can be used. Also, non-powdered gloves are mostly preferred to powdered gloves while treating the virus affected patients [5].

Fig 5:- Different types of gloves used

It is most important to change gloves after treating each patient and must use proper hand hygiene procedures after removal so that it helps the healthcare workers to minimize the risk of virus transmission [19].

D. Effective design and materials used for Shoe cover and headcover

Impermeable fabric which are used for making coverall is the suitable material for making shoe covers which facilitate better protection and decontamination. Moreover, these shoe covers are disposable one time use and made of polypropylene or polyethylene fibres with an elastic attached to fit to secure the shoe cover above the ankle level [5]. A statement has been made that shoe covers are not an important part of PPE and no evidence has been found to describe the effectiveness of shoe covers. A study has been made in which a positive swab for SARS-CoV-2 was obtained from shoe cover which determines a risk of splashing from infected persons so that more research is needed on shoe cover as an important component of PPE [20].

Coveralls usually cover the head, but wearing a separate headcover is used for high prevention. Headcover makes covering from head to neck that can provide a complete coverage of their hair to fit inside the headcover while providing clinical care to the patients [6]. These headcovers are disposable one made up of polypropylene fibres using spun-bond technique

E. Effective design and material used for Goggles and face shield

In medical professions, the threat of random airborne fluids and particles is frequently present. For this reason, proper eye and faceguard is important. Many doctors, nurses and hygienists choose lightweight safety eyewear with wraparound anti-fog lenses [24].The lenses or windows are made from various materials such as polycarbonate, acetate, polyethylene terephthalate glycol (PETG)and polyvinyl chloride [23].

The goggles used should have zero power with transparent glasses, must be well-fitted and should cover all sides with an elastic band or adjustable holder [22]. They must be easily fit with all face lines without any pressure with the flexible frame.

The face shield is usually made of clear plastic which gives good visibility to both the doctors and the patient. Face shield provides barriers to expelled aerosols of body fluids which are commonly used as the alternative for goggles or sometimes worn above the goggles which provides high protection to the face [24]. They are secured with an adjustable band to support firmly over the head and fit closely against the forehead to make complete cover to the side and length of the face. [21]. A report has been made that about 96% and 92% risk is reduced by using the face shield while treating the patient immediately after they cough [24].

Fig 6:- Front and side view of the Face shield

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Components of PPE	Characteristics	Design and fit	Figure	Quality standards
Gloves	● Non-sterile ● Powder free	● Outer gloves preferably should reach the mid-forearm and should be minimum 280 mm of total length		● EU standard directive 93/42/EEC Class I, EN 455. ● ASTM D6319-10 ● ANSI/SEA 105-2011
Coverall	● Resistant to blood and body fluid ● Single use ● Light colours are preferable to better detect possible contamination	● Thumb/finger loops to anchor sleeves in place ● Adjustable neck closures with tape foe close fitting.		● Meets or exceeds ISO 16603 class 3 exposure pressure, or equivalent
Goggles	● With zero power, transparent glasses, well-fitting and should covered from all sides with elastic band/ or adjustable holder. ● Must have good seal and good fitting with the face ● Fog and scratch resistance	● Flexible frame to easily fit all face contours without too much pressure ● Adjustable band provided to firmly secure so as not to become loose during clinical activity		● EU standard directive 86/686/EEC,EN 166/2002 ● ANSI/SEA Z87.1-2010
N-95 Mask	● Shape that will not easily collapse ● High filtration efficiency ● Good breathability, with an expiratory valve	● Elastic head-loops to firmly secure the mask to face, and a flexible aluminium strip positioned above the nose for a close-fitting seal around the nose and face		● NIOSH N95, EN149 FFP2, or equivalent ● ASTM F1862, ISO 22609, or equivalent
Shoe Covers	● Made up of same fabric as of Coverall	● Must cover the entire shoe and should reach above the ankle level		
Face shield	● Made up of clear plastic material which provides good visibility to the user. ● Fog resistant ● May be re-usable or disposable	● Completely covers the sides and length of the face ● Adjustable band to support firmly around the head and fit snuggly against the forehead		● EU standard directive 86/686/EEC, EN 166/2002 ● ANSI/SEA Z87.1-2010

Table 1:- Components, characteristics, design and quality standard of PPE

IV. CONCLUSION

The Personal Protective Equipment used by the healthcare personnel during a pandemic influenza, must be highly capable to protect them without infecting from virus transmission and should create a confidence in them that they are safely working with PPE. Thus in this paper, the components used for protecting the healthcare workers during pandemic influenza has been discussed in detail that how they are designed and the material used for PPE. However, more effective and wearable PPE products may arise in future with the help of evolving technology so that more designs and development of the product to highly safeguard the healthcare workers will exist.

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