Review

Infection Prevention Strategy in Operating Room during Coronavirus Disease 2019 (Covid-19) Outbreak

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Abstract A novel coronavirus that emerged in late 2019 rapidly spread around the world. Most severe cases need endotracheal intubation and mechanical ventilation, and some mild cases may need emergent surgery under general anesthesia. The novel coronavirus was reported to transmit via droplets, contact and natural aerosols from human to human. Therefore, high-risk aerosol-producing procedures such as endotracheal intubation and airway suction may put the healthcare providers at high risk of nosocomial infection. Based on recently published articles, this review provides detailed feasible recommendations for the primary anesthesiologists on infection prevention in operating room during COVID-19 disease outbreak.

Coronavirus disease 2019 (COVID-19), caused by a novel coronavirus (SARS-CoV-2), is a highly contagious disease. Despite rigorous global containment and quarantine efforts, the incidence of coronavirus disease 2019 (COVID-19) is continuously rising, with 5,058,300 laboratory-confirmed cases and 332,550 deaths worldwide as of May 22, 2020. [1] Most of the infected patients have mild symptoms, including fever, fatigue and cough. But in severe cases, symptoms can progress rapidly and develop to the acute respiratory distress syndrome (ARDS), septic shock, metabolic acidosis and coagulopathy. [2] SARS-CoV-2 can be transmitted from person to person through respiratory droplets, direct or indirect contact and viral-containing aerosols. [3] Incorrect infection prevention may warrant a super spreader, who can introduce SARS-CoV-2 infections into a high-volume healthcare facility, and cause serious nosocomial outbreak. Several recommendations on

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perioperative protection for health care workers (HCWs) have been issued, but detailed references for infection control strategy of environment and devices were very limited. Based on the existing experience from major designated hospital for COVID-19 and previous experiences from treating SARS, we provide recommendations on the perioperative infection precaution during SARS-CoV-2 pandemic. These recommendations include the appropriate use of personal protective equipment (PPE), preparation of the operating room, intraoperative management, cleaning and disinfection of anesthesia devices and environment. [4]

**PRINCIPLES OF PERIOPERATIVE INFECTION CONTROL DURING COVID-19 EPIDEMIC**

Common infection control practices include the use of PPE, hand hygiene, and respiratory hygiene/cough etiquette, etc. Since transmission of SARS-CoV-2 almost certainly occurs through multiple routes, including large droplets, direct and indirect contact and even viral-containing aerosols, advanced infection control practices should be applied in OR for COVID-19 related patients.[5] Recommended measures include: 1) hand hygiene, 2) use of PPE to avoid direct contact with the patient's blood, body fluids, secretions and incomplete skin, 3) avoid incidental needle stab or cutting injury, 4) proper disposal of medical waste, 5) equipment cleaning and disinfection, 6) environment disinfection. Recommended PPE for HCWs for different control level was shown in Table 1. PPE should be donned and doffed in a strict order according to one's specific institutional guidelines and under careful supervision of an infection control officer.

**OPERATING ROOM MANAGEMENT PRINCIPLES DURING THE EPIDEMIC**

During the SARS-CoV-2 outbreak, all elective surgeries for COVID-19-related patients should be postponed when possible. Patients with the exposure history of SARS-CoV-2 but without clinical symptoms need to receive a 14-day isolation and surveillance. The surgery can be carried out if COVID-19 could be excluded after the quarantine. When the suspected or confirmed COVID-19 patients are scheduled for emergency surgeries, they should be transferred to the designated hospital with standardized protective conditions, if possible. However, in some cases, the surgery might be urgent or the patient is not able to be transferred due to the severe illness, thus HCW in non-designated hospitals should also know how to implement strict three-level protection standard during the perioperative period.[6,7].

**PARTITION MANAGEMENT AND INFECTION PRECAUTION FOR OPERATING ROOM**

During the epidemic period, detailed administration rules and regulations on infection precaution should be established. Contaminated zones, buffer zones and clean zones should be clearly demarcated. Contaminated PPE must be removed at the designated area and deposed properly. Face shield, goggle, fluid-resistant gown, outer gloves, and outer shoe covers should be removed and left at the contaminated area. Protective coverall, inner gloves, and inner shoe covers should be removed and left in the buffer area. Hair cover and N95 respirator should be removed at the clean zone and sealed in a double-layer bag in a designated area. These pollutants should not be worn or taken into the clean public area. Otherwise, contamination of the public area could result in a major clustering outbreak, since anesthesia department is a relatively enclosed area with high staff volume. Hand hygiene should be emphasized and alcohol-based hand disinfectant should be easily accessed in different areas. The public areas, including the doctors' offices,
restaurants and toilets should be disinfected at least twice daily. The door handles, switches, telephones, and other frequently touched surfaces should also be disinfected regularly. Surfaces should be cleaned immediately when known to be contaminated with secretions, excretions or body fluids. The disinfection requirements and frequency for each area are presented in Table 2.

**Negative-pressure operating room for COVID-19 patients**

Anesthesia and surgery for confirmed/suspected COVID-19 patients should be performed in a negative-pressure operating room with an adjacent anteroom where HCWs could apply and remove PPE. If no permanent negative-pressure OR is available, an OR with a separate air-conditioning and humidification system should be chosen. If the OR also has separate atmospheric air inlets and exhaust systems, it can be changed into a negative-pressure operating room temporarily[8]. For a positive-pressure OR, the air-conditioning and humidification system should be shut down during the surgery. After the surgery, strict terminal disinfection should be implemented throughout the used OR and the adjacent ORs as well under the guidance of Hospital Infection Control Office.

If a negative-pressure OR is applied, negative room pressure should be tested before surgery. The room pressure should be maintained below -5Pa in the main operating room during the surgery. It is recommended to spray chlorine-containing disinfectant on the damper at the exhaust duct. During the operation, it is necessary to keep the OR closed and restrict the HCW pass through the door. After the operation, cleaning and terminal disinfection should be implemented to the environment and object surfaces of the OR. Then, the negative-pressure system should be run for another 30 minutes. After that, the exhaust duct and damper should be disinfected or replaced. It is suggested that the OR should be re-used only after careful detection by the Hospital Infection Control Office.

**Transportation of COVID-19 patients**

COVID-19 patients should be transferred directly to the negative-pressure operating room through an exclusive path and elevator by a physician wearing proper PPE. During the transportation, contact and respiratory precautions should be implemented. In addition, the transfer vehicle should be marked with a bold COVID-19 sign and parked in the designated isolation area, in case of being used by other patients without COVID-19 before proper disinfection. Patients undergoing general anesthesia should receive extubation and postoperative recovery within the negative pressure operating room, or be directly transferred to the isolation ward with tracheal intubation. Do not transfer the patients to the post-anesthesia care unit for tracheal extubation and postoperative recovery. For the patients who are not intubated during the operation and those who are extubated in the OR, disposable surgical mask or medical protective mask should be applied. After the operation, the patient should be covered with a one-off waterproof operation sheet, and be transferred directly to the isolation ward through an exclusive path and elevator by a physician wearing proper PPE. Before transfer, it is recommended to assign someone to disperse the transfer channel in advance. After the transfer and handover of the patient, the physician in charge of transportation should remove PPE at the designated area in the ward and properly disinfected before returning to the operating room.

**Cleaning and disinfection of anaesthetic equipment**

Remove the unnecessary devices out of operating room before surgery as far as possible. All
necessary devices, such as computer, keyboards, display and telephones, are protected with disposable plastic wrap. Adequate medications, fluids and equipment should be prepared before the surgery and placed in the operating room away from the operating area. Any remaining medications and fluids should be discarded. During the surgery, it is recommended to choose single-use consumables and discard them whenever possible, such as laryngoscope blades, threaded pipe, mask, rebreathing bag, breathing system filters (BSF), end-tidal carbon dioxide sampling tube, reservoir cup and suction tube. BSF with high efficiency particle filtration function are placed between the tracheal intubation and the respiratory circuit and at the machine end of the respiratory circuit. It has been proven that the use of BSF can prevent ventilation system of anesthesia machine against virus and bacteria contamination, and it is recommended to change the BSF every 3-4 hours.

The re-use equipment, object surfaces and environment in operating room should be sterilized after operation. Disinfection and sterilization methods are divided into high level disinfection (HLD) and middle level disinfection (MLD) according to the ability of killing microbe. HLD is defined as complete elimination of all kinds of microorganisms, including vegetative forms of bacteria, mycobacteria, fungi and fungal spores, viruses, bacterial spores (can inactivating a large part of bacterial spores). HLD can be achieved with some disinfectants with appropriate dose, concentration and effective time, such as glutaraldehyde, peracetic acid, hydrogen peroxide, chlorine solutions and bromine-containing disinfectant. MLD is defined as elimination and removal of many kinds microorganisms, including vegetative forms of bacteria, mycobacteria, viruses fungi and fungal spores, except for bacterial spores. MLD can be achieved by iodine disinfectants (Iodophor, Iodine tinctures and chlorhexidine-iodine), alcohol and chlorhexidine with enough effective time, enough dosage and concentration. However, it should be noted that chlorhexidine can't inactivating SARS-CoV-2.

The terminal disinfection of articles and equipment in the OR should follow the principle of first precleaning and then disinfecting. It is recommended that the user be responsible for disinfection after the surgery. The whole environment of OR and medical waste should be treated and disinfected by assistants wearing PPE. They should receive the training of SARS-CoV-2 infection prevention under the professional guidance and supervision.

1. Cleaning and disinfection of anaesthesia devices
All the anaesthesia devices in the operating room should be strictly disinfected according to the procedure of “Operating room management of special infections” when used on patients with suspected or confirmed COVID-19. And the principle of final disinfection should be strictly followed.

1) Protection and disinfection of anaesthesia machine: clean off the surface of anaesthesia machine and protect operation panel and surface with a disposable transparent cover. Disinfection machine can be used for disinfecting the internal respiratory pipeline. Both ozone or alcohol complex can achieve effective disinfection. However, it may be prudent to select the ozone disinfectant machine since it has certain corrosive effect on metal despite fulfilling the requirement of high-efficacy disinfection. If disinfection machine is unavailable, the traditional methods of soaking and rinsing with disinfectant could be used. The choice of disinfectant is depended on the characteristics of each component in the circuit. The high-temperature/pressure and ethylene oxide gas (EO) sterilization is commonly used. EO sterilization requires a prolonged (one week) aeration for EO evaporation from treated equipment to avoid EO associated harm to patients.

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2) The surfaces of monitor, computer, infusion pump and anesthesia machine only need middle/low-level disinfection. They should be protected with a disposable transparent cover before used. \(^{[11]}\) All equipment surfaces should be in contact with disinfectant, such as 500-1000 mg/L active chlorine, 500 mg/L chlorine dioxide, or 2000 mg/L peroxyacetic acid, for at least 30 min. \(^{[12]}\). When cleaning the place apparently contaminated with blood or body fluids, the surface should be wiped with higher concentration of disinfectant carefully. Electrothermometers need to be covered with film as soon as possible during the surgery and wiped with 75% alcohol after surgery, since they can’t tolerance the temperature more than 100°C.

3) It is recommended to choose disposable visual laryngoscope or single-use laryngoscope blades for endotracheal intubation when it possible. The laryngoscope handle and screen should be protected by disposable sheaths before using and then disinfected by any of the following four methods (alcohol 75%, chlorine-containing disinfectant, hydrogen peroxide or disinfectant machine).

4) Mainframe of ultrasound scanner should be covered with a disposable transparent film before using, and wiped with 3% hydrogen peroxide after the power is turned off. The probe should be covered with disposable sterile protective sheath, and wiped with disinfectant (3% hydrogen peroxide, 2% glutaraldehyde, 0.55% ortho-phthalaldehyde, 0.55% Clorox) after examination.

5) The infusion support, guard bar, bed board and wheels could be wiped with 2000 mg/L active chlorine. One wiping cloth is exclusively used for one device, and the contact time with chemical should be up to 30 min\(^{[13]}\). After 30min, those disinfected surfaces should be wiped with water. All disinfecting clothes and disposable goods should be thrown into double-layer medical waste bags after disinfection. Members of the department’s infection control commission should evaluate and record the effectiveness of disinfection for backtracking. Suggestions on disinfection of anesthetic devices are presented in Table 3.

2. Cleaning and disinfection of other medical devices

Medical apparatus and instruments should be soaked for 30-40min in 1000-2000 mg/L chlorine disinfectants before sent to central sterile supply department (CSSD). The instruments contaminated with blood or body fluids should be immersed in 5000-10000 mg/L disinfectant for 60min. All used instruments should be packed into double-packaging medical bags labeled with time, operating room and sign of “SARS-CoV-2 infection”.\(^{[14]}\) The labeled package bag should be hermetically sealed in a designated box and sent to CSSD separately. The CSSD should be notified by staff of OR before transportation, in order to prepare disinfection in advance according to the principle of "special infection” disinfection.

Disposal of medical waste

The medical waste created during the operation should be managed by designated personnel. It should be collected, sorted, recorded, transported to designated areas and disposed at fixed-site timely. The waste should be transported in double-sealed medical bags, and even the sharps container should be sealed in a medical garbage bag. Every bag and sharps container should be marked with a special label of "SARS-CoV-2 infection", along with the department, date and
category of the medical waste. All the bags with medical waste should be tighten and sealed before being taken out of the contaminated area. After that, the bag surface should be sprayed with 1000 mg/L chlorine-containing disinfectant, or covered into another bag from the outside, and then handed to professional staff.

**Operating room environment cleaning and disinfection**

After closing the laminar air-flow handling system and independent fresh air system, the air disinfection in the OR should be performed with 3000 mg/L peroxyacetic acid and 30000 mg/L hydrogen peroxide water-soluble aerosol spray. The dosage of disinfectant should be satisfied 20-40ml/m³, sprayed evenly from inside to outside, top to bottom, left to right, and remain the aerosol full of a confined space for 60min. Automated room disinfection also make effect, such as ultraviolet light for one hour. Ensure that nobody is exposed whether using the disinfectant spray or UV light. The smooth floor should be disinfected with 2000 mg/L peroxyacetic acid or 1000-2000 mg/L chlorine solutions. Air disinfection and surface cleaning cannot replace each other.

**Conflict of interest statement**

None.
Table 1. Standards of personal protective equipment (PPE) for medical workers at different levels of protection[16]

| Levels of protection | Applicable healthcare facilities | Applicable healthcare procedures | Working clothes | Disposable hair cover | Surgical masks | Latex gloves | Medical protective masks | Fluid-resistant gown | Protective overall | Goggles/Face shield | Disposable shoe covers | Positive pressure breathing headgears |
|----------------------|---------------------------------|---------------------------------|-----------------|-----------------------|---------------|-------------|--------------------------|---------------------|------------------|------------------|--------------------------|-------------------------------------|
| First level          | General clinics and ward         | General diagnosis and treatment | ✓               | ✓                     | ✓             | If need     |                          |                     |                  |                  |                          |                                     |
| Second level         | Fever clinics                    | Diagnosis and treatment         | ✓               | ✓                     | ✓             | ✓           | If need                  | ✓       | ✓    | ✓    | If need                  |                                     |
| Third level          | Isolation ward, fever clinic, isolation area, confirmed and suspected infection operating room | Perform sputum aspiration, lower respiratory tract sampling, endotracheal intubation and tracheotomy for patients; work that may cause the secretion of the patient’s respiratory tract and internal substance spillage; relevant laboratory work | ✓   | ✓                     | ✓             | ✓           | If need                  | ✓       | ✓    | ✓    | If need                  | Recommended                         |
### Table 2. Suggestions on disinfection methods of different areas

| Risk levels | Areas                                                                 | Cleaning and disinfection objectives | Methods | Frequency |
|-------------|-----------------------------------------------------------------------|--------------------------------------|---------|-----------|
| Low risk area | administrative department, library, conference room, medical record room, etc | object surface, ground, walls/ceilings, vents | wipe with clean water | once a day |
|             |                                                                      | low-frequency contact surfaces, medical devices surfaces, high-frequency contact surfaces | wipe with 75% alcohol or 0.5‰ chlorine-containing disinfectant | once a season |
| Medium risk area | general ward, outpatient department, functional examination rooms | low-frequency contact surfaces | wipe with 75% alcohol or 0.5‰ chlorine-containing disinfectant | ground twice a day, walls/ceilings once a month |
|             |                                                                      | medical devices surfaces | wipe or clean with alcohol-containing disinfectant wipes, and then wipe with 75% alcohol or 0.5‰ chlorine-containing disinfectant | after used; once or twice a week |
|             |                                                                      | high-frequency contact surfaces | clean with alcohol-containing disinfectant wipes, and then wipe with 75% alcohol or 0.5‰ chlorine-containing disinfectant | twice a day; bed rails, bed railings and bed |
| High risk area | emergency department, operating room, delivery room, NICU, ICU, catheterization room, hemodialysis center, CSSD, labs | low-frequency contact surfaces, ventilation system | wipe with 75% alcohol or 0.5‰ chlorine-containing disinfectant after cleaning | walls/ceilings once a week; air cleaning system once a week; air conditions once a month |
|             |                                                                      | medical devices surfaces | clean with alcohol-containing disinfectant wipes, and then wipe with 75% alcohol or 0.5‰ chlorine-containing disinfectant | after used; once or twice a week |
|             |                                                                      | high-frequency contact surfaces | three times a day | |
| Extremely high risk area | fever clinic, isolation ward, nucleic acid testing laboratory, elevators and stairs in these places | low-frequency contact surfaces | wipe with 1‰ chlorine-containing disinfectant after cleaning | ground four times a day; walls/ceilings twice a week |
|             |                                                                      | medical devices surfaces | clean with alcohol-containing disinfectant wipes, and then wipe with 75% alcohol or 1‰ chlorine-containing disinfectant | after used; twice a week |
|             |                                                                      | high-frequency contact surfaces | six times a day | |
|             |                                                                      | ventilation system | | |
Table 3. Suggestions on disinfection methods of anesthetic devices

| Devices                                    | Disinfection methods                                      | Remarks                                                                 |
|--------------------------------------------|-----------------------------------------------------------|-------------------------------------------------------------------------|
| internal respiratory circuit of anesthesia machine | compound alcohol disinfectant machine (recommendation). ozone disinfectant machine (caution) ethylene oxide or autoclave sterilization soak in chlorine-containing disinfectant (1:1000) for 30min | Ozone disinfectant machine has certain corrosive effect on metal; the devices should be left for one week to remove drug residue after ethylene oxide disinfection; both sterilization and immersion disinfection require the removal of the inner circuit. Select sterilization or immersion disinfectant according to the characteristics of each component. |
| surface of anesthesia machine, monitors, pumps and computers | wipe with 500-1000mg/L active chlorine, 500mg/L chlorine dioxide or 2000mg/L peroxycetic acid disinfectant | Protect with a disposable transparent cover before used. The surfaces should be in contact with disinfectant at last 30 min after used. |
| handles of video laryngoscopes             | wipe with 75% alcohol, 3% hydrogen peroxide solution or 500-1000mg/L active chlorine disinfectant. | Protect the handle and display screen with disposable protective sheath. |
| ultrasonic machines                         | mainframe: wipe with 3% hydrogen peroxide, 0.55% sodium hypochlorite, 2% glutaraldehyde, or 0.55% ortho-phthalaldehyde. probe | cover with a disposable film. Remove protective film and disinfect machine after use. use the disposable sterile protective sheath and sterile couplant on probe surface; wipe with disinfectant after use. |
| non-invasive blood pressure cuff            | wipe with 75% alcohol, 3% hydrogen peroxide solution, or chlorine-containing disinfectant. | Make sure that no disinfectant enters the valve when cleaning NBP cuffs and pressure pip. |
| SPO2 sensors                               | wipe with 75% alcohol                                      | /                                                                       |
| temperature probes                         | wipe with 75% ethanol                                      | Use protection covers. The temperature probe can not tolerate higher than 100℃ |

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