THE NEW ADAPTATION OF PEDIATRIC ANESTHESIA IN THE COVID-19 PANDEMIC ERA

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Abstract

Coronavirus Disease (COVID-19), caused by the SARS-CoV-2 virus, has become a pandemic that impacts pediatric patients, especially in pediatric anesthesia. The increase of COVID-19 cases in pediatric, diverse clinical manifestations, morbidity, and mortality in pediatric patients. The risk of virus transmission encourages anesthesiologists to provide pediatric anesthesia adjustments. The health care professional's safety, perioperative procedures, anesthesia management, and pain management, both intraoperative and postoperative, become a great challenge for the anesthesiologist. The authors will present a review of the adaptation of pediatric anesthesia in the COVID-19 pandemic era. This review aims to provide an overview of the impact and adjustments made in the COVID-19 pandemic era to reduce the risk of viral transmission to healthcare professionals, especially those performing pediatric anesthesia.

Keywords: pediatric anesthesia; COVID-19; anesthesia management.

Introduction

The mysterious pneumonia was first reported in Wuhan, China, in December 2019. Clinical manifestations of this pneumonia range from asymptomatic to breathing failure. In January 2020, SARS-Cov-2 was identified as the cause of pneumonia, and the disease is referred to as COVID-19. SARS-Cov-2 is transmitted by human-to-human contact through a droplet.[1] In a short period, the outbreak spread to various parts of the world, and on March 11, 2020, the World Health Organization established it as a pandemic outbreak.

COVID-19 is not only infecting the adult population but also the pediatric population. Although the total case of COVID-19 in the pediatric population is lower than the adult population, the number of COVID-19 in pediatrics is increasing. Pediatric patient with COVID-19 generally has milder clinical manifestations than the adult. Close contact with adult patients suspected to become COVID-19 transmission in pediatric.[2] Asymptomatic pediatric patients may also have a role in COVID-19 transmission. The Center for Disease Control and Prevention recommends restrictions on contact between children with adulthood or those with comorbid diseases.[3]

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The high risk of COVID-19 transmission has a major impact on other health care services, including surgical services. A droplet from crying and coughing pediatric patients with COVID-19 potentially causes the spread of the SARS-CoV-2. Anesthesia and surgery may result in the formation of aerosols. Anesthesiologists are at a high risk of exposure by performing airway management, positive pressure ventilation using facemasks, endotracheal intubation, extubation, and exposure to oral secretions.[4]

COVID-19 Epidemiology in Pediatric Population

The COVID-19 in pediatric patients was first reported on January 20, 2020, in Shenzen, China. At the beginning of the outbreak, the data of COVID-19 in pediatric is limited due to the limited virus screening.[3] In the United States, the number of confirmed COVID-19 in pediatric was 7.3% of the total cases on August 3, 2020.[5] In Indonesia, the number of COVID-19 in pediatric aged 0-5 years old is 4,880 (2.4% of the total cases) with 67 deaths (0.8% of the total deaths) and ages 6-18 years old by 14,437 (7.1% of the total cases) with 92 deaths (1.1% of the total deaths).[6]

Clinical Manifestations of COVID-19 in Paediatrics

SARS-CoV-2 is one of seven types of coronavirus that infect humans. SARS-CoV-2 enters the cell through ACE-2 receptors in the mucosal membranes, especially in the airway. Transmission occurs both by direct inhalation and indirect exposure through the mucosal membranes of the eyes, nose, and mouth.[1,7]

Clinical manifestations of COVID-19 vary from asymptomatic to breathing failure. Severe respiratory failure in COVID-19 is associated with the hyper-inflammatory syndrome. Cytokine storms in COVID-19 infections can cause excessive inflammation.[8,9] Clinical symptoms of COVID-19 in pediatric are generally milder than in adult patients. The symptoms often overlap with other symptoms of other viral infections. Systemic symptoms of COVID-19 include fever, malaise, fatigue, headache, and myalgia. The respiratory system symptoms include coughing, shortness of breath, nasal congestion, sore throat, and colds. Other symptoms, such as diarrhea, vomiting, nausea, and abdominal pain can also occur. The clinical examination usually found desaturation of SpO_2< 92%, tachypnea, nasal flaring, cyanosis, retraction, rhonchi/wheezing, tonsil enlargement, rash, conjunctivitis, and mucocutaneous infection.[8]

The whole blood tests usually indicate leukopenia, normal leukocytes, thrombocytopenia, variable absolute lymphocyte count, increased blood sediment rate in most cases, normal to increased C-Reactive Protein (CRP), normal or elevated procalcitonin levels in the severe phase. At the roentgen thorax examination, obtained a normal picture, mild to severe pneumonia. Chest X-rays reveal bilateral opacity with peripheral, sub-pleural, and consolidated parts distribution. In several cases, pleural effusion may be found. A small and large picture of plaque and interstitial changes in the peripheral area at the initial CT-scan examination is reported. In severe conditions, CT scans show bilateral multiple ground-glass opacities, infiltrates, and consolidations.[8]

The criteria of COVID-19 in pediatric patients can be found based on epidemiological history and clinical symptoms. Anamnesis on epidemiological history focused on the last two weeks, consisting of travel history or living in the local transmission area, history of contact with patients who have traveled from the local transmission area and have symptoms of fever and respiratory distress, a history of close contact with confirmed or suspected patients of COVID-19, the absence of clinical symptoms such as fever, airway infections leading to suspicion of COVID-19, the inside of a cluster confirmed or suspected of COVID-19, and a baby born to a confirmed or suspected mother of COVID-19. However, the gold standard for COVID-19 diagnosis was the Polymerase Chain Reaction (PCR) test.[8,10]

Morbidity and Perioperative Mortality of Pediatric with Covid-19

Surgery in patients with COVID-19 increases morbidity and mortality of patients. A retrospective study that analyzed the postoperative outcomes of 34 patients with SARS-CoV-2 infection showed that

all patients had pneumonia-related to COVID-19 immediately after surgery, 15 patients needed intensive care, and 7 of them died. Older patients, patients with comorbidities, and patients undergoing complex surgeries usually require Intensive Care Unit (ICU) admission and management.[11]

A cohort study involving 235 hospitals from 24 countries analyze 1,128 COVID-19 patients who underwent surgery (835 cases of emergency surgeries and 280 elective surgeries) reported a mortality rate of about 23.8% in the first 30 postoperative days. Complications of pneumonia occurred in 577 cases (51.2%), and the mortality rate was 38.0% at 30 days. Based on these reports, several recommendations were made to postpone any non-urgent surgery in COVID-19 patients.[12]

Impact of Pediatric Surgery Services in COVID-19 Pandemic Era

The COVID-19 pandemic threatens populations that are susceptible to infection with COVID-19, as well as the pediatric population. Because of that, the surgery services must be classified base on the procedure urgency. In some countries, as of March 2020, all elective, semi-elective, and outpatient surgical procedures are postponed due to diverting existing resources to treat COVID-19 patients and reducing the risk of SARS-COV-2 infection.[13,14] Some emergency surgery such as orchiopexy in pediatrics still can be performed to reduce the risk of infertility and malignancy of the testicles.[13,14]

Special approaches and strategies are needed to address the impact of postponing surgery due to the risk of COVID-19 transmission. Surgical services between pediatric patients with COVID-19 and those who are not exposed must be separated. For regions with high prevalence and local transmission of COVID-19, elective surgery services can be performed only after performing rigorous screening with PCR testing, clinical symptoms, and contact history/epidemiology.[16,15] Several factors, such as the availability of PCR tests, human resources, adequacy of personal protective equipment (PPE), the number of treatment beds available, and ICU availability, should be considered.[16]

Specific guidelines are needed by the health care team who treat pediatric patients with COVID-19.[17] All departments must develop policies and protocols for suspected or confirmed COVID-19 patients to obtain the best outcomes for patients and prevent viral transmission to the health care professionals.[18]

The Safety of Health Care Team

The health care team's safety can be obtained by making good planning, proper use of personal protective equipment (PPE), and good communication. The health care team performing pediatric anesthesia with COVID-19 usually consist of experienced anesthesiologists, junior anesthesiologists, nurses, and technicians who can check the equipment and the operating room's needs. Senior anaesthesiologist can lead the team. The team member should not have comorbidities or are at high risks of infection. All health care teams should wear PPE, including waterproof dresses/gowns covering the entire body or hazmats, goggles, face shields, N95 masks, and short and long gloves.

Operating Room Preparation

The operating room of confirmed or suspected COVID-19 patients must be separated from the non-COVID-19 operating rooms.[19] Operating rooms should be negatively pressurized with adequate PPE availability. With an exhaust fan, the room needs about 30 minutes to negatively pressurized.[20] Air exchange cycles should be done at least 25 times per hour if the room is not negatively pressurized.[21] An air exchange up to 15 times per hour can eliminate contaminants up to 99% within 20 minutes after the aerosol release.[22] Equipment that is not needed should be removed from the operating room to prevent viruses' spread and contamination. The number of the team inside the operating room should be limited. During intubation and extubation, nurses and surgeons should stay outside the operating room. Anesthetic trolleys should be placed in corridors outside the operating room. The monitor screen should be covered with transparent plastic.[21,22] Disinfection and sterilization of the operating room is carried out immediately after surgery in confirmed or

suspected cases of COVID-19. Sterilization includes routine disinfection of all equipment in the operating room, ultraviolet radiation, disinfectant sprays, and floor mopping.[17]

Perioperative Procedures

Confirmation of COVID-19 suspected-pediatric patients should be done regularly. In non-emergency cases, PCR examination should be done first. The operation can be postponed if the result is positive for COVID-19. For emergency and urgent cases on COVID-19 suspected patients, surgical procedures are performed with the COVID-19 protocol.[23,24,25] During the patient's transfer to/from the operating room and vice versa, the patient must use a surgical mask while the accompanying team uses the N95 mask.[26]

Premedical Procedure

Before surgery, pediatric patients often experience anxiety and psychomotor agitation, crying, screaming, and other behaviours. These behaviours are potentially causing droplets and respiratory aerosols formation. Therefore, adequate pre-operative anxiolysis may lower the risk of transmission in health care professionals. Patients are recommended to receive oral or intravenous premedication before the patient is transferred to the operating room. Midazolam or clonidine is effective as pre-operative ankylosis in pediatrics. Intranasal premedication should be avoided, as it can stimulate sneezing and coughing. Parental attendance is not recommended due to the risk of viral transmission.[27,28] Intravenous accesses must be secured before entering the operating room. Intravenous cannulation can trigger anxiety in pediatrics. Because of that, the use of intravenous cannulation must be considered. Topical anesthesia (EMLA) can be administered 30-60 minutes at the injection area before the intravenous line is installed.[28,25]

Intra-Anesthesia Procedures

Aerosol Barrier

Induction, positive pressure ventilation, suction, and intubation result in the formation of aerosols. Several modifications to anesthesia techniques were made in pediatric patients to reduce COVID-19 transmission, such as the use of a barrier with transparent plastic or aerosol box during anesthesia procedures (Table 1). Transparent clear plastic can be placed over the patient's body, covering the patient's head to the sternum (Figure 1). Simulation of using three layers of transparent plastic barrier in mannequins (the first plastic is placed under the patient's head covering the operating table, the second plastic covers the neck to the chest, and the third plastic covers the head up to the patient's sternum) can reduce contamination around the patient.[29] The use of aerosol boxes became popular at the beginning of the pandemic. Aerosol boxes are transparent acrylic that covers the patient's head and shoulders, with access or holes for intubation and assistance. However, the use of an aerosol box slows down the duration of intubation. Besides, the holes

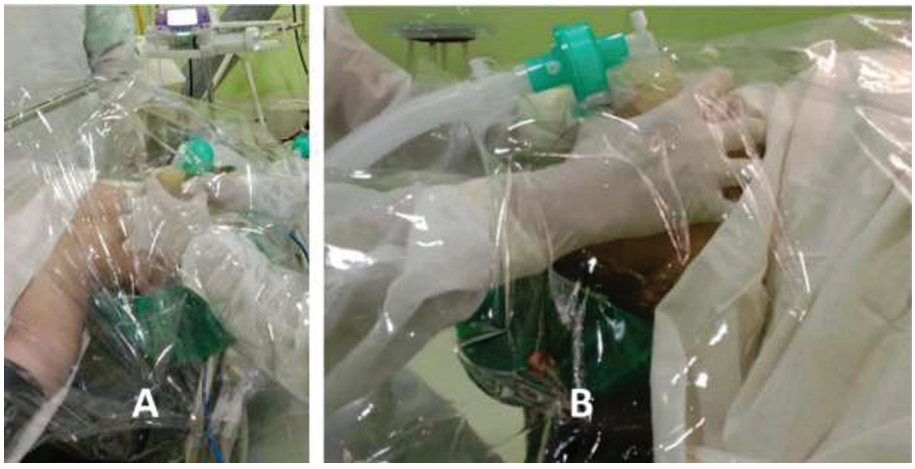


Fig. 1
The use of transparent plastic in an aerosol barrier. The installation can be done vertically with a barrier to form a tent (A) or horizontally by placing it directly covering the patient's head (B). The anesthesiologist's hand is under a plastic barrier.

Table 1
Modification of pediatric anesthesia management during COVID-19 pandemic

Procedure	Aerosol prevention	Minimize exposure
Pre-operative	· Prevent patients from crying: premedication with ancyolithic (oral midazolam or IV if the infusion has been attached), installation of intravenous cannula before entering the operating room (administration of topical local anesthesia before performing the venous injection, the technique of distraction with video, games).	· If possible, postpone the surgical procedure until the acute phase is handled. · Using complete PPE during the procedure and donning according to the protocol
Induction-intubation (anesthesia)	· IV induction with RSI technique. · Avoid providing positive pressure ventilation. If needed, use the minimum volume of tidal ventilation. · Two people carry out ventilation. One holds and closes the facemask, and the other provides ventilation. · Avoid administration of High Flow. · Intubation is carried out after the onset of muscle paralysis is reached and adequate. · Intubation with conventional or video laryngoscope according to the skill · Use ETT with cuff/micro cuff, ETT fixation well, connection to the anesthetic circuit should be good. Prevent ETT disconnect to anesthesia circuitry. In case of unexpected intubation difficulties, LMA can be used. · Mechanical ventilation considering pulmonary protection: low tidal volume 5-6 ml/kg BW, breath frequency is increased to maintain vital minute ventilation. Peak airway pressure ≤ 30 mmHg	· Use complete PPE during the procedure. · The action is carried out in a negative pressurized operating room or room with a gas exchange of at least 15 times per hour. · Staff restrictions inside the operating room. During intubation action, only the anesthesia team is in the operating room. · Use aerosol barrier: transparent plastic, aerosol contact HME filter usage, virus filter/ HEPA
Extubation	· Prevent cough and laryngeal spasm during extubation by doing: deep extubation, administration of propofol 0.5 mg/kg, or lidocaine IV 3 minutes before extubation. · Deep extubation is performed after the patient is spontaneously deprived and adequate saturation. · The liquid in the oropharynx is cleaned /suction by using a suction closed system first before extubation.	· During the extubation, only the anesthesia team is inside the operating room using aerosol barriers during extubation. · If oxygen supplementation is required, provide it with low flow. · Installation of surgical masks to the patient immediately after extubation.
Postoperative	· Recovery is performed in the operating room.	· Transport the patient to the treatment room using aerosol barriers. · Doffing, PPE release according to the protocol, decontamination of officers, and operating room.

IV: intravenous, PPE: Personal Protective Equipment, RSI: rapid sequence induction, ETT: endotracheal tube, LMA: laryngeal mask airway, HME: heat and moist exchange filter

can cause personal protective equipment damage.[30] Simulation of exposure to airborne particles by comparing barrier, barrier using plastic, aerosol boxes, aerosol boxes equipped with gas exchange moisturizer filters, and active suction when patients cough showed higher airborne particles in aerosol boxes compared to without barriers or plastic barriers. The lowest exposure is reported in aerosol boxes equipped with gas exchange moisturizer filters with active suction.[31]

Intubation

Intubation should be performed by an experienced anesthesiologist. Ideally, intubation is done using video laryngoscopy to decrease the risk of exposure. Video laryngoscope minimizes direct contact between anesthesiologists and patients. For the patients, a video laryngoscope reduces the risk of trauma in pediatric patients.[32,33] The use of cuffed endotracheal tubes (ETT) is recommended to avoid airway leakage and repeated intubation. ETTs with micro cuffs are recommended in patients under six years old, while ETTs with standard cuffs are recommended in patients over six years old. The use of cuffed ETT in pediatric patients is considered safe, with no significant differences compared to uncuffed ETT base on the parameters such as incidence of coughing during extubation, complications of stridor, and hoarseness.[34,35]

Intravenous induction is recommended because inhalational induction using high fresh gas flow increases the risk of aerosol formation. Pre-oxygenation is carried out with low oxygen flow. It is recommended to perform rapid sequence induction techniques. However, in infants with severe pulmonary disorders, this technique is difficult due to the risk of hypoxemia. Technical adjustments can be made by providing positive pressure ventilation. In this case, positive pressure ventilation is performed by two operators: one holding a face mask and closing it to the patient's face to prevent leakage and the other providing ventilation. Adequate ventilation can be given by observing the chest rise.[36,34]

Intubation can be performed after achieving adequate block.[28] Cuff of the ETT is inflated immediately after successful intubation. The success of intubation can be assessed using a capnograph and visualization of symmetrical chest rise. Auscultation with a stethoscope is challenging to do due to barriers.[36,34]

In unexpected intubation difficulties, airway and ventilation management can be achieved using second-generation laryngeal mask airway (LMA) (LMA supreme, LMA pro-seal, i-gel LMA Simulations of cough mannequin models with LMA showed minimal aerosol spread.[36,37] LMA also reported produces successful airway management in Pierre-robin, Treacher-collins, and Goldenhar syndrome. LMA installation can prevent excessive airway equipment use, minimize the risk of trauma and obstruction of the airway due to bleeding or edema, and 'Can't intubate can't ventilate' scenarios. LMA pro-seal with spontaneous and controlled ventilation can be used for many pediatric surgical procedures except for major abdominal surgery.[38]

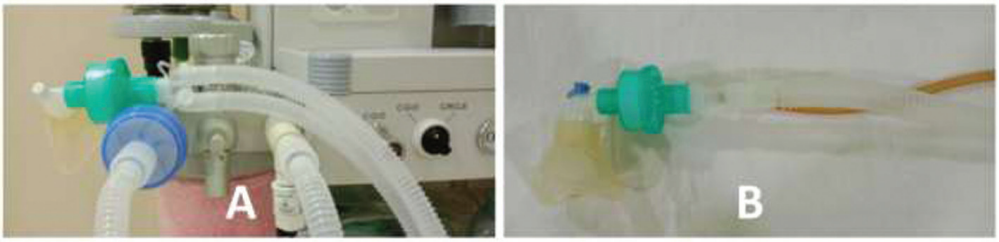
Intra-operative anesthesia maintenance

The connection between ETT and the circuit should be ensured to be tightly attached.[25,22] To reduce the risk of exposure to contaminants, Heat and Moisture Exchange Filters (HME filters) are placed between circuits and face mask/ETT/LMA during anesthesia (figure 2A). HME can filter airborne particles (size 0.3 microns or more) up to 99.995%.[39] However, HME filters can cause a dead space in neonates and infants, resulting in the risk of hyperventilation with severe hypercapnia. The filter should be adjusted to the dead space and the range of tidal volume requirements.[28] In patients with a weight greater than 5 kg, HME filters with a dead space of 10 ml can be used with a minimum tidal volume of 30 ml. To protect the anesthesia machine from exposure to airborne particles, a High-Quality Mechanical Viral Filter (HQMVF)/HEPA filter between the end of the expiration tube with the anesthesia machine (figure 2A) can be used. The placement of this filter does not affect the dead space. These filters should be disposable because moisture can block the filters.[39]

Mechanical ventilation during anesthesia should follow a lung-protective strategy by using a low tidal volume of 5-6 ml/kg BW, increasing the breathing frequency to maintain adequate ventilation, and

Fig. 2

HME filter placement and virus filter/HEPA. HME filters are installed between the anesthetic circuit and facemask/ETT/LMA before the elbow connector, and the virus filter/HEPA filter is installed at the end of the expansive tubing leading to the anesthesia machine (A). The HME filter is mounted on a type D mappleson, placed before the elbow connector (B).



maintaining peak airway pressure < 30 cmH_2O.[36]

Extubation

Coughing, holding breaths, and laryngospasms often occur in pediatric patients while performing extubation. The handling of laryngospasm with positive pressure ventilation results in the formation of aerosols. Deep extubation is an option to avoid the incidence of coughs and laryngospasms. Also, intravenous anesthesia at the end of anesthesia using dexmedetomidine[40], propofol 0,5 mg/kg shortly before extubation, or lidocaine 1.5 mg/kg BW three minutes before extubation may reduce the incidence of coughing and laryngospasm during extubation.[41,42]

Before deep extubation, make sure that spontaneous ventilation and adequate saturation are achieved. The oropharynx should be adequately suctioned using closed system suction.[36] Antiemetics can be administered to prevent vomiting. Extubation is carried while using adequate aerosol barriers. After extubation, oxygen supplementation can be administered through a facemask with low oxygen flow.[28]

Post-Anesthesia Recovery and Administration

Post-anesthesia recovery is performed in the operating room. The anesthesiologist should monitor airway status and oxygen saturation. Surgical masks are used on patients, and where possible aerosol barriers are retained to prevent the risk of contamination. A multimodal approach can be used to avoid hypothermia, agitation, and postoperative pain.[28]

Post-surgery, patients can be transferred to a negatively pressurized isolation room if the patient is in good condition. During the transfer to the treatment room, the patient should wear a surgical mask. If the patient intubated, oxygen supplementation can be done with a type D mappleson circuit while using an HME filter between the elbow connector and the mappleson (figure 2 B). During the transfer, transparent plastic can be used as a barrier to cover the patient's head.[36]

Regional Anesthesia in Paediatrics

Regional anesthesia is a suitable technique for a patient suspected or confirmed COVID-19 because it can avoid aerosols' spread.[43,44] The use of regional anesthesia techniques in pediatrics has several advantages, including 1) reduce the need for opioids, 2) reduce the incidence of postoperative vomiting and nausea, 3) reduce postoperative pain and adequate postoperative pain management, 4) and lower respiratory system complications. Regional anesthesia in pediatrics can reduce the length of treatment in the hospital and is often used as an anesthetic option for outpatient surgery.[45,46]

Caudal epidural, spinal, and peripheral nerve block can be used as sole anesthesia techniques or in combination with general anesthesia.[47,48,49] Caudal and spinal epidural techniques can be viable options in premature infants at risk of apnea after general anesthesia.[50] Catheter placement in both neuraxial and peripheral nerve block provides a long duration of anesthesia and becomes access to local anesthesia agents for postoperative pain management.[45,51]

The controversy over nerve block in pediatric patients relates to when the block should be done, whether the patient is conscious or unconscious. The advantage of performing this procedure in conscious patients is that it can early detect complications of systemic toxicity of local anesthesia, reducing the risk of intraneural injection and nerve damage. Psychological factors such as fear and anxiety in pediatric patients are inhibitive for nerve block techniques. Pediatric patients with older age have better psychological tolerance. However, the use of ultrasound imaging guidelines and peripheral nerve stimulation when performing nerve blockades can reduce the risk of such complications in sedated pediatric patients.[49]

Regional techniques of both neuraxial anesthesia and nerve blockade are more likely to be performed. The selection of regional anesthesia techniques should be taken properly. Conversion from regional anesthesia to general anesthesia should be avoided. In epidural anesthesia, continuous administration of the regimen through an epidural catheter is recommended. The use of supraclavicular brachial plexus block should be closely considering the risk of respiratory function disruption. Perineural catheter installation should be considered on a case-by-case basis, as it will require more frequent contact by health care professionals in the treatment of postoperative pain. However, the perineural catheter has the advantage of being an opioid-sparing effect in patients with respiratory system morbidity.[45,46]

Postoperative Pain Management

The analgesic modality in pediatric patients is given based on the intensity of pain caused by surgery. In mild pain, Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) or paracetamol can be administered. In moderate to severe pain, multimodal analgesia can be used by administering NSAIDs or paracetamol combined with opioids, local anesthesia infiltration in surgical wounds, or with regional analgesia techniques.[52]

The use of NSAIDs in COVID-19 patients is still controversial. The use of NSAIDs, mostly ibuprofen, is presumed to increase the expression of ACE2 receptors as the entry pathway of the SARS-CoV-2 infection.[53] However, some studies show that the use of NSAIDs is not associated with increased mortality of COVID-19 patients.[54,55]

Summary

COVID-19 affects not only the adult population but also the pediatric population. Clinical manifestations of COVID-19 in pediatrics are milder than in adulthood but may have a role in spreading the SARS-CoV-2 infection. COVID-19 outbreak affects anesthesiologists, especially in pediatric patients who require surgery. Anesthesia, airway management, intubation, and extubation are risks for causing aerosols. Pediatric characteristics differ from adult patients, especially pediatric, the psychological responses to surgery. Anxiety, fear, and crying are often present in pediatric patients, which increases the risk of exposure to contaminants in anesthesiologists. New adaptations of anesthesia are needed to treat pediatric patients who will undergo surgery to prevent COVID-19 transmission to anesthesiologists and other health care professionals while paying attention to patient safety. COVID-19 is a new disease, and information about this disease will continue to develop. Thus, the new guidelines and new adaptation techniques of pediatric anesthesia may change according to new developments and knowledge about the COVID-19 disease.

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