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Review Article

Anesthesia Management and Perioperative Infection Control in Patients With the Novel Coronavirus

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Anesthesiologists have a high risk of infection with COVID-19 during perioperative care and as first responders to airway emergencies. The potential of becoming infected can be reduced by a systematic and integrated approach that assesses infection risk. The latter leads to an acceptable choice of materials and techniques for personal protection and prevention of cross-contamination to other patients and staff. The authors have presented a protocolized approach that uses diagnostic criteria to clearly define benchmarks from the medical history along with clinical symptoms and laboratory tests. Patients can then be rapidly assigned into 1 of 3 risk categories that direct the choice of protective materials and/or techniques. Each hospital can adapt this approach to develop a system that fits its individual resources. Educating medical staff about the proper use of high-risk areas for containment serves to protect staff and patients.

Key Words: COVID-19; infection; anesthesia; safety

THE WORLD HEALTH Organization has declared a pandemic with more than 120,000 people diagnosed with the novel coronavirus disease 2019 (COVID-19) and at least 4,200 deaths owing to complications of infection.[1] The COVID-19 is a zoonosis, a virus that originates in animals but mutated to infect humans.[2] Examples of other zoonoses are Ebola virus, human immunodeficiency virus, and salmonellosis.[3–6] The COVID-19 shares similarities with other coronavirus types that cause severe acute respiratory distress syndrome (SARS) and Middle East respiratory syndrome (MERS).[7,8]

In December 2019, the city of Wuhan in the Hubei province of China became the epicenter of a pneumonia outbreak. It was not until January 7, 2020, that investigators for the World Health Organization identified the infectious agent as a novel coronavirus.[9,10] COVID-19 is now a global threat with a high rate of infectivity and mortality rate of at least 2%.[10–12] The median age of patients diagnosed with COVID-19 pneumonia is 59 years. Children younger than 15 years of age are relatively spared and have either lower infection rates, fewer symptoms, or both. Although estimated mortality rates are less than that for SARS and MERS, the degree of spread is greater.[1,13,14] This raises global concerns that a greater total number of patients will die from the disease.

Disease spread is increased by a relatively long asymptomatic period that ranges from 8 to 15 days but may be as long as 24 days.[15,16] Healthcare workers are a major route of transmission, similar to the related viruses that cause SARS and MERS.[17] The expected number of secondary cases arising from 1 infected individual is approximately 2 to 3 people at a minimum.[16]

Anesthesiologists are at increased risk of exposure during perioperative management through direct contact, especially tracheal intubation. Transmission can occur from asymptomatic infected individuals. Therefore, healthcare workers should consider all patients as a possible source of infection unless

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Table 1
Diagnostic Criteria for Novel Coronavirus Pneumonia Used in the People's Republic of China*

Epidemiological History	Clinical Manifestations and CT Scan	Etiology and Serology
1. A history of travel to or residence in Wuhan, China, surrounding areas, or other regions with reported cases within 14 d before symptom onset 2. History of contact with COVID-19–infected persons (positive nucleic acid test) within 14 d before symptom onset 3. History of contact with patients who have fever and respiratory symptoms from Wuhan, surrounding areas, or other regions with reported cases within 14 d before symptom onset 4. Cluster onset: 2 or more cases of fever and/or respiratory symptoms in small area such as home, office, school, or class, etc, within 2 weeks	1. Fever and/or respiratory symptoms 2. CT shows multiple small, patchy shadows and interstitial changes in the early stage, which is obvious in the peripheral lung field, and then develops multiple ground-glass shadows and infiltrates in bilateral lungs. In severe cases, lung consolidation may occur. 3. The total number of white blood cells is normal or decreased in the early stage of onset, and the lymphocyte count is reduced.	1. Positive RT-PCR test result for COVID-19 nucleic acid 2. Viral gene sequencing: highly homologous to COVID-19 3. COVID-19–specific IgM is positive after 3-5 d of onset, and IgG antibodies in the recovery phase are 4 times or more higher than that in the acute phase.
Suspected case	1. One of the 3 epidemiological histories and 2 of the clinical manifestations 2. Those with no clear epidemiological history but meet 3 of the clinical manifestations	
Confirmed case	Suspected case + etiology or serological evidence	

Abbreviations: COVID-19, coronavirus disease 2019; CT, computed tomography; IgG, immunoglobulin G; IgM, immunoglobulin M; RT-PCR, reverse transcriptase-polymerase chain reaction.

* General Office of the National Health Commission. Diagnosis and treatment protocols of pneumonia caused by a novel coronavirus (trial version 7), March 4, 2020.

proven otherwise. This is particularly true for anesthesiologists who are commonly in close contact with patients and come into contact with airway aerosols and secretions.

How to Identify the Infected Patients

Signs and symptoms of COVID-19 infection are fever in 83% to 98%, dry cough in 76% to 82%, and fatigue or myalgia in 11% to 44% of patients.[18] The infection progresses rapidly in some patients, with approximately 10% of hospitalized patients requiring mechanical ventilation. Patients who develop acute respiratory distress syndrome, septic shock, refractory metabolic acidosis, coagulation dysfunction, and multiple organ failure have a high mortality rate.

Diagnostic criteria for novel coronavirus pneumonia used in the People's Republic of China is detailed in Table 1. The radiographic imaging during the early stages of infection shows multiple small, patchy shadows and interstitial changes in the peripheral lung field.[19] As pneumonia progresses there are bilateral and multiple ground-glass images and infiltrates with pulmonary consolidation. These changes are accompanied by a normal or decreased peripheral white blood count with a reduction in lymphocytes. Current test kits use reverse transcriptase-polymerase chain reaction (RT-PCR) from a nasopharyngeal and oral swab. A lower respiratory tract sample such as expectorated sputum, tracheal aspirate, or bronchoalveolar lavage can be used in intubated patients.[19] Testing is recommended in all patients with signs or symptoms of infection. Geographic areas with high infection rates such as South Korea offer testing to all residents, and others test those who report contact with a known infected person. Postinfection testing is done routinely in some countries as asymptomatic individuals who recovered from a known infection can still carry and transmit the virus. All healthcare workers should be familiar with the recommendations for RT-PCR testing in their geographic region.

The inability to obtain deep respiratory secretions or an inadequate nasopharyngeal swab for screening can result in a high false-negative rate of nucleic acid detection and difficulty in diagnosis and excluding COVID-19 infection from other types of respiratory infections. Serologic detection of specific immunoglobulin M antibodies is possible at 3 to 5 days after exposure. In the recovery period immunoglobulin G antibody titers can be 4 times or higher than that of the acute phase.[19]

Perioperative Infection Control

Patient Classification and Graded Protection

The authors present an approach for infection control for all healthcare workers and patients in preoperative areas. The resulting protocol is designed to identify all possible infected individuals because the crowded conditions in the pre- and postoperative care areas can facilitate viral transmission. The approach therefore aims to minimize or prevent transmission of COVID-19 among patient visitors and healthcare providers. The approach considers current evidence about methods of transmission and the consequences of infection in medically compromised patients. The authors have applied their practical experience from the management of patients during the COVID-19 epidemic in the People's Republic of China.

The number of visitors and distance between beds in the preoperative areas should be based on current recommendations made by the Centers for Disease Control and Prevention for social distancing. The latter is defined as reducing the number of people in common areas and trying to maintain a distance (approximately 6 feet) between individuals when possible.[20] All healthcare providers and visitors should practice handwashing when entering,

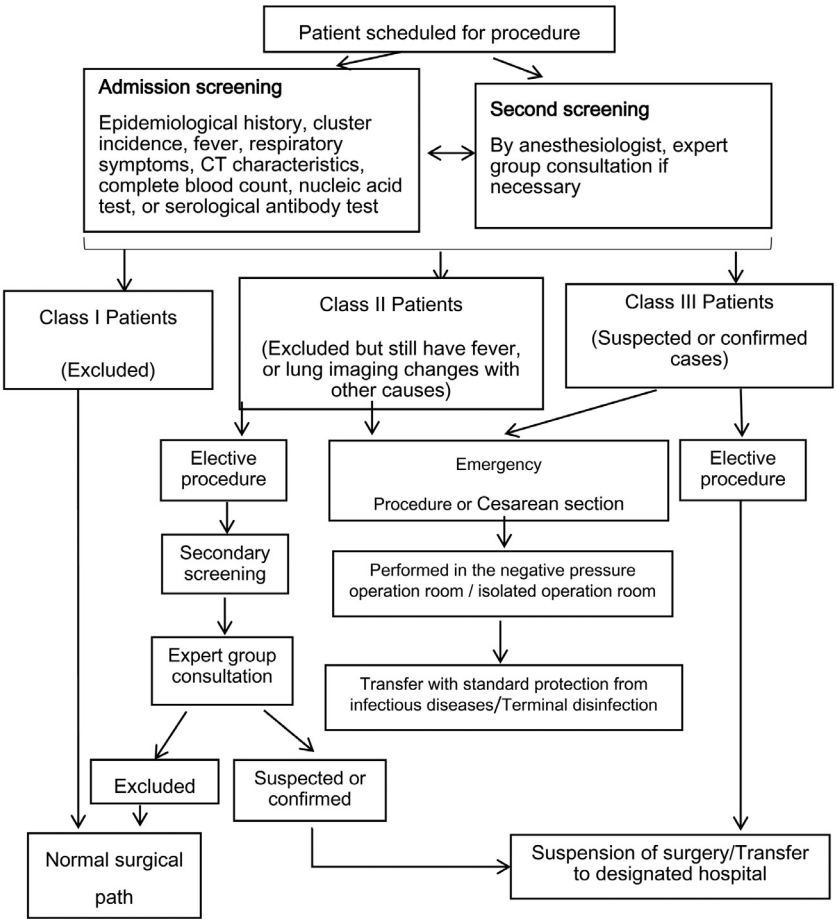

Fig 1. Surgery classification management process.

touching, and leaving the pre- and postoperative areas of care. The authors' approach uses a protocol in the perioperative care areas that segregates patients into 3 simple and distinct groups based on the risk of transmission (Fig 1).

Class I patients are those who have been shown to be negative for novel coronavirus pneumonia after screening with RT-PCR, symptoms, laboratory examinations, and imaging. Grade 1 protection is recommended and includes: (1) disposable surgical cap and surgical garments; (2) disposable gloves; (3) surgical mask; and (4) protective goggles with sterilized surgical gowns during tracheal intubation.

Class II patients have negative screening tests but fever or lung imaging suggestive of COVID-19 changes. These patients are considered potentially infective. Grade 2 protection is recommended for healthcare providers and includes: (1) disposable surgical cap and disposable impermeable surgical gown (isolation gown); (2) protective goggles or headshield, disposable gloves; (3) medical surgical mask and medical N95 mask; and (4) disposable shoe covers.

Class III patients are (1) those who need emergency surgery prior to screening for novel coronavirus pneumonia or (2) suspected or confirmed cases of novel coronavirus pneumonia who require emergency surgery and cannot be transferred to a designated COVID-19 hospital. Grade 3 protection is recommended and includes: (1) disposable surgical cap, scrubs, and disposable impermeable surgical gown (isolation gown); (2) protective goggles and headshield, double-layer disposable latex gloves; (3) medical N95 masks; a positive pressure headgear is recommended for tracheal intubation; and (4) disposable boot cover. Anesthesia staff should try to review the history, laboratory results, and imaging before engaging in care, including intubation or resuscitation to determine the degree of protection needed.

Preoperative Evaluation

Pre- and postoperative areas and the operating room are busy care sites. All these sites require healthcare providers from a number of different specialties. This leads to a greater amount of human traffic through these care sites and can result in a greater than average number of potentially exposed personnel owing to cross-contamination. The latter can lead to epidemic infection in the hospital. The authors therefore recommend that surgeons, anesthesiologists, and infectious disease experts form a cohesive team to conduct the 3-level evaluation system previously described. The current best practices used in the People's Republic of China consist of the 7 diagnostic criteria (epidemiologic history, cluster incidence, fever, respiratory symptoms, complete blood count, nucleic acid test, and/or serologic antibody test) (Fig 2).

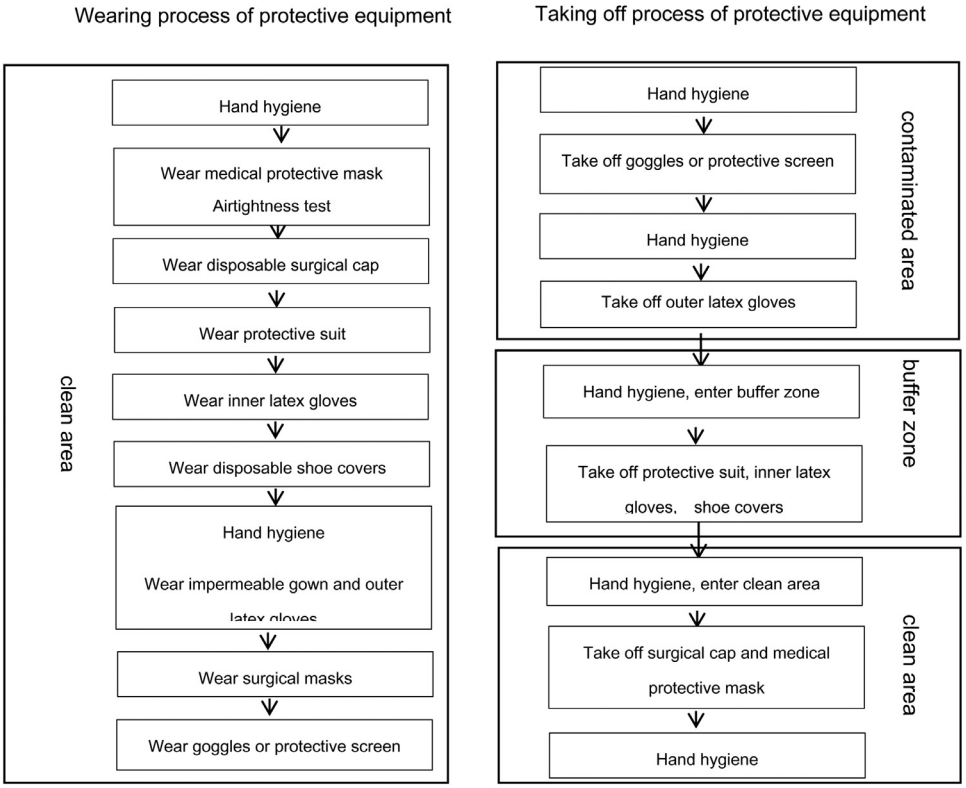

Fig 2. Steps for medical staff to put on and take off protective clothing in and out of the contaminated area.

Surgeons are the first-line barrier against nosocomial COVID-19 infection by collecting a complete history including travel and completing laboratory screening tests. Anesthesiologists protect the hospital and patients by performing a preoperative evaluation with updated data from the 7 diagnostic criteria. A clearly written protocol for evaluation and management should be posted in each hospital and the corresponding care sites to assure that all care providers follow the same approach. Patients with any criteria suggestive of COVID-19 infection and those with insufficient findings or information to determine the risk of infection should be isolated and referred to an infectious disease expert. In an emergent situation with insufficient time to assess the risk of infection, patients should be treated as active cases and at the highest risk of transmission.

Most hospitals in the People's Republic of China screen all elective patients for COVID-19 prior to surgery. This preventive position was taken to control the growing epidemic crisis. The intent was to eliminate all possible cross-infection to healthcare workers and patients in the perioperative care areas and operating room. The progressive reduction in cases suggests this is an effective technique.

Partition Management and Personnel Allocation in the Operating Room for Suspected/Diagnosed Patients

Patients may require emergency/urgent care in any hospital setting. Some hospitals are more prepared to receive patients with COVID-19 infection than smaller community care sites. Hospitals that do not have advanced infrastructure for multiple isolation and quarantine care should consider transferring confirmed or suspected cases to facilities with available containment. All patients without adequate screening or testing should be treated as active cases and cared for in a negative pressure/isolation operating room. Containment areas should have strict partitions where the clean area, buffer zone (supporting space outside the operating room), and contaminated area (negative pressure/isolation surgery room) are clearly marked for easy recognition by every team member. Infected patients or those who are awaiting results of COVD-19 testing should wear medical surgical masks during care.

In the operating room, anesthesiologists should use closed circuits and take all measures to minimize coughing after extubation. Anesthetic and resuscitation medicines, devices, and surgical instruments should be well prepared in advance to reduce the amount of traffic into and out of the operating room. Specific personnel assigned to the buffer area can be responsible for communication between areas and replenishing items. All medical personnel participating in the surgery must wear protective equipment and implement personal protection according to the infection control regulations (Fig 2).

Anesthesia Management

Anesthesia Method

Indication and contraindications to general anesthesia and regional anesthesia do not differ in most patients with COVID-19 pneumonia. However, platelet counts should be checked in patients with advanced or systemic COVID-19 owing to possible complicating thrombocytopenia, which may preclude regional anesthesia. For patients with confirmed or suspected

novel coronavirus pneumonia, minimizing exposure to airway aerosols, droplets, and fluids especially during coughing can reduce contamination. Intrathecal anesthesia is still recommended as the major anesthesia method for patients undergoing cesarean section, and patients should wear medical protective masks to reduce cross-infection by aerosol or droplets.

Induction of General Anesthesia and Tracheal Intubation

Rapid induction with expedient intubation is recommended to reduce aerosolized spread of viral particles. Video-laryngoscope with a disposable blade works well with a transparent plastic cover to protect the screen and handle. Clearly designated disposal sites for airway equipment that is contaminated can help reduce exposure. Placing a wet gauze on the patient's mouth and nose during positive pressure ventilation reduces droplet dispersion. A full dose of muscle relaxant should be injected at 1 time and tracheal intubation performed only when muscle relaxants are fully active to prevent coughing. Healthcare providers may want to consider the risks and benefits of giving opioid analgesics prior to induction of general anesthesia because they can lead to significant coughing.[21] Heat and moisture exchanging filters are recommended on both the inspiration port and the aspiration port of the respiratory circuit and should be replaced every 3 to 4 hours. There is evidence that filters can effectively reduce contamination of the anesthesia machine with pathogens including bacteria or viruses. However, use of filters has also been associated with increased airway pressures and auto-positive end-expiratory pressure, which can increase the risk of pulmonary barotrauma.[22] Care must be given to the placement of the scavenging outlet because low flow circuits with filters may not eliminate all pathogens. Medical staff should change gloves after touching the patient's secretion, making sure not to contaminate items in the operating room.

Extubation and Anesthesia Recovery

Extubation should be performed to minimize aerosol spread through coughing. Anesthesia care providers have a number of options to help accomplish this goal. These include deep extubation in the appropriate patients or use of analgesic narcotics to facilitate a smooth extubation. Laryngeal mask airways provide a relatively smoother emergence in many patients and can be used in appropriate circumstances. The goal is to adapt the anesthesia plan to reduce aerosol and droplet exposure. Patients who are positive for COVID-19 or whose status is unknown should be sent to a negative pressure isolation area after surgery. Patients who still need artificial ventilation after the surgery should be transferred to an isolation unit in the intensive care unit with a special transfer bed and ventilator by well-protected and trained staff.

Disposal of Anesthetic Items

Following surgery, all disposable items should be discarded and packed in well-marked medical hazard waste bags, which are labeled clearly as "coronavirus pneumonia infected materials" and disposed of by a person who has received COVID-19 training. Some equipment such as fiberoptic bronchoscopes, rigid bronchoscopes, and nerve stimulators must be fully decontaminated using local disinfection standards. After decontamination, all instruments require inspection by a hospital infection control agent before use in another case. All anesthesia machines used in infected patients or those with unknown status should be treated using disinfection standards established for communicable fungi, viruses, and vegetative bacteria.[23]

There are commercial sterilization packages available for anesthetic machines. Different brands or models of anesthesia machines may require specific procedures.[24–26] All aim to disinfect the internal breathing circuit by distributing agents such as ethylene oxide, peracetic acid, vaporized hydrogen peroxide, or glutaraldehyde to kill residual pathogenic agents such as COVID-19.

Out of the Operating room Airway Emergencies

All hospitals should ensure that the contents of portable airway kits are complete and ready for transport to an emergency. Referring healthcare providers should try to provide the airway team with an update on the patient's medical history and infectious status especially in regard to COVID-19. This will allow the emergency airway team to choose appropriate protective equipment based on a rapid assessment of transmission risk. For example, providers can choose first-, second-, or third-level protection for class I, class II, and class III patients, respectively. When there is insufficient information to determine the relative risk, all patients should be treated as infected and capable of rapid transmission (class III).

Maximum measures to prevent transmission should be used when patients have any symptoms consistent with a diagnosis, including fever/cough or radiological imaging suggestive of COVID-19. Anesthesia teams need prior training to understand how the wards are organized to minimize transmission of pathogens by persons entering and leaving the area. In teaching centers, intubation of patients out of the operating room by more experienced staff may reduce the risk of transmission under emergency conditions. Designation of a well-coordinated emergency airway team can reduce potential transmission by working together as a coordinated unit to assemble materials, assist with intubation, and dispose of contaminated materials. Portable airway kits should be left in the buffer zone during intubation and subsequently thoroughly disinfected or disposed of.

Conflict of Interest

None.

References

1 World Health Organization. There is a current outbreak of coronavirus (COVID-19) disease. Available at: https://www.who.int/health-topics/coronavirus. Accessed March 10, 2020.

2 Zhou P, Yang XL, Wang XG, et al. A pneumonia outbreak associated with a new coronavirus of probable bat origin. Nature 2020;579:270–3.

3 Baseler L, Chertow DS, Johnson KM, et al. The pathogenesis of Ebola virus disease. Annu Rev Pathol 2017;12:387–418.
4 Schnittman SM, Fauci AS. Human immunodeficiency virus and acquired immunodeficiency syndrome: An update. Adv Intern Med 1994;39: 305–55.
5 World Health Organization. Guideline on when to start antiretroviral therapy and on pre-exposure prophylaxis for HIV. Geneva, Switzerland: WHO; 2015.Available at: http://apps.who.int/iris/bitstream/10665/186275/1/9789241509565_eng.pdf. Accessed March 26, 2020.
6 Draper AD, Morton CN, Heath JN, et al. An outbreak of salmonellosis associated with duck prosciutto at a Northern Territory restaurant. Commun Dis Intell Q Rep 2017;41:E16–20.
7 Yin Y, Wunderink RG. MERS, SARS and other coronaviruses as causes of pneumonia. Respirology 2018;23:130–7.
8 de Wit E, van Doremalen N, Falzarano D, et al. SARS and MERS: Recent insights into emerging coronaviruses. Nat Rev Microbiol 2016;14:523–34.
9 Zhu N, Zhang D, Wang W, et al. China Novel Coronavirus Investigating and Research Team. A novel coronavirus from patients with pneumonia in China, 2019. N Engl J Med 2020;382:727–33.
10 Wang C, Horby PW, Hayden FG, et al. A novel coronavirus outbreak of global health concern. Lancet 2020;395:470–3.
11 Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020;395:497–506.
12 Tang B, Bragazzi NL, Li Q, et al. An updated estimation of the risk of transmission of the novel coronavirus (2019-nCov). Infect Dis Model 2020;5:248–55.
13 Novel Coronavirus Pneumonia Emergency Response Epidemiology Team. The epidemiological characteristics of an outbreak of 2019 novel coronavirus diseases (COVID-19) in China [e-pub ahead of print]. Chin J Epidemiol. doi: 10.3760/cma.j.issn.0254-6450.2020.02.003, Accessed
14 Sohrabi C, Alsafi Z, O'Neill N, et al. World Health Organization declares global emergency: A review of the 2019 novel coronavirus (COVID-19). Int J Surg 2020;76:71–6.
15 Lauer SA, Grantz KH, Bi Q, et al. The incubation period of coronavirus disease 2019 (COVID-19) from publicly reported confirmed cases: estimation and application. Ann Intern Med 2020. https://doi.org/10.7326/M20-0504.
16 Bai Y, Yao L, Wei T, et al. Presumed asymptomatic carrier transmission of COVID-19. JAMA 2020. https://doi.org/10.1001/jama.2020.2565.
17 Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. JAMA 2020. https://doi.org/10.1001/jama.2020.1585.
18 Del Rio C, Malani PN. COVID-19-new insights on a rapidly changing epidemic. JAMA 2020. https://doi.org/10.1001/jama.2020.3072.
19 National Health Commission of the People's Republic of China. Diagnosis and treatment protocols of pneumonia caused by a novel coronavirus (trial version 7) [2020]184, 2020-3-4. Available at: http://www.nhc.gov.cn/yzygj/s7653p/202003/46c9294a7dfe4cef80dc7f5912eb1989/files/ce3e6945832a438eaae415350a8ce964.pdf. Accessed
20 CDC. Preventing COVID-19 spread in communities. Available at: https://www.cdc.gov/coronavirus/2019-ncov/community/index.html.
21 Kamei J, Nakanishi Y, Asato M, et al. Fentanyl enhances the excitability of rapidly adapting receptors to cause cough via the enhancement of histamine release in the airways. Cough 2013;9:3.
22 Güldner A, Kiss T, Neto AS, et al. Intraoperative protective mechanical ventilation for prevention of postoperative pulmonary complications: A comprehensive review of the role of tidal volume, positive end-expiratory pressure, and lung recruitment maneuvers. Anesthesiology 2015;123:692–713.
23 CDC. Guideline for Disinfection and Sterilization in Healthcare Facilities (2008). Available at: https://www.cdc.gov/infectioncontrol/guidelines/disinfection/index.html. Accessed May 24, 2019.
24 Zeraatkari K, Soltani H, Veisy A, et al. Disinfection effect of cidex, savlon and H_2O_2 on ventilator tubes. Can J Anesth 2005;52:A163 https://doi.org/10.1007/BF03023201.
25 Berry AJ, Nolte FS. An alternative strategy for infection control of anesthesia breathing circuits: A laboratory assessment of the Pall HME Filter. Anesth Analg 1991;72:651–5.
26 Perioperative infection control branch of Chinese society of cardiothoracic and vascular anesthesia. Recommendations for disinfection and sterilization of breathing circuit in anesthesia machine. Chin J Anesthesiol 2018;38:1417–20. https://doi.org/10.3760/cma.j.issn.0254-1416.2018.12.003.