What is the Ideal Personal Protective Equipment for the Orthopedic Surgeon during COVID-19?

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ABSTRACT
Coronavirus disease-2019 (COVID-19) pandemic has created many challenges. The suddenness of this mandate and the concomitant spread of the disease have left orthopedic surgeons with notable anxiety and confusion. As the orthopedic practice is now resuming, there is yet no clarity on the guidelines on the personal protective equipment (PPE) that is needed for orthopedic surgeons, and the guidelines coming from multiple sources has been difficult to assimilate. In this article, we seek to provide a summary of available PPE, the latest recommendations for various clinical areas (outpatient, inpatient and operating room), and the procedure for donning and doffing the PPE.

Keywords: COVID-19, Full face mask, Half face mask, Health care workers, Orthopaedics, Personal protective equipment.

INTRODUCTION
The novel Coronavirus disease-2019 (COVID-19) can be transmitted even when the disease progresses asymptomatically in some patients and hence carries a high risk for the society and healthcare providers (HCP). The main source of infection is infected people. The virus is transmitted through droplets and close contact. Infectivity appears to start 2–5 days before the onset of symptoms, and it significantly decreases 7 days later. The infectivity period depends on the severity and the stage of infection in the patient. The virus survives on nonliving surfaces at 22–25°C and 40–50% relative humidity for up to 5 days, and these characteristics make the virus more infective. The virus can remain alive and can be detected in the aerosol for up to 3 hours after aerosol-generating procedures.

Healthcare workers carry the risk of getting infected three times more than the general population. In many countries, different strategies are planned to optimally protect healthcare workers. All healthcare workers should practice social distancing, avoid unnecessary contact, perform hand hygiene, and should wear three ply mask, gloves, gown, and goggles/face shield. However, the recommendations have varied in different countries and over time as the disease is being understood. There is as yet no clear consensus on the recommendations for personal protective equipment (PPE) for the healthcare workers (HCW) of orthopedics and traumatology. Adorning a full PPE kit is often times not possible, as it can be uncomfortable and unnecessary and can reduce the efficiency of the HCW. On the other hand, adequate protection is essential to protect self and for the prevention of spread of infection. In this report, we summarize the various PPEs that are available, their indications, and the latest recommendations.

CURRENT EVIDENCE ON COVID-19 TRANSMISSION
The common transmission routes of novel coronavirus are direct transmission (cough, sneeze, and droplet inhalation transmission) and contact transmission (contact with oral, nasal, and eye mucous membranes). Oflate, there are also concerns of airborne transmission.

Conflict of interest: None


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Concept and Definition of PPE
The PPE stands for personal protective equipment. This equipment is used to protect healthcare workers and prevent the spread of germs to others. The equipment is personal because it is used individually and not shared with others. Most of them need to be disposed off after single use. They are protective, as they act as a barrier between the body and the germs. Gloves, gowns, and masks are the most common pieces of equipment used. Other important ones include goggles, respirators, face shields, and head and shoe coverings. The ideal combination depends on a lot of factors, including the clinical environment, status of disease spread in the
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Components of Personal Protective Equipment

Gloves

Gloves provide protection from contaminated surfaces and dormant infectious materials. Two layers of gloves are worn while putting on PPE. Wearing double gloves provides an extra layer of safety during direct patient care and especially while removing the PPE. Using different colors of gloves for each layer helps to rapidly identify any breaches in glove integrity. Hence, it is better to have two different colors for both the layers. Cuffs of second pair of gloves should be long to cover the sleeves of the gown.

Gloves are made up of three different materials: latex, vinyl, and nitrile. Latex gloves, made from natural rubber, are preferred during surgeries, as they are comfortable, flexible, durable, and provides high-tactile sensitivity. However, they are inferior to nitrile gloves in terms of puncture resistance. Vinyl gloves, made from polyvinyl chloride, are cheap, soft, and comfortable. However, they are less durable and less resistant to puncture. Vinyl gloves are most commonly used for examination purposes. Nitrile gloves are made from a synthetic copolymer derived from natural rubber. And are protein- and latex free. They have the highest chemical and puncture resistance while also being expensive and least tactile sensitive due to their thickness. These are ideal alternatives for surgeons who are latex sensitive (Fig. 2).

Masks

The terminologies “masks” and “respirators” are sometimes loosely used. The most commonly used device is the mask or the surgical mask that helps to protect the nose and mouth from splashes, droplets, and spit. In contrast, a respirator or mask respirator is designed to seal tight to the face of the wearer and filter the air before it is inhaled to protect from exposure to biological aerosols, including viruses and bacteria.

Different Types of Masks and Respirators

Surgical mask: It covers mouth and nose, provides physical barrier, and blocks liquid droplets, splatter, and splashes. Mostly surgical masks are three-ply. The typical disposable surgical mask is composed of three basic parts: The outer and inner layers are made up of non-woven fabrics, and the middle layer is made from microfiber glass or melt-blown polymer that acts as a filter. It reduces person-to-person transfer of respiratory droplets and large particles and also blocks blood, sprays, splashes, and splatters from reaching the surgeons mouth and nose. Surgical mask filters particles ≥5 μm.

As per FDA recommendation, surgical mask should have four qualities: fluid resistance, differential pressure, filter effectiveness, and combustible. There are two types of filter efficiency (1) particulate filtration efficiency (PFE) and (2) bacterial filtration efficiency (BFE). Both filter efficiencies are measured as per FDA guidelines. PFE is tested by 0.1 mm non-neutralized aerosol with velocity between 0.5 and 0.25 cm/s (approximately 8 to 380 L/minute for a 9-cm radius mask), and BFE test is done by a non-neutralized 360.3 mm Staphylococcus aureus aerosol at a flow rate of 28.3 L/minute.

There are 2 types of surgical masks: Type I surgical mask is mostly used for patients to control the spread of infection, and the bacterial filtration efficiency is lower than Type II or Type IIR mask. It does not protect from splashes. Type II or type IIR where R stands for “resistant” mask is mainly indicated for HCW in procedural settings (Fig. 3).
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**Fig. 3:** Three-plier surgical masks

**Fig. 4:** N95 mask respirator

*N95 mask respirator:* It is a respiratory protective device designed to achieve a close facial fit and efficient filtration of airborne particles. A fit testing is required for the device to be fully effective. It prevents inhalation of 95% of 0.3-μm particles, thereby reducing person-to-person transfer of respiratory droplets. It also provides protection from blood, splashes, splatter and body fluids.

The N95 surgical respirator is a convex-shaped mask and has polyamide/spandex elastic head loops to secure the mask to the face. To provide a tighter seal around the nose and face, a pliable aluminum strip is placed above the nose. It has four layers: an outer spun-bond polypropylene layer, a second cellulose/polyester layer, a third melt-blown polypropylene filter layer, and an inner layer of spun-bound polypropylene. Apart from providing barrier, the two outermost layers of N95 mask also deactivates the virus. The outermost layer is laminated with a hydrophilic plastic and citric acid which inactivate virus by lowering pH, while the second layer carries copper and zinc ions which helps in inactivating virus by ionic disruption.

Disadvantages of N95 mask are breathing resistance, heat and moisture build up, and facial hair/beard may make the fit improper.

Application technique for masks/respirators: Wash your hands thoroughly before donning the respirator. Hold the respirator in your dominant hand in a way that convex/outside of the respirator fits in your palm with a pliable aluminum nose stripe upside and let the head loops fall behind your hand. Grasp the respirator under your chin with the nosepiece up. The top strap goes over and lies at the back of your head and above the ears, while the bottom strap lies below the ears, do not crisscross straps. Afterward, mold the metal strips with your fingertips according to the shape of your nose area. The fit of respirator on face should be air tight to check for the leakage of air place your both the hands over the respirator and exhale; if air leaks from the edges and the respirator is not properly fit, readjust the straps and nose piece till a proper seal is achieved.

Take off technique for masks/respirators: The front of the respirator should not be touched, as it may be contaminated. Remove the bottom strap first followed by the top strap, without touching the respirator. Discard in a waste container and wash hands (Fig. 4).

**FFP2 mask respirator:** This device protects the wearer from inhalation of droplets, aerosol, and fine particles in suspension in the air when in contact with patient. It filters >94% of aerosols, and total inward leakage is <8. HCWs should wear it while performing invasive medical procedures that may generate aerosols. N95 and FFP2 are approximately equivalent apart from their certified authority. N95 is NIOSH certified, while FFP2 is tested in accordance with EN149:2001, European authority.

**FFP3 mask respirator:** FFP3 respirator is superior to FFP2 and N95 mask. FFP3 filters >99% of aerosols and total inward leakage <2%. N100 and P3 rated respirators are approximately equivalent, with FFP3 trailing narrowly behind. The closest European equivalent to N99 is FFP3.

**KN95 mask respirator:** The closest Chinese equivalent to N95 mask is KN95. These two masks are nearly equivalent based on their features. KN95 also prevents inhalation of 95% of 0.3-μm particles and reduces person-to-person transfer of respiratory droplets.

**PAPR mask respirator:** It is a powered air purifying respirator that provides positive airflow through a filter, cartridge, or canister into a face piece. It has a similar filtration as P100, i.e., it filters at least 99.97% of particles 0.3 μm in diameter. It also provides head and neck protection, and because of full hood, it does not require fit testing and permitted to use with facial hair. The PAPR is superior in terms respiratory protection than N95 mask, and it also eliminates all the disadvantages of N95. However, there are certain disadvantages of PAPR masks, such as difficulties in communication due to its bulk and noise, the inability to use a stethoscope, and the obligation for batteries to ensure proper airflow into the hood. Used filters are contaminated with infectious material and therefore pose a potential risk.

**Valve mask respirator:** It is designed for industrial workers for protection against dust or asbestos and not viruses. It filters inhaled air only, but does not filter exhaled air. The valve makes breathing more comfortable and mask less hot and humid for the wearer. As the mask is more comfortable, people prefer it over other masks; however, the air exhaled through the valve is like a jet and travels faster and farther, and chances of infection increases to others. Hence, it is not advisable to wear valve mask not only for an orthopedic surgeon but also for the common people.
Half-face and full-face mask respirators: These respirators cover the mouth and nose with or without the face and eyes as the name suggests. Both types have filters, pre-filters, and cartridges that help in purifying the air. A full-face respirator has better sealing characteristics and covers the eyes and face in addition to the mouth and nose and hence provides a higher level of protection than a half-face respirator. Similar to the previously discussed respirators, the type of filter depends on the need based on the exposure and risks. In addition to protecting from direct exposure, gases, vapors, and particles are filtered by the prefilters, filters, and cartridges on the outside of the mask. A built-in valve allows easy exhalation (Fig. 5).

Other Face and Eye Protection Devices

The goggles, face shield, and shoe covers provide protection from splatters and direct contact.

Face Shield

A face shield protects the facial area and related mucous membranes: eyes, nose, lips. It offers advantages as well as some disadvantages: glare, fogging, optically imperfect, bulkier, improper fit over some respirators. Face shield consists of three components: visor, frame, and suspension system.

Visors are made from acetate, polyvinyl chloride, polycarbonate, propionate, and polyethylene terephthalate glycol (PETG). Visors are available in three different types: disposable, reusable, and replaceable. Acetate offers the best clarity, PETG is most economical, and polycarbonate is most commonly used. They are accessible in different extents: half-face piece, full-face piece, and face/neck length. CDC recommendation for breadth of visors is stretched to the ear, as this will trim down the probability that a splash could reach the eyes. There is at present no universal criterion for face/eye safety from biological hazards; however, masks with eye protection devices, for instance goggles or glasses with chin-length face shields, should be worn during aerosol-generating procedures.

Application technique: Wear a face shield over the N95 respirator and surgical hood to protect the face including ear. Lean forward, hold on the face shield with both hands, and expand the elastic with your thumbs and place the elastic behind your head so that the foam rest on your forehead. Once the face shield is put on make sure no areas are left uncovered (Fig. 6).

Gowns

Next to gloves, gowns are the most commonly used part of PPE. It protects the user from the contamination of clothing with potentially infectious material. Isolation gowns help protect HCWs exposed body areas from blood, bodily fluids, secretions, and excretions. Various such gowns are currently available in the market with varying resistance to blood and other bodily fluids depending on the type of the material, its impermeability, and wear and tear.

Natural fibers (e.g., cotton, wool, silk, etc.) in general have the character of high absorbance, and hence it absorbs the liquid more rapidly and consequently, and microorganisms can be trapped within the fiber structure. While synthetic fibers, polypropylene, polyester, and polyethylene, are hygroscopic, the basic raw materials for disposable isolation gowns are synthetic fibers. There are three different fabric construction types: knit, woven, and nonwoven, and these fabrics have different barrier properties. The nonwoven fabrics reduce liquid absorption by decreasing the capillary formation and offer a filtering media. The nonwoven fabrics are better compared to other two techniques. The most commonly used nonwoven fabrics for isolation gowns are spunbond and spunbond/meltblown/spunbond technologies.

The most susceptible part to strike through (the extent of liquid penetration through the fabric) are the cuff, forearm, thigh, chest, and abdomen. Leakage often occurs in the gown–glove interface. Based on this, there are three types of gown present in the market: (1) Elastic around the wrist, (2) cotton blend knit cuffs, and (3) thumb loops. Similarly, based on neck closure, there are three types of isolation gowns present in the market: tie, tape tab, and hook and loop neck closures. Gowns with hook and loop neck closures are easily adjustability, while tape tab neck closures reduce the time for donning and doffing.

Shoe and Head Covers

Shoe and head covers provide a barrier against possible exposure within a contaminated environment.
PPE Recommendations: When to Wear What

The understanding of COVID-19 with respect to the mode of transmission and the infectivity risks keeps evolving. However, the present guidelines based on currently available evidence is presented below:

**Outpatient Department**

Considering the fact that majority of COVID-19 patients are asymptomatic and its highly infectious nature, to contain disease spread, it is imperative for Out Patient Department to follow standard protocol. De Caro has proposed a multilevel gated approach for both the patient population and the orthopedic team for safety. Lal and team in their study mentioned that doctor and all staff in OPD should wear triple-layer medical mask and examination gloves. Similarly, WHO recommended HCWs to perform hand hygiene and wear medical mask, gloves, gown, and face shield/goggle if indulged in examining patient with COVID-19 symptoms; however if HCVs are providing care to patients without COVID-19 symptoms, they should wear PPE as per standard precaution and risk assessment. No aerosol-generating procedure should be performed in OPD.

**Inpatient Department**

There is an uncertainty regarding the optimal PPE for different tasks in our daily work. There is general opinion that all healthcare workers should wear regular surgical masks and gloves for all patient interactions. However, WHO has provided various specific guidelines depending upon different IPD situations—if the HCW is providing direct care to COVID-19 patients, in the absence of aerosol-generating procedures, he/she should wear a surgical mask, gown, gloves and face shield/goggle; if aerosol-generating procedures are being performed, HCWs should wear an N95 or FFP2 respirator, gown, gloves, eye protection, and apron.

**Minor/Major Procedure**

It has been established that COVID-19 virus transmits via droplets, but the virus is also found in the blood and other bodily fluids. Jewett evaluated that power tools such as bone drills, bone saw, and electrocautery leads to aerosol generation with particle <5 μm. Hence, orthopedic procedures should be defined as aerosol-generating procedures. Wong also highlighted that aerosol might be generated during use of high-speed power tools, and in this COVID-19 circumstances, every person present during surgery should wear PPE and try to minimize the use of power tools. Hirschmann recommended that orthopedic surgeons should wear PPE consisting of surgical gown, face shield or goggles, double gloves, and FFP2-3/N95-99 respirator mask.

**Doning of PPE**

First of all, remove all personal belongings, such as pens, cell phones, jewelry, watches, etc. Afterward, wear scrub suit and rubber boots or cover the shoes with shoe covers. Once scrub is put on move to the isolation unit and put on PPE with the help of a colleague, start the procedure with washing hand and then put on PPE in the following manner: gloves, disposable gown, face mask/respirator, face shield/goggles, head and neck covering, afterward a waterproof apron is worn over it and to finish put on second pair of gloves over the cuff.

**Doffing of PPE**

On every occasion, try to remove PPE with the help of an assistant. As doffing PPE has more chances of contamination, it should be done very vigilantly. To start with, perform hand hygiene on gloved hands and remove apron with the help of assistant. Try to avoid the front part of apron, as it might be contaminated with splashes, splatter, and bodily fluids. Untie the back and rip it off at the neck and roll down without touching the front area. Afterward, take off outer pair of gloves and dispose of them safely. Remove head and neck covering and then remove the gown by untying the knot first, then pulling from back to front rolling it from inside to outside and dispose of it safely. Remove eye protection by pulling the string from behind the head and dispose of it safely and in the same manner remove the mask as well dispose of it safely. Remove rubber boots without touching them. Finally, remove gloves.
carefully with appropriate technique and dispose of them safely and perform hand hygiene.

**Limitations of PPE**

Based on the facts wearing PPE protects from exposure to pathogens, but it has certain limitations:

- Restricts mobility and view
- Causes heat stress
- Impacts on concentration and listening
- Increase in error rates due to fatigue
- Increase in body temperature as well as the fluid loss.

**Conclusion**

COVID-19 infections have entered community spread in many countries, and the infections are going to worsen before they get better. However, emergency and semi-emergency procedures and limited outpatient and essential inpatient care have to continue. Sufficient knowledge of the characteristics of the infection and methods both to protect self and to prevent spread to other HCWs. Sufficient knowledge of the characteristics of the infection and methods both to protect self and to prevent spread to other HCWs. There is no “one-size-fits-all” PPE, and it is essential to know the various PPE that are available and the guidelines for their usage.

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