



Infection control management strategy for operating room during COVID-19 pandemic

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Abstract: Coronavirus disease 2019 (COVID-19) outbreaks have occurred in many countries around the world. The numbers of confirmed cases and deaths continue to increase. It is increasingly likely that COVID-19 patients will require emergency surgeries in the operating room (OR). As COVID-19 can easily be transmitted to healthcare workers and other patients during surgery, it is important to establish a set of infection prevent and control management strategy to prevent COVID-19 from spreading in the OR. Based on our experience in COVID-19 prevention and control in the OR, we introduce this COVID-19 prevention and control management strategy for preventing COVID-19 from spreading in the OR. This management strategy includes a number of COVID-19 prevention and control procedures including (I) conduct COVID-19 knowledge training at the early stage of outbreak, (II) formulate the surgery arrangement procedures and suspend the elective surgery if the patient confirmed to COVID-19, (III) divide an isolated OR area for COVID-19 surgery, (IV) preoperative preparation procedures, (V) procedures for wearing and removing personal protective equipment, (VI) anesthesia management, intraoperative management, (VII) post-operative disposable waste management and disinfection. This management strategy has worked very effectively since the outbreak of COVID-19 in Wuhan at the end of 2019. We have performed emergency surgeries on several COVID-19 confirmed patient and dozens of COVID-19 suspected patients under this COVID-19 prevention and control management strategy, and have achieved an excellent result of zero COVID-19 infection in the OR.

Keywords: Coronavirus disease 2019 (COVID-19); severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2); operating room; anesthesia; infection control

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Introduction

Coronavirus disease 2019 (COVID-19) has spread rapidly worldwide. Globally, as of 7:24 PM CEST, 23 June 2022, 539,893,858 confirmed cases of COVID-19, including 6,324,112 deaths, have been reported to the World Health Organization (1). The numbers of confirmed cases and deaths continue to increase. COVID-19 is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). This virus can easily spread from person to person through droplets and microparticles exhaled from an infected person (2,3). At present, the prevention and control of COVID-19 remains a formidable challenge for governments and health agencies around the world.

Given that the number of confirmed cases continues to increase dramatically, it is increasingly likely that COVID-19 patients will require emergency surgeries in the operating room (OR). Many factors during surgery may accelerate the spread of COVID-19, such as frequent contact with the patient in proximity, exposure to the patient's bodily fluids, multi-person participation in a confined space, indirect contact through anesthesia apparatus, and the viral aerosol produced by the operation. It is extremely difficult to prevent COVID-19 from spreading during surgery on a COVID-19 patient; thus, it is important to establish a set of strategy to prevent COVID-19 from spreading in the OR. A few recommendations for the prevention of COVID-19 during surgery have been issued (4); however, comprehensive and specific OR management strategies for the perioperative COVID-19 prevention process are limited.

The Fifth Affiliated Hospital of Sun Yat-Sen University is a designated hospital for COVID-19 patients in the urban cluster on the west bank of Pearl River in Guangdong Province, China. Since the outbreak of COVID-19 in Wuhan at the end of 2019, more than 200 confirmed and 300 suspected cases of COVID-19 have been admitted to our hospital. We have performed emergency surgery on 1 patient with acute calculous cholecystitis and choledocholithiasis who was confirmed to have COVID-19 (5), and dozens of emergency surgeries on patients who were suspected to have COVID-19. We have achieved the satisfactory result of zero COVID-19 infections in the OR.

Based on our COVID-19 prevention experience in the OR, we developed this perioperative infection control management strategy to prevent COVID-19 from spreading in the OR during the COVID-19 pandemic. This strategy included COVID-19 knowledge training, surgery arrangement procedures, OR area arrangements, preoperative preparation procedures, procedures for

wearing and removing personal protective equipment (PPE), anesthesia management, intraoperative management, and post-operative management. We hope this management strategy will help OR administrators around the world to develop some efficient infection prevention and control processes to prevent COVID-19 from spreading in the OR during the COVID-19 pandemic.

COVID-19 knowledge training

During the early stage of a COVID-19 outbreak, the number of elective surgeries in the OR should decrease due to government restrictions on traffic. This period should be taken full advantage of to conduct comprehensive COVID-19 knowledge training. Comprehensive COVID-19 knowledge training, including training on scientific prevention behaviors, should decrease the spread of COVID-19 (6,7). The training should involve all staff in the OR, including healthcare workers and non-healthcare workers, as all such staff may be exposed to the virus. Non-healthcare workers are at an increased risk of infection during a COVID-19 outbreak, as they have more exposure to the virus, but less medical knowledge to protect themselves. Given that SARS-CoV-2 can spread through respiratory droplets, the training should not be held in a crowded room. Remote online or video training should be provided. The director of the OR needs to monitor the training effect and re-train staff as necessary.

The COVID-19 training courses cover:

- (I) The etiological features, epidemiological characteristics, clinical manifestations, clinical classification, diagnostic criteria, and treatment of COVID-19;
- (II) Occupational health and safety for health workers during the COVID-19 epidemic;
- (III) Hand hygiene;
- (IV) Wearing and removing PPE;
- (V) Surgery arrangement procedures for patients' suspected or confirmed to have COVID-19;
- (VI) COVID-19 medical waste disposal procedures;
- (VII) A COVID-19 prevention and control policy issued by the government and hospitals.

Surgery arrangement process during the COVID-19 pandemic

In principle, elective surgery must be suspended if a patient has been confirmed to have or is suspected to have

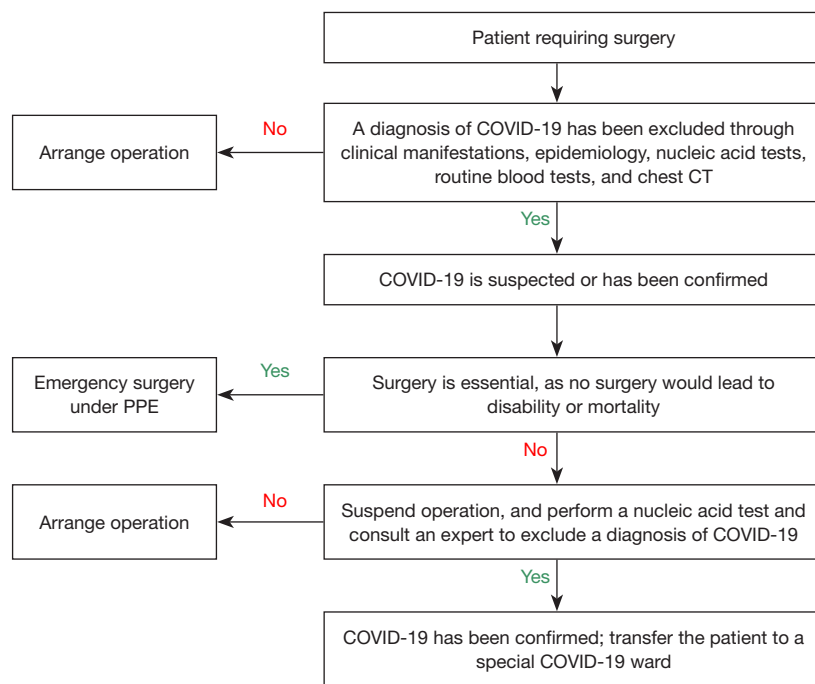


Figure 1 The surgery arrangement process during COVID-19 pandemic. COVID-19, Coronavirus disease 2019; CT, computed tomography; PPE, personal protective equipment.

COVID-19. Emergency surgeries should only be scheduled in situations in which not undergoing surgery would lead to disability or mortality. The surgery arrangement process during COVID-19 pandemic is shown in *Figure 1*. In making surgery arrangements during the COVID-19 pandemic, the following approaches should be adopted:

- (I) For all surgical patients, a diagnosis of COVID-19 should first be excluded based on clinical manifestations, epidemiology, nucleic acid tests, routine blood tests, and chest computed tomography (CT);
- (II) For patients suspected or confirmed to have COVID-19, elective surgeries should not be scheduled. Emergency surgeries should only be scheduled in situations in which not undergoing surgery would lead to disability or mortality;
- (III) For patients suspected to have COVID-19 who require emergency surgeries, the patients should be treated as if a diagnosis of COVID-19 has been confirmed, and a diagnosis of COVID-19 should only be excluded following expert consultation.

OR area arrangements for COVID-19 surgery

A negative-pressure operation room (NPOR) that can prevent contaminated air from flowing out of the OR is preferred for COVID-19 patients (8). The negative-pressure system should be turned on 30 minutes before the operation to maintain room pressure at -5 to -10 Pa. However, as most hospitals do not have a NPOR, an isolated normal pressure OR with an isolated air exchange system should be used for COVID-19 patients who are too critical to transfer. A non-isolated positive-pressure OR cannot be used for COVID-19 patients, as the positive pressure can blow the virus out of the OR and contaminate the surrounding areas. Some ORs can adjust the volume of air output and input, such that if the air output of a positive-pressure OR is increased and continuously greater than the air input, the positive-pressure OR can be temporarily converted into a negative-pressure OR in which the pressure may reach -5 Pa. The OR area for COVID-19 patients should be physically separated from other routine ORs with a specially designated hallway to enter and exit. A clean zone and a buffer zone should be set up outside the contaminated zone

Wearing PPE		Removing PPE	
Clean zone	Hand hygiene	Contaminated zone	Take off surgical gown and gloves
	Put on surgical mask		Hand hygiene
	Put on surgical cap	Half-contaminated zone	Take off goggles or face shield
	Put on inner surgical gloves		Take off PPE
	Put on PPE		Take off shoe covers
	Put on shoe covers		Take off inner surgical gloves
	Put on goggles or face shield		Hand hygiene
OR	Hand hygiene	Buffer zone	Take off surgical cap
	Put on surgical gown		Take off surgical mask
	Put on surgical gloves		Shower and leave

Figure 2 The recommended procedure for wearing and removing PPE. PPE, personal protective equipment; OR, operating room.

to provide an isolated space for wearing and removing PPE.

Preoperative preparation procedures

- (I) Sufficient PPE should be provided to all the healthcare workers and cleaners involved in the surgery. The minimum PPE for the OR includes a disposable surgery coat, surgery cap, surgery gloves, long-sleeved waterproof disposable coverall, N95 medical mask, face shield, and waterproof shoe covers (9).
- (II) Review the COVID-19 patient's physical condition preoperatively by reading the electronic medical records and avoid unnecessary contact with the patient outside the OR.
- (III) All surgical and anesthetic items (e.g., medical equipment, surgical instruments, medical consumables, and anesthetic) should be readied in the OR in advance. All the items prepared for surgery in the OR should be 1-way; that is, they should only enter and not leave the OR.
- (IV) The anesthetic machine must be checked and put on standby in advance.
- (V) Any unnecessary items and equipment should be removed from the OR to prevent virus infection.
- (VI) Areas that may come in direct or indirect contact with patients and are difficult to clean (e.g., surgery mattresses, computer monitors, mice, and keyboards) should be covered with a transparent waterproof plastic wrap.
- (VII) Patients should be transported between the isolation ward and the OR through a dedicated hallway with

the cooperation of healthcare workers and transport workers wearing PPE. Patients should wear an N95 medical mask and be covered with medical non-woven disposable items during the entire transportation.

Wearing and removing PPE

The proper use of PPE, which protects against contact, droplet, and airborne transmission can prevent healthcare workers from being exposed to the virus (10). An appropriate procedure for wearing and removing PPE can provide the highest level of protection, and thus strengthen occupational safety and prevent the virus from spreading between healthcare workers and COVID-19 patients (11). A PPE supervisor should be present to oversee the healthcare workers and ensure they are correctly wearing and removing the PPE to achieve reliable protection. The procedure recommended for wearing and removing PPE is detailed in *Figure 2*.

Anesthesia management

Both regional anesthesia and general anesthesia can be used in COVID-19 patients, but regional anesthesia techniques are preferable (12,13). Regional anesthesia techniques, including Intervertebral anesthesia and regional nerve block anesthesia, do not require intubation and extubation, which can produce viral aerosols. If general anesthesia is required for the surgery, it is important to avoid SARS-CoV-2 transmission during endotracheal intubation. Rapid sequence induction and intubation are recommended (14).

The most familiar endotracheal intubation tool should be chosen to perform the intubation, and a visual laryngoscope that can increase the operating distance between the anesthesiologist and the patient during intubation is a primary tool for COVID-19 patients. A fiber electronic bronchoscope may also increase the operating distance; however, it is not recommended for use by inexperienced anesthesiologists, as its use may increase the time of intubation and the risk of virus infection.

Before intubation, the handle and the display screen of the laryngoscope should be covered with a disposable transparent protective film to avoid contamination. Before induction, the patient should be pre-oxygenated and denitrogenated sufficiently. To prevent the spread of viral aerosols, 2 layers of wet gauze should be used to cover the patient's mouth and nose before performing the mask ventilation, as this method does not affect the ventilation and oxygenation. Once the patient's respiration disappears, oxygen should be administered by a mask in the mode of mechanical ventilation. The tidal volume should not be too large; 6–8 mL/kg is appropriate. The endotracheal intubation should be performed approximately 90 seconds after the induction of anesthesia. Adequate doses of opioids and muscle relaxants should be administered to avoid choking.

In total, 3 disposable heat and moisture exchange filters should be used (15,16); 1 between the endotracheal tube and the respiratory circuit, and 1 for the air inlet and air outlet of the anesthesia machine to minimize the probability of the virus entering breath circuits and the anesthesia machine.

At a minimum, anesthetists should wear an N95 mask and a face shield during endotracheal intubation or wear positive-pressure ventilation equipment if conditions permit. Other protective instruments, such as an Aerosol Box (17) or protective sleeve (18), can also be used to protect healthcare workers from viral aerosol pollution.

In principle, the endotracheal tube should be removed in the OR before the patient returns to the ward; however, patients with unstable vital signs will need to be sent to the intensive care unit with the endotracheal tube.

During extubation, agitation and coughing in patients should be avoided as much as possible, as such behaviors increase the production of virus aerosols, and thus increase the chances of COVID-19 transmission. Inhalation anesthetics should be stopped 30 minutes before the end of surgery. It is highly recommended that dexmedetomidine, which can effectively attenuate agitation, be administered during surgery. Tracheal sputum suction should be

performed under deep sedation before extubation. For the same reason, extubation should be performed under sedation if the patient resumes spontaneous respiration and the tidal volume and respiratory rate are sufficient to maintain normal oxygen saturation.

Intraoperative management

- (I) The door of the OR must remain closed during the operation to prevent the virus from spreading outside the OR through air movement. All the medical materials, medicines, and equipment needed for the operation should be fully prepared before the patient enters the OR. All the medical materials and medicines left following the operation must be disposed of according to COVID-19 medical waste disposal procedures and cannot be used again.
- (II) If regional anesthesia is used for the surgery, the patient should wear an N95 mask throughout the whole operation to prevent the virus spreading.
- (III) The surgical team should be well protected by PPE during the surgery. It is highly recommended a PPE supervisor be employed to check that the healthcare workers wear and remove the PPE properly.
- (IV) The surgical team should be well-trained, cooperative, and operate with high precision and cautiousness to reduce aerosol production, avoid unintentional injury to other surgeons and nurses, and avoid damaging the PPE.
- (V) An electrocautery that can reduce the time of surgically separating tissue should be set as low as possible to reduce the smoke. Smoke must be sucked away as quickly as possible to avoid the virus spreading through the smoke.
- (VI) When pollution occurs, it should be contained immediately. A small amount of pollution can be wiped away using disposable water-absorbing fabric with 1,000–2,000 mg/L chlorine-containing disinfectant (19). A large amount of pollution should be completely covered with disinfectant powder or an absorbent material, and soaked in 500 mg/L of disinfectant containing chlorine for >30 minutes (19). The pollution materials should be disposed of according to the COVID-19 medical waste disposal procedures.
- (VII) Touch screen equipment and screens in the OR should be wrapped with transparent plastic film to prevent the virus from surviving on surfaces, such

as grooves, buttons, computer mice, and screen peripheries.

- (VIII) Goggles and condensation: If goggles, glasses, and face shields are worn, condensation from breath may easily form on the surface of the goggles and face shields, affecting visibility. In our experience, wiping hand sanitizer on the inside surface of the goggles and face shields prevents condensation from forming.
- (IX) During the operation, a runner should be stationed outside the OR in case additional medications, materials, or equipment are needed.

Post-operative management

The primary goal of post-operative management is to prevent viruses from remaining, multiplying, and spreading. It is important to ensure that terminal disinfection is carried out to keep the sites, items, and substances virus-free. This should be completed with the cooperation of healthcare workers and cleaners who are familiar with the SARS-CoV-2 disinfection process.

Disposal of medical waste

In principle, the disposal of medical materials is the best way for COVID-19 surgery patients to avoid the risk of iatrogenic infection that is caused by the repeated use of medical materials. All the waste in a COVID-19 OR should be considered medical waste, regardless of whether or not it has come into direct contact with patients. The medical waste should be carefully put into a double-layered medical garbage bag. The medical garbage bag should be tightened, sealed, sprayed with 75% alcohol, and marked with a label that states, "COVID-19 infection, (the department), and (the date)" before being transported from the contaminated OR. Medical waste should be transported to designated locations for treatment through dedicated hallway by well-trained cleaners.

Post-operative disinfection

Contaminants (blood, secretions, and vomitus of patients)

Any visible contaminant (e.g., the tissue debris, blood, secretions, and vomitus of patients) should be removed as soon as possible, and the site should be disinfected with 1,000 mg/L of disinfectant containing chlorine. If not

removed immediately, the contaminant should be covered with disinfectant powder containing water-absorbing ingredients, or disposable water-absorbing materials, and soaked in 500 mg/L of disinfectant containing chlorine for >30 minutes (19). Direct contact with contaminants in the removal procedure should be avoided. Surgical suction bottles should be half pre-filled with 2,000 mg/L of disinfectant containing chlorine mixed with a surgical aspirate. After the removal of the contaminants, the surfaces of the contaminated objects need to be thoroughly disinfected.

Surgical instruments

As surgical instruments are contaminated with blood, secretions, and tissue debris, they carry a high risk of spreading viruses, and should be disinfected before being cleaned. Disposable surgical instruments should be discarded as medical waste after the operation, while reusable surgical instruments should be put in a hollow metal wire basket and soaked in 500 mg/L of disinfectant containing chlorine for >30 minutes. Surgical instruments should be disassembled to increase their contact area with the disinfectant. After being soaked in 500 mg/L of disinfectant containing chlorine for 30 minutes, it is recommended that the metal instruments be cleaned with water to avoid oxidation and rust, as metal instruments are easily corroded by highly oxidizing disinfectant containing chlorine. After the above process, the surgical instruments can be cleaned and sterilized as per the routine process by workers wearing PPE.

Floors, walls, and other surfaces

After the operation, the floors, walls, and other surfaces should be sprayed from outside to inside with 1,000 mg/L of disinfectant containing chlorine at the ratio of 100–300 mL/m², and this should be repeated again 30 minutes later. Any visible contaminants on the surfaces, should first be removed, and then the surfaces should be sprayed or wiped with 1,000 mg/L of disinfectant containing chlorine.

Air sterilization

As SARS-CoV-2 can form aerosols suspended in the air, the OR should be air-sterilized after surgery. The methods of air disinfection in the OR include spray, fumigation, and ultraviolet light. The principle of the spray disinfection method is to atomize the disinfectant into tiny particles and spray it evenly in the air to ensure it comes into full contact with the microbial particles and kills the microorganisms in

the air. Hydrogen peroxide (3%), 5,000 mg/L of peracetic acid, or 1,000 mg/L of chlorine monoxide disinfectant can be added to an electric ultra-low volume sprayer and sprayed at a dosage of 20–30 mL/m³ by disinfecting personnel and then sprayed in the following order: up to down, left to right, inside to outside, and surface to space. The doors and windows should be closed before spraying and opened 60 minutes after spraying.

Ultraviolet disinfection could reduce the risk of bacterial and viral medical-associated infections by killing bacteria and viruses on surfaces and in the air (20). Given that UV disinfection cannot reach the shaded areas and it is difficult to sanitize grooves and corners by surface disinfection, OR disinfection after the surgery of COVID-19 patients must combine these 2 disinfection procedures to avoid any cleaning failures due to human and environmental factors.

Pathology specimen management

The pathological tissue should be carefully placed in a double leak-proof specimen bag and fixed with 20% formaldehyde as soon as possible. After being sealed and sprayed with 75% alcohol, the specimen bag should be put into a special storage container or bag. This storage container or bag should be labeled as follows: “COVID-19 infection, (the department), and (the date)”. The container or bag should then be transported to the Pathology Department for further processing by a well-trained worker wearing PPE. Automatic transport systems cannot be used for COVID-19 specimens.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <https://atm.amegroups.com/article/view/10.21037/atm-22-4850/coif>). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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