# ANESTHESIA IN THE OPERATING ROOM DURING THE COVID-19 PANDEMIC

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## Abstract

The novel coronavirus, SARS-CoV-2, was first isolated in Wuhan, China in December 2019, after clusters pneumonia of unknown etiology surfaced. The infectious disease caused by this virus, known as COVID-19, overwhelmed healthcare systems worldwide; often causing shortages of personal protective equipment (PPE), ventilators, and intensive care unit beds. This pandemic prompted radical healthcare system modifications, affecting all hospital activities and in particular operating room (OR) activities where transmission between patients and healthcare providers happens easily. Multiple policies and protocols on the administrative, engineering and PPE levels need to be implemented to mitigate the effects of the virus. Firm infection control strategies need to be established including proper PPE donning and doffing, organized movement of staff and patients into and out of the operating theatre, and adequate OR ventilation and engineering systems to combat the virus spread. Protocolization of different anesthetic techniques is necessary, aiming at unifying the best available evidence and creating a common ground for anesthesiologists to provide safe care, under the umbrella of effective interdisciplinary communication between the anesthesia, surgical and nursing teams. Finally, a plan for emergency surgeries that takes into consideration the acuity of the condition, and the level of COVID-19 suspicion guides the segregation of patients in order to maintain a smooth, effective and safe OR workflow.

**Keywords:** COVID-19, Anesthesia, Anesthetic techniques, Operating room.

## Introduction

On January 30, 2020, the world health organization (WHO) declared a public health emergency of international concern in response to the widespread human-to-human transmission of a novel coronavirus causing a severe acute respiratory syndrome: the disease now called coronavirus infectious disease 2019 (COVID-19).[1]

On December 31st 2019, multiple cases of a pneumonia of unknown origin were reported in the Chinese city of Wuhan, a major transportation hub. The number of cases quickly rose, surpassing the number of SARS and MERS cases within only one month. The disease spread beyond the Chinese border and was declared a pandemic by WHO on March 11, 2020. The alarming number of cases forced governments to take unprecedented measures, such as closing borders, grounding planes, withholding international trade, closing businesses and canceling conferences. With the absence of any effective treatment or preventative vaccine, multiple approaches were adopted to deal with the virus by governments and public health experts, generally advocating self-isolation, quarantine, social distancing, aggressive testing and contact tracing to protect the most vulnerable.

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The burden of the disease overwhelmed healthcare systems everywhere, with worldwide reports of shortages in personal protective equipment (PPE), intensive care unit (ICU) beds, and ventilators.

Little was known about the virus at that time, yet its shattering burden prompted multiple organizational modifications to be instituted immediately: physicians from multiple specialties were mobilized to COVID-19 wards, elective surgeries were cancelled, and multiple hospital strategies on the administrative, engineering, and medical levels were adopted to create a safe environment in keeping with the most recent updates about the virulence and mode of transmission of the novel coronavirus. A case series of 138 patients in Wuhan showed an infection rate of 29% among medical staff.[2] More than 3,000 of the 44,672 cases reported to have been infected with the virus as of February 11 were hospital staff or other health care workers.[3]

From performing aerosol-generating procedures (AGPs) like intubations in ICUs, to providing surgical anesthesia for coronavirus infected patients in the operating room (OR), anesthesiologists are most definitely on the frontline in this global fight against the virus. Many US and international societies have issued recommendations for perioperative care based on expert opinions, case series, what is known about the novel coronavirus and what can be extrapolated from the 2003 SARS outbreak. In this document, we will be reviewing the most recent strategies adopted in ORs by anesthesiologists worldwide when dealing with COVID-19 patients. These guidelines and recommendations are constantly being updated as new information about the virus comes to light.

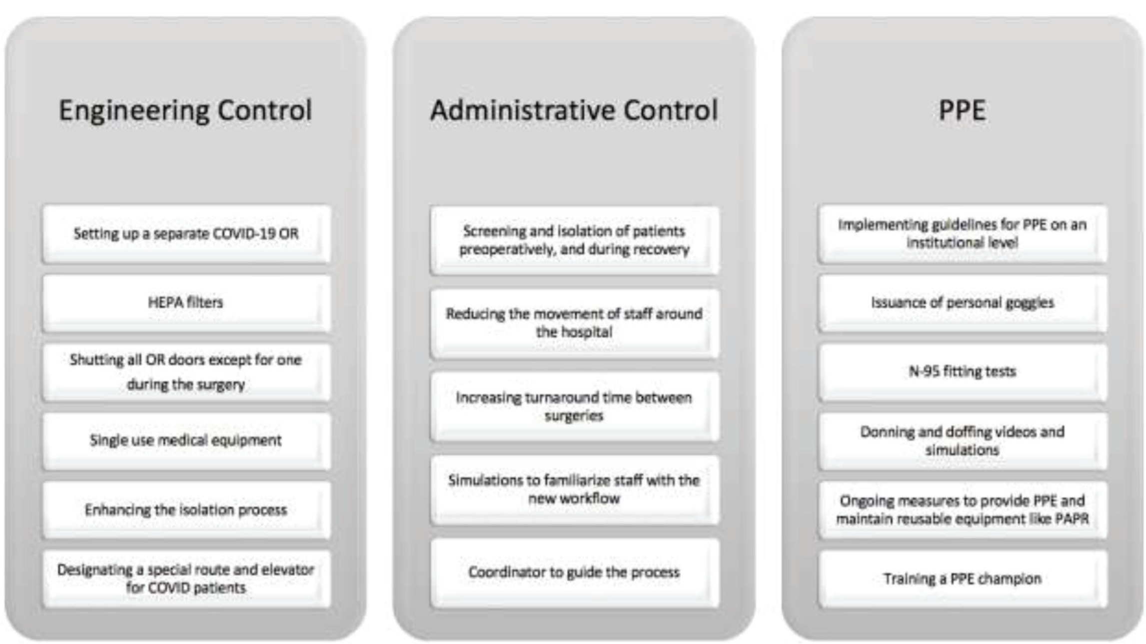
We start by describing the general institutional hierarchy of control when faced with disease outbreaks, epidemics, and pandemics with specific references to the OR setting during the COVID-19 outbreak. We will then detail the different infection control measures that should be adopted in the ORs, from proper PPE donning and doffing, to perioperative patient care, OR and equipment decontamination processes, and the choice of anesthetic technique. We will finally target the appropriate precautions to be taken when dealing with emergency cases requiring immediate surgical intervention.

## Hierarchy of control

To control the exposure of healthcare workers to a new disease, multiples measures should be

*Fig. 1*

*Summary of the measures implemented on the engineering, administrative and PPE levels in the anesthesia department of a large tertiary hospital in Singapore to enhance infection prevention during the COVID-19 pandemic.*



implemented in the hospital setting, and specifically in the OR setting. They are usually, from the most to the least effective:

1- Elimination of the hazard.

2- Substitution of the hazard.

3- Engineering control.

4- Administrative control

5- Personal protective equipment (PPE).

The *elimination of the hazard* is usually considered the most effective. It aims to eliminate the exposure to the virus by enforcing strict stay-at-home orders and working remotely.

The *substitution of the hazard* means replacing the hazard with a non-dangerous alternative. This level of control has not been achieved yet in the COVID-19 pandemic. It is usually attained once an effective vaccine is tested and made available.

The other three measures are the most effective once the virus starts spreading in the community and is beyond the containment phase. These measures should be updated regularly as the disease spread evolves from solely imported cases to local community spread.

Effective *engineering control* measures include:

- Replacing door handles with automated doors, or hygienic hands-free foot operated doors.

- Using physical barriers like ropes to reinforce the safe distancing concept, plexiglass screens to limit droplet spread.

- Creating special routes and setting up private elevators for COVID-19 patient transport.

- Setting up a separate COVID-19 OR with its own negative pressure ventilation system.

- The use of high-efficiency particulate air (HEPA) filters and sealing all OR doors except for one to limit environmental and personnel exposure.

*Administrative control* measures include:

- Adequate screening and isolation of COVID-19 positive patients.

- Postponement of elective surgeries.

- Increasing turnaround time between surgeries to enhance the decontamination process.

- Simulation sessions to familiarize staff with the new workflow as well as the donning and doffing process, and minimizing exposure of patients and personnel not involved with COVID-19 patients.

- Social distancing measures.

- Employee symptom checks.

- Dividing healthcare staff into groups to limit work-related exposure.

- Specific cleaning and disinfection procedures in the ORs.

- The distribution of educational pamphlets and brochures.

- Reinforcing the importance of interprofessional communication and high levels of coordination between the different healthcare teams e.g. a collaboration in the OR between the anesthesia, surgical, nursing and housekeeping teams ensures the safety of all personnel. The responsibility and scope of practice of each member should be well known to all team members. The whole process should be facilitated by an Operating Room coordinator.

*Personal protective equipment* measures include:

- Implementing clear guidelines for PPE use on an institutional level.

- Distributing personal goggles.

- N95 mask fit testing.

- Using donning and doffing PPE guides, videos and simulations under the supervision of a PPE champion.[4] In case of difficulty in obtaining a steady supply of PPE the use of powered air-purifying respirators (PAPRs) should be considered.

## Infection control for anesthesia

### Hand-hygiene

Hand-mediated transmission is believed to be the major contributing factor to the spread of infection among healthcare workers. Appropriate hand hygiene should be performed before any task, and in between the multiple steps of PPE donning and doffing.[5] It is recommended to use alcohol-based hand gel or foam, and to leverage proximity of the alcohol rub to the provider by placing the alcohol-based hand rub on the IV-pole to the left of the provider in the OR setting.[6]

## Personal protective equipment (PPE)
### Face masks

*Regular loose-fitting surgical masks* are effective in preventing droplet-transmission, by blocking large droplets from spreading to the immediate environment.

*Respirators with air-filtering abilities*: they are classified based on oil resistance (letter NRP), and the percentage of air particles that can be filtered according to the US National Institute for Occupational Safety and Health (NIOSH) classification e.g. N95: Not oil resistant, 95% of air particles are filtered. Respirators are effective in preventing airborne transmission of viruses, and it is recommended to use an N-95 level respirator or higher especially when performing AGPs.[5] These masks are single use and require fit testing to ensure optimal protection.

*Powered air-purifying respirators (PAPR)*: these respirators actively filter hazards from ambient air and deliver clean air to the user's face. They have a higher protective factor compared with N95 masks and are less likely to be dislodged during resuscitation scenarios if the patient is agitated. They eliminate N95 fit concerns and provide full facial and head coverage. However, they may be more complicated to remove and sterilize, increasing the risk of contamination, are more expensive and may pose communication challenges between staff due to fan noise.[3] (Figure 2).

Guidelines for extended use and reuse of N95 masks have been introduced given the severe PPE shortages that have happened worldwide. Studies have shown that most healthcare personnel can tolerate wearing N95 respirators for up to eight to 12 hours defined as extended use.[7] Re-use refers to the practice of using the same N95 respirator for multiple encounters but removing it between encounters. Extended use is usually recommended over re-use by the WHO, NIOSH, and FDA.[8]

Appropriate technique for wearing a facemask includes the following:

- Performing hand hygiene before putting on the mask.

- Covering the nose and mouth, and performing a seal check if wearing a respirator.

- Avoiding touching the front of the mask once it is on.

- Removing it from behind without touching the front and discarding it immediately, then performing hand hygiene.[5]

### Gloves

All anesthesia providers should wear gloves when taking care of the patient. They are encouraged to use double gloves when handling the airway of the patient, or being in contact with any other body fluid. Once the AGP procedure is done the outer set of glove should be discarded immediately, and hand hygiene performed.[5] Double gloving has been shown to reduce transmission in a simulated environment.[9] Longer sleeved gloves are preferred to prevent exposure of the wrists.[3]

*Fig. 2*
*Pros and cons of PAPR compared with N95*

| Pros of PAPR | Cons of PAPR |
|---|---|
| Higher protection than N95 | Challenges in communication |
| No fit testing required | More expensive than N95 |
| More comfortable than N95 | Higher risk of contamination during donning and doffing |
| Less likely to be dislodged | Risk of battery failure |
| Can be used with facial hair | Decontamination required after use |

## Coverall Suits

Coverall suits protect the wearer from liquid (droplets) and solid material. All perioperative providers should wear an impermeable coverall suit during their care for COVID-19 patients. The coverall suit is made of a polyethylene-coated fabric that is durable, resistant to tear and abrasion and has a zipper that provides complete closure. Surgical isolation gowns can be worn on top of the coverall suit to protect it and save it for multiple uses.[5]

## Goggles or Face shields

They are used to protect the eyes from splashes. Face shields should have side shields as well to provide protection from side exposure.[3] The advantage of face shields is that they can protect the respirator from contamination as well. In the absence of a face shield, a surgical facemask worn on top of the respirator can protect it from contamination during extended use. Overall, goggles and face shields are not as important as N95 masks and coverall suits against airborne transmission.[5]

## Shoe covers

Shoe covers are not considered a mandatory part of a biosafety level III protective equipment because they may increase the risk of self-contamination during donning and doffing. However, it is recommended to wear impermeable shoes that can be cleaned and disinfected.[3]

## PPE for care of patients while performing AGPs

Airborne precautions prevent the transmission of agents that remain suspended in the air e.g. COVID-19, Varicella, tuberculosis, *etc*. This requires the provider to wear biosafety level III equipment: an N95 or higher-level respirator, a coverall suit, goggles or face shield and double gloves.[10] Airborne precautions should be instituted when performing high risk AGPs such as intubations and deep tracheal aspirations.[3] Some institutions advocate wearing double surgical masks, double isolation gowns, and a third pair of gloves when performing intubations and discarding them immediately after the AGP. However, such recommendations remain institution-specific, and are not a part of the general guidelines issued by leading medical organizations.[11]

The correct sequence of PPE donning and doffing varies depending on the scientific society. It is important to have one clear unified institutional protocol that all healthcare providers should follow in order to avoid confusion and contamination mistakes (Figure 3).

*Fig. 3*
*Example of a PPE donning sequence*[5]

| PPE Donning |
|---|
| Head cap |
| N95 mask |
| Surgical mask |
| Coverall suit |
| Gloves |
| Disposable isolation gown |
| Goggles |
| Shoe Cover |
| Full head hood |

Correct donning and doffing of PPE are key to avoiding self- contamination. Donning usually starts with the N95 mask and doffing ends with the correct removal of the N95, "mask on first, mask off last" approach. The majority of self-contamination occurs during doffing of PPE.[12] During doffing, the gown is removed by pulling away from the neck, shoulders and body, and gloves are removed at the same time as the gown or using the glove-in-glove technique, making sure that the skin does not touch the contaminated

*Fig. 4*
*An example of a PPE doffing sequence. Hand hygiene is performed between each and every step of the doffing process (courtesy of the Department of Anesthesiology at the American University of Beirut (AUBMC)).*


surface.[13] The doffing process should be supervised ideally by a PPE champion, to reduce the chance of contamination (Figure 4). A shower is recommended after removal of personal protective equipment.[14] Visual aids and mirrors should be posted in the donning and doffing areas to guide the healthcare worker during the processes. According to a survey by Amrita *et al.*, formal training in correct PPE donning and doffing is uncommon, particularly among physicians, which may greatly jeopardize medical staff safety in the face of disease outbreaks.[15]

## PPE for care of patients undergoing low risk procedures

Initially, the Center for Disease Control (CDC) recommended that optimally, airborne precautions should be adopted when caring for a suspected or confirmed COVID-19 patient, irrespective of the type of procedure (figure 5).[5] However, given the worldwide shortage of N95 respirators, the recommendations were modified to include wearing regular surgical masks instead of respirators if the patient isn't coughing and if the procedure is not aerosol-generating, e.g. during

*Fig. 5*
*Risk stratification of procedures during the COVID-19 pandemic*

| Lower risk interventions | Higher risk interventions |
|---|---|
| Placement of an oral airway | High-flow nasal canula |
| Placement of an oxygen mask with filter | CPAP/BiPAP |
| Defibrillation/ cardioversion | Endotracheal intubation |
| Obtaining IV access | Bronchoscopy |
| Administration of IV drugs | GI endoscopy |
| Peripheral nerve blocks | Laparoscopic surgery |
| Neuraxial anesthesia | Thoracoscopic surgery/ Thoracotomy |
| Monitored anesthesia care/sedation | Tracheostomy |

*Fig. 6*
*Risk of transmission of SARS-coV1 to healthcare workers when exposed and not exposed to AGP during the 2003 SARS outbreak (reproduced from Tran et al)[16].*

| AGP | Odds ratio |
|---|---|
| Tracheal intubation | 6.6 |
| Tracheostomy | 4.2 |
| Suction before intubation | 3.5 |
| Non-invasive ventilation | 3.1 |
| Manual ventilation before intubation | 2.8 |
| Chest compressions/ defibrillation | 2.5 |
| Bronchoscopy | 1.9 |

preoperative assessment, loco-regional and neuraxial anesthesia. Obviously, the patient himself should be wearing a surgical face mask at all times once suspected to be COVID-19 positive. Tran *et al,* compared the risk of transmission of SARS-CoV-1, during the 2003 SARS outbreak, between exposed and non-exposed healthcare workers to different AGPs, using odds ratio, and found that tracheal intubation constitutes the riskiest procedure when compared to non-invasive ventilation, suction, and tracheostomy (Figure 6).[16]

The CDC in the United States and similar organizations worldwide establish sets of biocontainment precautions required to ensure the safety of personnel dealing with pathogens, ranging from routine to level III biosafety precautions. Routine precautions, usually followed in the clinics or on regular wards, include hand hygiene, wearing scrubs, and a surgical face mask with or without gloves. Level I protection, usually adopted in fever and infectious diseases clinics, include wearing an isolation gown and mandatory gloves, in addition to routine precautions. Level II biosafety precautions are usually followed when having noncontact encounters with confirmed or suspected COVID-19 patients. They include wearing a respirator instead of a surgical face mask, with or without eye protection, in addition to protective clothing (coverall suit). It is important to note however, that the decision to wear a surgical face mask instead of a respirator, and a coverall suit instead of disposable isolation gowns, varies at this level according to the policy of the institution and depends on the availability of resources and the probability of aerosolization of the virus. Level III biosafety precautions, mandate wearing eye protection, a respirator, and protective clothing (coverall suit) in addition to all of the previously mentioned protective equipment. At this level, healthcare workers should be prepared to deal with high-risk AGPs (Figure 7).

## Patient transport

The patient, wearing a surgical mask, should be transported from the isolation unit along a special route with minimal contact with others, bypassing holding areas and induction rooms. The patient should be reviewed, induced and recovered in the operating room itself. Consent and charting are done electronically with touchscreen devices to facilitate decontamination.[17] For transporting an intubated patient, HEPA filters should be applied to the patient side of the Y-piece, and between the expiratory limb and the transport ventilator. If a transport ventilator is not available, a filter is applied between the tube and the self-inflating (Ambu) bag, with the reminder that placing such a filter might increase the dead-space and further compromise ventilation in young children.[16] The transporting staff should wear biosafety level III equipment. A surgical mask can be worn instead of a respirator if there is a shortage of N95 masks. In case the patient requires supplemental oxygen during

*Fig. 7*
*Scaled protection for healthcare workers amid the COVID-19 epidemic (Tongi hospital in Wuhan, reproduced from Meng et al. with modifications)*[14].

| Scale | Routine | Level I | Level II | Level III |
|---|---|---|---|---|
| Setting | Clinics, floors | Fever clinics | Noncontact care for suspected or confirmed COVID-19 | Direct contact with patients with suspected or confirmed COVID-19 |
| Surgical mask | + | + | - | - |
| Respirator | - | - | + | + |
| Eye protection | - | - | +/- | + |
| Hand Hygiene | + | + | + | + |
| Gloves | +/- | + | + | + |
| Scrubs | + | + | + | + |
| Isolation gown | - | + | x | _ |
| Protective clothing | - | + | x | + |
| Head cover | - | - | - | + |
| Shoe cover | - | - | + | + |

+ mandatory; - not needed; +/- decision made according to work scenario; x choice between isolation gown and protective clothing is decided based on local resources.

transport, then a surgical mask can be worn on top of the nasal prongs.[3]

## Preoperative preparation

The in-room anesthesia care team should communicate with the transferring team and infectious diseases committee, and inform them that the COVID-19 patient is to be transferred to the OR.

Only select equipment and drugs should be brought into the OR, and single use equipment should be used whenever possible. The remainder of the drugs and resuscitation equipment should be kept inside the anesthesia trolley, in the preparation room if available or the anteroom. A runner stationed outside the OR, usually in the preparation room or anteroom, and should be ready to bring in extra medications or equipment needed whenever requested to do so by the anesthesia team inside the OR. The runner should wear appropriate PPE that includes droplet and contact precautions (Biosafety level II) before entering the operating room, if no AGP is taking place.[18]

Staff should be aware that communication and

*Fig. 8*
*Operating room designated for COVID-19 equipped with a positive/negative ventilation switch option (Courtesy of AUBMC).*

*Fig. 9*
*Air changes/hour (ACH) and time required for airborne-contaminant removal by efficiency (reproduced from the CDC website)[19].*

| ACH (air change/hour) | Time (mins.) required for removal 99% efficiency | Time (mins.) required for removal 99.9% efficiency |
|---|---|---|
| 2 | 138 | 207 |
| 4 | 69 | 104 |
| 6 | 46 | 69 |
| 8 | 35 | 52 |
| 10 | 28 | 41 |
| 12 | 23 | 35 |
| 15 | 18 | 28 |
| 20 | 14 | 21 |
| 50 | 6 | 8 |

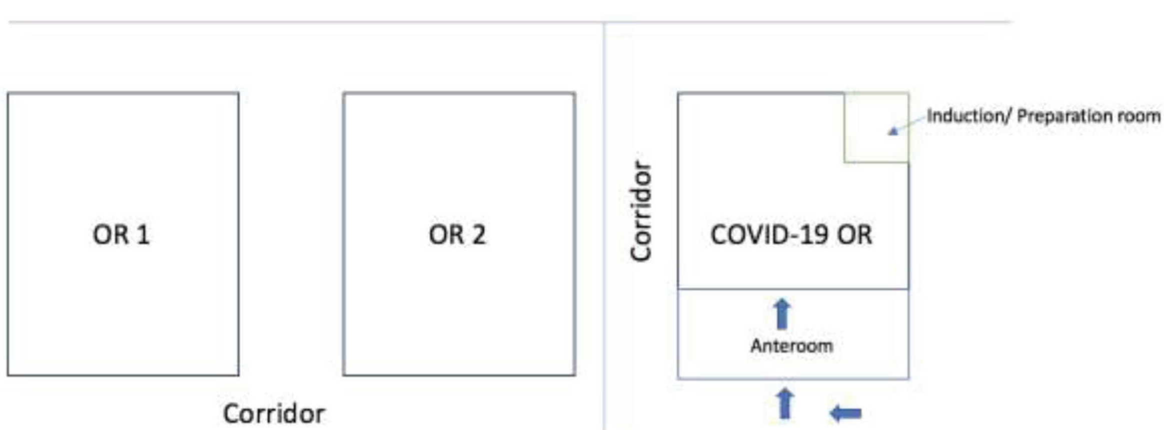
vision is more difficult with PPE. Only the personnel involved with direct patient care should be allowed inside the room. Due to the lack of familiarity of the staff with the workflow, an OR coordinator is assigned to each COVID-19 OR, and should direct the other team members.[17]

## Operating room

The dedicated COVID-19 OR and the anteroom should be equipped with a negative pressure system. If negative pressure is not available, then positive pressure system and air conditioning should be turned off (Figure 8). Clear donning and doffing areas should be indicated.[17] The location of these areas change according to the policy of each institution. In general, PPE donning and doffing take place in the anteroom.

Air change per hour (ACH) is often used to guide the turnover time between surgeries, and indicates the movement of a volume of air in a given period of time e.g. 1 ACH indicates that the air in the room

*Fig. 10*
*A sample schematic of an OR designed for COVID-19 patients. The COVID-19 OR has its own separate ventilation system. The anteroom as well as the OR are negatively pressured. Movement of the patient follows the arrows, from the corridor to the anteroom then to the OR. Donning and Doffing areas are clearly designated and are usually found in the anteroom. The induction room is where the anesthesia trolley is kept with all rescue devices and extra medication to be handed over to OR if requested. An OR runner should be stationed in the anteroom or induction room to facilitate transport of medications and specimens into and out of the OR.*



will be changed once every hour. The CDC publishes general guidelines linking the ACH number with the time required to efficiently remove 99%, and 99.9% of airborne pathogens (figure 9). Naturally, the ACH number is inversely proportional to the time required to remove airborne pathogens, and to the OR turnover time.[19] The COVID-19 dedicated OR should be isolated from the rest of the operating room complex. Appropriate laminar flow and HEPA filters should be in place. Ventilation systems between this dedicated COVID-19 OR and the rest of the OR complex should not be connected (figure 10).[16]

The same anesthesia machine and equipment should be used for all COVID-19 patients. A minimum of one hour is required to allow decontamination of the OR once the procedure is finished and the patient has left the premises. As an additional precaution, some sources recommend using a hydrogen peroxide vaporizer to decontaminate the OR.[18]

## Environmental cleaning

It is recommended to have a basket with zip closure plastic bags placed close to the anesthesiologist such as on the IV pole at the left of the anesthesia provider. The provider should place all contaminated instruments in the bag e.g. laryngoscope blade, suction catheters, *etc.* and should close the bag immediately afterwards. It is imported to designate and maintain clean and dirty areas in the OR to improve organization. After induction, all surfaces should be wiped down with specifically designated anti-viral products containing quaternary ammonium and alcohol.[6] The anesthesia work area, including the anesthesia machine, computers, ancillary equipment, and monitoring equipment should be considered high-touch dirty areas and should be thoroughly wiped as well between cases.[20]

## Anesthesia machine and equipment

Anesthesia machines are known to be pathogen reservoirs and can contribute to healthcare associated infections primarily because of their design that makes them difficult to clean frequently.[21] Regardless, the anesthesia machine and equipment should be cleaned and disinfected promptly or should be covered with a clean transparent disposable plastic film to be discarded at the end of the procedure. A HEPA filter should be applied between the expiratory limb of the breathing circuit and the anesthesia machine. The carbon dioxide absorber should be replaced between cases. The machine's internal respiratory circuit should be dissembled and sterilized with high temperature if feasible, or with 12% hydrogen peroxide or ozone. The surface of the machine, laryngoscope handles, and other non-disposable equipment should be cleaned with 2 to 3% hydrogen peroxide then wiped with at least 70% alcohol, or chlorine disinfectant.

All equipment that touches the patient's mucosa should be single use and disposed of if possible including video laryngoscope blades.[5] All equipment that was not used but exposed to the OR air should be considered dirty and disposed of or sterilized before subsequent use.

Medical waste should be disposed of in properly sealed double-bags that are labeled COVID-19. These bags should be sprayed with chlorinated solution before taking it out of the OR.[5]

## Choice of anesthetic technique
## General anesthesia
## Adult patients

### *Induction*

Adequate preoxygenation, with 100% oxygen for 5 minutes, should be done via a tight-fitting face mask (use both hands to maintain the tight seal on the patient's face (figure 11)).[22]

Rapid sequence induction is the preferred induction method to avoid the need for bag-mask ventilation, and subsequent generation of aerosols. If positive pressure ventilation is unavoidable, such as in the case of a difficult airway or inadequate lung reserve, small tidal volumes should be used.

Deep anesthesia and full neuromuscular blockade (monitored by the train-of-four ratio) should be achieved before attempting intubation to minimize the risk of coughing and gagging. Judicious timing of opioid administration is required as well to avoid

*Fig. 11*
*Two-handed technique for preoxygenation and ventilation if needed (Courtesy of AUBMC)*

induced cough. The fresh gas flow should be paused during the intubation attempt. The most experienced provider should intubate, preferably using a video laryngoscope to increase the distance between the patient and the anesthesiologist. The cuff should be inflated right after intubation and prior to ventilation. It is important to minimize circuit disconnection and if this is unavoidable, then the gas flow should be paused, disconnection should be done beyond the HEPA filter on the patient side and the endotracheal tube should be clamped.[23] Asleep fiberoptic intubation can be used to further increase the distance between the provider and the patient, if the anesthesiologist is familiar with the technique.[5]

Repeated tracheal intubation attempts can potentially spread the virus, so in case of failure to intubate, a laryngeal mask airway (LMA) should be rapidly inserted, preferably second generation providing a better seal, until backup is called.[5] Fogging of goggles and overall decreased vision in another problem during induction that can render the intubation process difficult, and potentially hazardous. One possible solution is to apply antifogging agents to the inner part of the goggles.[11]

For muscle relaxation, rocuronium is preferred over suxamethonium because its effects are longer-lasting, with less risk of cough in case of a prolonged attempt (figure 12). The dose of rocuronium should be in the order of 1 to 2 mg/kg of body weight, usually around 1.2 mg/kg.[24]

In-line (closed airway) suctioning is preferred

*Fig. 12*
*Intubation checklist in the operating room (Reproduced with modification from Greenland et al)[25].*

Intubation checklist

- **Wear biosafety level III PPE**
- **Have the minimal number of staff in the OR**
- **Use disposable equipment when available**
- **Preoxygenate for 5 mins with 100% oxygen**
- **Use RSI to avoid bag-mask ventilation**
- **Use SGA device, or 2-person, 2-hand mask ventilation in case of difficult intubation**
- **Rocuronium in preferred in anticipation of a prolonged intubation**
- **Use video-laryngoscopy when available**
- **Inflate the cuff immediately after intubation**
- **Connect the circuit by placing a filter between the tube and the Y-piece and the expiratory limb and the machine**

over open-suctioning because it is associated with a decreased risk of aerosol generation.[16]

### *Maintenance of anesthesia*

It is recommended to wear full PPE throughout the surgery in case of inadvertent circuit disconnection or tube dislodgement. It is also recommended to keep a plastic physical barrier on top of the patient's head during the whole case.[26]

### *Emergence and tracheal extubation*

In-line tracheal suctioning should be used. The administration of antiemetic medications reduces the incidence of postoperative nausea and vomiting, and gagging that can cause viral spreading. Deep extubation techniques should be considered to reduce the incidence of bucking and coughing on the endotracheal tube. It is recommended to use remifentanil, dexmedetomidine, or intravenous xylocaine during the extubation process[27,28]. The WHO recommends the use of a physical barriers to reduce the risk of COVID-19 spread. One example of such barriers is the transparent plastic cover placed on top of the patient's face during extubation (figure 13). It is advised to pause fresh gas flow during the extubation process. After extubation, a surgical mask is immediately placed over the patient's nose and mouth, on top of the nasal prongs in the patient requires supplemental oxygen. Matava *et al.* performed a series of experiments using mannikins to trace the pattern of aerosolization and spread of droplets sprays and found that low cost physical barriers significantly limited such spread.[29] While a supraglottic airway (SGA) can be used as a bridging technique before emergence to reduce coughing, it is not the preferred method, because a difficulty to place a SGA can jeopardize patient safety.[30]

*Fig. 13*
*Example of a clear plastic cover used to limit aerosol generation during extubation in a simulation session (Courtesy of AUBMC).*

## Pediatric patient

The routine use of sedatives is recommended in all pediatric patients because it reduces agitation and crying, reduces the need for physical restraint and increases compliance if an IV is placed awake. In order to limit the number of people in the room, parental presence is not recommended throughout the induction process, and pharmacological anxiolysis is preferred. The Pediatric Difficult Intubation Collaborative (PeDI-C).[26] which includes 35 hospitals from six countries, generated consensus guidelines on airway management in pediatric anesthesia during the COVID-19 pandemic. Intravenous induction is preferred, unless the child becomes agitated, increasing the risk of droplet generation. Rapid sequence induction is recommended; it may, however, not be feasible without hypoxemia in children. These patients should receive positive pressure ventilation, with small tidal volumes, and a tight mask seal. If mask induction is required, the use of a transparent plastic barrier around the elbow of the facemask is recommended to reduce the spread of droplets, and OR contamination. A supraglottic device like a second-generation LMA is an acceptable alternative to an endotracheal tube in case of a difficult airway.

## Management of a difficult airway

The same principles for difficult airway management apply to patients with COVID-19. However the use of an awake fiberoptic technique is discouraged because it is highly aerosol-generating. Anesthesiologists should have a low threshold to use a second-generation LMA, in case of a difficult intubation. Mask ventilation is performed using the two-handed, two-person technique to ensure a tight seal. Mask ventilation can be deferred, in favor of the less aerosol-generating SGA (figure 14).[31]

## Recovery from general anesthesia

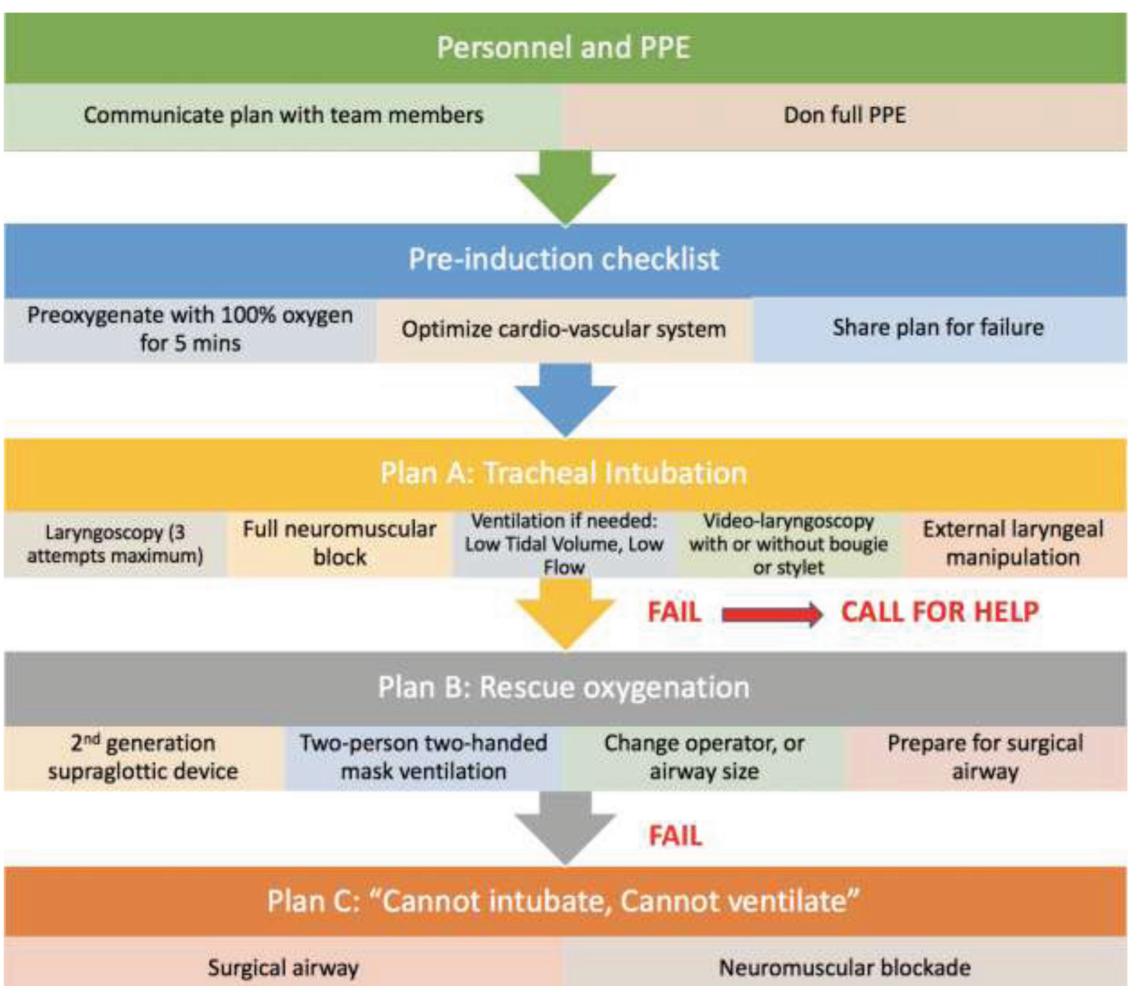
It is recommended that patients with COVID-19 recover in the COVID-19 OR itself, or be sent directly to the isolation room in the ICU, keeping in mind that patient transport out of the OR should follow the same precautions that were taken during patient transport into the OR.[5]

## Regional anesthesia

Avoiding general anesthesia (GA) is beneficial both for the patient and the anesthesia providers with lower post-operative complications for the patient, and a lower risk of aerosol generation. It is important to keep in mind that a rushed conversion to GA halfway through the surgery with suboptimal safety measures is the least desirable outcome. It is therefore important to assess the probability of such a conversion and to decide accordingly on the best anesthetic technique.[32]

Neuraxial anesthesia and peripheral nerve blocks are not considered aerosol-generating, therefore dealing with COVID-19 patients in these settings requires droplet and contact precautions only, which corresponds to a level II biosafety precaution (refer to Figure 8). Ideally, a respirator should provide the most protection in case of aerosolization e.g. patient coughing, but because of the global shortage of respirators, a surgical mask is preferred in these cases.[19]

*Fig. 14*
*Difficult airway algorithm, modified for COVID-19 patient[31]*



All patients should wear a surgical mask, and high-flow oxygen therapy should be avoided to reduce the risk of aerosolization.

The ultrasound machine should be wrapped in a clear disposable plastic bag, and only necessary items should be brought into the OR where the block is being performed.[32]

## Spinal anesthesia

According to the Society for Obstetric Anesthesia and Perinatology (SOAP), spinal anesthesia is not contraindicated for COVID-19 patients.[33]

An adequate dose of the local anesthetic should be given intrathecally to make sure that a conversion to GA is unlikely. It is advisable to rule out thrombocytopenia that can be associated with COVID-19 infection.[34] COVID-19 has been isolated from the CSF of patients with COVID-19 encephalitis, so the cerebrospinal fluid should not be left to drip freely.[35]

## Peripheral nerve block

It is important to avoid preprocedural sedation in order to decrease the chance of aerosolization with high-flow oxygen supplementation. When possible, it is recommended to aim for blocks that do not interfere with the respiratory function, therefore, axillary blocks are usually preferred over interscalene or supraclavicular blocks.

The American Society for Regional Anesthesia (ASRA) and the European Society for Regional Anesthesia (ESRA) recommend that all blocks should be performed under ultrasound guidance;[36] to avoid the chance of local anesthetic systemic toxicity.[37] It is advisable to choose blocks that do not require patient repositioning (Figure 15).

## I. Emergency surgery

The diagnosis of coronavirus depends on epidemiological data, history, symptoms, Reverse-Transcriptase Polymerase Chain Reaction (RT-PCR) and CT chest findings. In emergency cases, these diagnostic modalities might not be available in a timely manner. The indications for emergency surgery are similar for COVID-19 and non-COVID-19 patients. If COVID-19 infection cannot be totally ruled out, then the highest level of protection should be adopted.[38] Zhao *et al.* demonstrated in a retrospective, multicenter clinical study that cross-infection in the OR during

*Fig. 15*
*Regional Anesthesia for COVID-19 checklist*

| Regional Anesthesia Checklist |
|---|
| Wear appropriate PPE |
| Assess the chance of conversion to GA |
| Cover the patient's nose and mouth with a surgical mask |
| Avoid preprocedural sedation and high-flow oxygen |
| Bring only necessary equipment into the room |
| Cover the ultrasound with plastic bags |
| Use ultrasound for peripheral nerve blocks |
| Avoid patient repositioning |

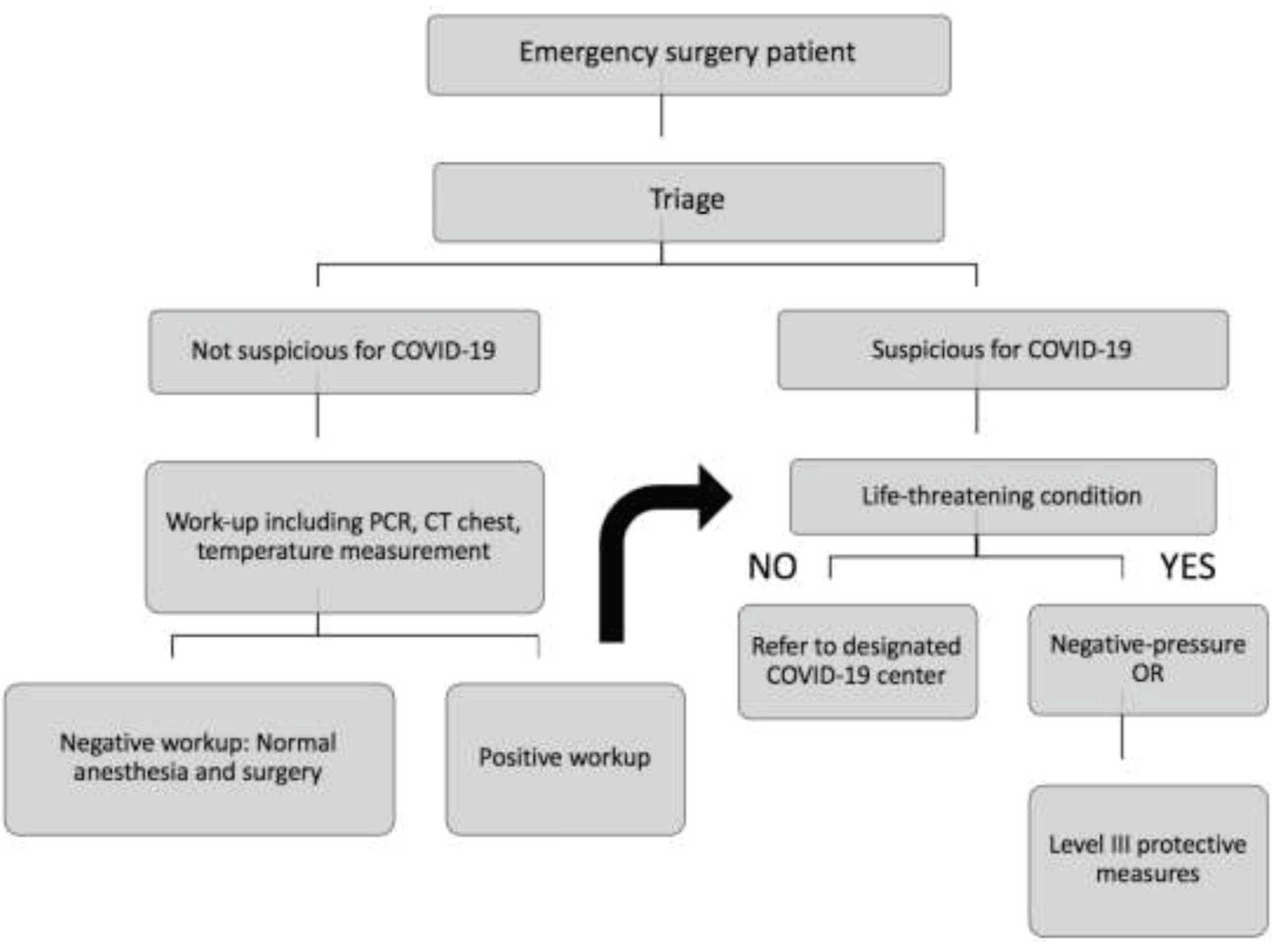
emergency procedures for patients with confirmed or suspected COVID-19 may be effectively prevented by following the COVID-19 anesthesia management protocols.[39]

## II. Conclusion

The COVID-19 pandemic has paralyzed healthcare systems worldwide, and pushed healthcare professionals to draw from their experience with the SARS and MERS infections to establish early guidelines and protocols. COVID-19 OR workflows have to follow strict infection control protocols to ensure the safety of patients and healthcare workers.[40,41] Institutional engineering and administrative measures, as well as PPE guidelines have to be established, and should be regularly updated as more light is shed on this new pandemic and its progression, taking into consideration the global shortage of essential PPE. An effective interdepartmental communication and cooperation strategy remains essential to provide a safe working environment, and to create some familiarity in the era of the "new normal", especially in a high acuity setting like the operating room.

*Fig. 16*

*Emergency surgery algorithm during the COVID-19 pandemic (Reproduced from Zhao et al. with modification)[39].*



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