Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Editorial

Perioperative Preparations for COVID-19: The Pediatric Cardiac Team Perspective

WORLD leaders and their nations' healthcare systems have seldom been tested as they are currently with the emergence of a novel coronavirus from Hubei province, China, in late 2019. This virus has been named severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). On March 11, 2020, the World Health Organization declared coronavirus disease 2019 (COVID-19) a pandemic. On March 29, 2020, the US Centers for Disease Control and Prevention issued a level 3 warning and a statement recommending that everyone should avoid nonessential travel.[1] As of April 6, 2020, there were more than 1.3 million reported COVID-19–positive patients in the world, and more than 81,000 people had died of the disease. In just less than 1 month, COVID-19 became the third-leading cause of death in the United States after heart disease and cancer.[2] It was reported that asymptomatic individuals could transmit COVID-19.[3,4] Therefore, estimating the asymptomatic proportion of the population is a useful method to gauge the true burden of the disease and better model true estimates of COVID-19 transmission potential.[5] Using recent evacuation and quarantine data, the asymptomatic proportion of COVID-19–positive individuals was reported as 17% to 30%.[5,6]

As perioperative physicians with expertise in providing anesthesia for critically ill patients undergoing cardiac surgery and other cardiac procedures, the clinical skills of the cardiac anesthesiologist may be helpful in the care of the anticipated large number of critically ill COVID-19 adult patients.[7] Our critical care colleagues may need our assistance, as illustrated in 3 reports from Hubei province, where 20% to 25% of critically ill COVID-19 patients required intubation, ventilation, and invasive monitoring in the intensive care unit (ICU) and where 60% to 70% of ICU patients developed acute respiratory disease syndrome.[8-12] The purpose of this freestanding editorial is to review the literature and present current recommendations to inform the pediatric cardiac team preparing to take care of all children and adults during this COVID-19 pandemic.

Institutional Initiatives

An institution's response to the COVID-19 pandemic may be influenced by the proximity to an epicenter of COVID-19 outbreak and the institution's prior experience with a pandemic. Most healthcare institutions have rapidly set up local and regional COVID-19 command centers, with key stakeholders from local government, hospital leadership, emergency medicine, anesthesiology, intensive care, infectious disease, surgery, and nursing.[13,14] These teams meet once or twice per day in online virtual meetings to address the rapidly changing needs and logistical planning necessary for a tiered response of the hospital system to the anticipated surge in patients who will present with COVID-19. In addition, it is very helpful to set up a local scientific advisory committee of key experts from all disciplines.[15] Meetings are held virtually to rapidly assess peer-reviewed evidence and personal correspondence with colleagues treating COVID-19 patients in other parts of the world. The scientific advisory committee can quickly assemble documents to help inform the COVID-19 command centers, who then can disseminate critical information to all members of the healthcare team.

Protecting Our Patients and Healthcare Workers During Procedures

There is no emergency in a pandemic. Taking the time to "don and doff" personal protective equipment (PPE) correctly protects our colleagues and us so that we all can continue to safely care for sick patients in the long term.[16] It has been argued that previous pandemic plans and their existing ethical guidance often have been ill-equipped to anticipate and facilitate the navigation of unique ethical challenges that arise during infectious disease pandemics.[17] This uncertainty (eg, the scale of anticipated patients and potential ventilator shortages during a pandemic) is difficult to anticipate.[17] To meet the challenges of the COVID-19 pandemic, professional societies, healthcare institutions, and hospital networks have set up local and regional ethics committees and developed guidelines to help inform decision- making for critically ill patients, including front-line clinicians, hospital administrators, professional societies, and public health or government officials.[15] It is critical to limit the risk of exposure within the team and to plan for potential staffing shortages because team members exposed to COVID-19 will need 14 days of quarantine before coming back to work. Healthcare facilities cannot inform healthcare

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workers (HCW) if any colleagues they work with have tested positive for COVID-19. Furthermore, not all HCWs who are ill with COVID-19 symptoms are tested. HCWs with presumed COVID-19 illness should not return to work until at least 7 days have passed since symptoms first appeared and at least 3 days of recovery as defined by resolution of fever without the use of fever-reducing medications and improvement in respiratory symptoms (eg, cough, shortness of breath). Other efforts to limit HCW exposure include screening all team members on entry to their healthcare facility, wearing masks in clinical areas, and social distancing.[16] Usually, occupational health teams assess the potential exposures by staff who test COVID-positive. It is safest to assume that anyone with whom we are interacting is positive, and all HCWs should use established best practices.[16] The rules of engagement must be followed—wash hands or sanitize them regularly, maintain social distance, wear appropriate masks in clinical areas, follow all protocols and policies, and do not go to work if sick.[18]

For healthcare systems, the Centers for Disease Control and Prevention and World Health Organization guidelines for PPE should be followed. Local variations may be made depending on what equipment is available. Strategies to decrease the risk of exposure to viral particles during aerosolizing procedures include the use of a powered air purifying respirator devices or an N95 mask with a face shield.[19] Due to the limited availability of PPE, many organizations have created a central airway team to limit PPE usage to a small number of highly trained individuals. During the severe acute respiratory syndrome outbreak in 2003, HCWs who performed intubations had an increased risk of contracting the disease (odds ratio [OR]) 6.6), as were those who performed noninvasive ventilation (OR 3.1), tracheostomy (OR 4.2), and manual ventilation before intubation (OR 2.8)[20,21]

Organizing and Allocating PPE

Organization of PPE, airway equipment, and anesthetic supplies in special carts for COVID-19 cases that may be wheeled to the bedside or used in the operating room avoids the contamination of larger anesthesia workstations. Simpler strategies also include the use of large, clear "to-go" bags containing PPE such as protective face masks, filters to fit on the bag-mask, face shields, gowns, and gloves. Clear plastic household storage boxes can house powered air purifying respirator machines and hoods that can be cleaned easily between patient use.

Monitoring and Use of PPE

Due to the need to closely monitor available supplies and their use, there may be an advantage to creating a team of "PPE guardians." These guardians often are nursing staff from low- census units who can be retrained as PPE guardians to help their frontline colleagues. Each PPE guardian must be familiar with the workflow of his or her assigned unit. They are trained to provide "just-in-time-training" for appropriate PPE use for colleagues and then monitor the donning and doffing process to ensure that team members do not contaminate themselves or others.[22] Areas in the hospital that are not being used during this pandemic, such as conference rooms, can be used for PPE storage. The presence of a PPE guardian allows teams to understand what PPE is available and to provide oversight of PPE distribution. Guardians also can aid in helping teams clean and reuse some PPE. Many centers, including our own, are using ultraviolet light sterilization of N95 masks. This sterilization method uses ultraviolet C radiation to inactivate microorganisms by causing deoxyribonucleic acid damage, thereby preventing replication.[23]

Environmental Safety

Within healthcare facilities, specific rooms are pressurized relative to their surrounding areas in order to protect their contents or the patients from surrounding airborne contaminants. Operating rooms, pharmacy workrooms, and trauma/resuscitation areas are among those where a positive- pressure state is designed to protect sterile medical equipment and patients from airborne bacteria, fungi, and viruses. These positively pressured areas are among the cleanest in the healthcare facility. Under normal operating circumstances, these steps help to ensure a sterile operating environment, with the goal of minimizing the likelihood of surgical site infection. However, with the current COVID-19 pandemic, it is recommended that operating rooms be converted to negative- pressure rooms (similar to triage and waiting rooms, microbiology laboratories, soiled workrooms, janitor's closets) so that infectious transmission or chemical contamination originating from within the room does not occur.[24]

Conceptually, the design of ventilation systems within the hospital requires air movement from clean to less clean areas. The Facility Guidelines Institute 2014 guidelines and state building codes mandated the minimum number of air exchanges per hour within the operating room, which usually is in the range of 15- to- 20 air exchanges per hour. Many, if not most, hospitals exceed this standard. The number of air exchanges per hour determines the time required for the removal of airborne pathogens with 99% efficiency.[25] However, these models are imperfect because they assume the perfect mixing of air within the space and constant aerosolization. The location of air inflow within the operating room is often specifically designed so that it disperses any airborne contaminants downward from the patient and away from the anesthesiologist at the site where airway management typically occurs.[26] Rules governing design and capacity of hospital ventilation systems are governed by the Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health for the purposes of employee health and safety.

Conversion of a positive- pressure room to a negative- pressure room may be accomplished by building an anteroom at the site of patient entry into the operating room and sealing off additional access points to the room. Airflow within the operating room also must be reversed.[24,27] The anteroom allows for the passage of equipment and personnel without contaminating the surrounding environment. It should be large enough for the passage of a large hospital bed and permit adequate space for donning and doffing of

PPE. In addition, it should have a self-closing door so that negative pressure in the room remains. The considerations for these changes are complex and require close collaboration with hospital epidemiology, facilities management, and industrial hygiene specialists.[27]

In the context of a pandemic, minimizing environmental contamination by respiratory droplets becomes essential to maintaining the safety of HCWs, while maintaining efficient patient flow throughout the hospital. The essential role of environmental services staff members often is underrecognized and underappreciated. After the use of an operating room for a COVID-19 patient, allowing adequate time for aerosolized particles to settle and for air exchanges to occur (usually 60-90 minutes) is essential for the safety of environmental services staff members. This is counter to the usual production pressure that governs the perioperative environment.[28,29] A thorough cleaning of all surfaces within the operating room during a terminal cleaning while wearing full PPE is essential to prevent virus transmission to others who will be in contact with these same surfaces within the hours or days that follow. Checklists designed to improve the thoroughness of the cleaning process help to ensure that operating room surfaces do not serve as a source of infection for HCWs. In addition, testing for residual biologic residue after cleaning, such as adenosine triphosphate testing, may serve as a check on the thoroughness of operating room cleanliness.[30]

Procedures Performed in the Cardiac Operating Room and Cardiac Catheterization Laboratory

Despite the almost universal moratorium on elective surgery during this pandemic, many newborns with complex congenital heart disease will require cardiac catheterization interventions and cardiac surgery in the first weeks of life. Palliative cardiac surgery for functional single- ventricle patients cannot always be delayed. Heart and lung transplantation programs must continue surveillance for rejection in their patients and currently are faced with the tough decision of who should undergo transplantation urgently or who can wait. Programs also have the difficult task of minimizing the risks of successfully transplanted patients from acquiring COVID-19 in the hospital. There are recent reports on the safe use of the cardiac operating room without contamination for emergency cardiac surgery in COVID-19–positive adult patients.[31,32] One important consideration that can affect urgent and emergency cardiac surgical decision- making is the current shortage of blood products being reported during the COVID-19 pandemic.[33] Although it is not very likely that the coronavirus can be transmitted through allogeneic blood transfusion, this remains to be fully determined.[33] Therefore, it is important for all cardiac surgery programs to procure enough blood products for high-risk cardiac surgeries that usually require additional blood products.[33]

Many hospitals and organizations have created exposure risk stratifications based on clinical duties and procedures. High-risk procedures are defined as those that cause aerosolization of viral particles and often involve instrumentation of a patient's airway during intubation and bronchoscopy.[18] The cardiac anesthesiologist regularly takes care of patients for these procedures. The cardiac catheterization laboratory should be prepared to manage unrelated cardiac conditions or patients with cardiac manifestations of COVID-19. Even though most patients with COVID-19 improve rapidly after a mild disease course, a significant proportion develop hypoxemic respiratory failure with viral pneumonia and diffuse alveolar disease that can progress to the need for veno-venous or arteriovenous extracorporeal membrane oxygenation (ECMO). Therefore, it is highly likely there will be an increased need for the pediatric catheterization laboratory to transition adolescents and young adults to ECMO in the hope of a recovery from COVID-19.[34] The Extracorporeal Life Support Organization and all of its worldwide chapters have released guidelines to describe when and how to use ECMO in COVID-19 patients.[34] They do not recommend institutions starting a new ECMO program just for COVID-19 patients, and currently there are shortages of ECMO equipment worldwide.[35] Even before ECMO, COVID-19–positive patients may undergo a number of investigative and therapeutic procedures requiring the expertise of the cardiac anesthesiologist. The perioperative anesthetic management of COVID-19–positive patients has been published in a very timely manner, and several excellent review articles are available.[12,21,36,37]

The risk of aerosolization and airborne transmission of SARS-CoV-2 during airway-generating medical procedures (AGMPs) is especially pertinent to the pediatric cardiac anesthesiologist given the high viral loads within the nose and nasopharynx of COVID-19–positive patients.[38] Aerosol formation during AGMP may be divided into procedures that induce the patient to produce aerosols (eg, bronchoscopy, intubation, cough-like force during cardiopulmonary resuscitation) and procedures that mechanically generate aerosols themselves (eg, bag-mask ventilation, nasotracheal suctioning, tracheostomy tube change, noninvasive ventilation, high-frequency oscillatory ventilation).[39] Among the various AGMPs, a systematic review showed that tracheal intubation was associated with the highest risk of transmission of acute respiratory infections to HCWs.[40] Experimental studies on the stability of SARS-CoV-2 in aerosols and on various surfaces (eg, plastic, stainless steel, copper, and cardboard) showed that SARS-CoV-2 remains viable up to 72 hours, indicating that aerosol and fomite transmission is plausible.[40] The use of a 3-layered clear plastic drape configuration during extubation in a simulated mannequin model has been shown to limit aerosolization and droplet spray significantly.[41] The first layer was placed under the head of the mannequin, a second torso-drape layer was applied from the neck down covering the chest, and finally, an overhead top drape was placed over the mannequin's head to prevent contamination of the surrounding surfaces, including the HCW. Similarly, experiments in cadaveric models showed a high risk of aerosolization during endoscopic endonasal surgery.[42] The pediatric cardiac anesthesiologist will be called on to help with placement of the transesophageal echocardiography (TEE) probe in COVID-19 patients because it is considered a significant AGMP.[43] Recent guidelines by the American, British, and Italian Societies of Echocardiography recommended that only a limited goal-directed examination should be performed in emergency life-saving situations, ideally with the TEE probe in a protective sleeve. An experienced airway proceduralist, such as a cardiac anesthesiologist, may be the best HCW to pass the echocardiography probe, in full recommended PPE. The TEE results should be reviewed well away from the patient.[43-47]

The Italian Society of Interventional Cardiology, the American College of Cardiology's Interventional Council, and the Society of Cardiovascular Angiography and Intervention recently published consensus statements on the care of COVID-19 patients in the cardiac catheterization laboratory.[28,29] During procedures in the catheterization laboratory, the risk of radiation necessitates wearing a protective lead apron and thyroid shield before donning PPE. Another important consideration is to remove all possible emergency medications that may be required during the procedure from the anesthesia workstation. This will prevent the reopening of the anesthesia workstation and potential contamination of all anesthetic supplies in the workstation. Ideally, the anesthetic workstation should be covered in a plastic sheet as a barrier to reentry to help minimize cross-contamination. Catheterization laboratories and cardiac operating rooms use positive ventilation systems and are not designed for infection isolation. Therefore, these rooms will require conversion to an air neutral or negative-pressure room to care for COVID-19 patients safely. In addition, the room will require a terminal clean at the end of the procedure.

The Role of the Cardiac Anesthesiologist in the ICU

In preparation for the COVID-19 pandemic, it is most important for hospitals to be able to increase their ICU beds to be able to care for the surge in COVID-19 patients. An example of this is a team in Italy who had to quickly ensure that enough ICU beds were available and that all staff were fully trained in the safe use of PPE.[14,48] Healthcare organizations have a limited number of respiratory therapists or intensivists. Adding to the challenge of a surge in the patient population, staff members may become ill, leaving ICU teams understaffed.[49] Cardiac anesthesiologists are very likely to be called on to aid in ICU patient care due to their expertise in cardiopulmonary physiology and procedural skills. Familiarity with pulmonary, vascular, and cardiac physiology enables the cardiac anesthesiologist with a unique skill set to care for COVID-19 patients in an expanded ICU setting. Some emergency room and ICU teams have developed procedural teams. Similar to airway teams, the most experienced personnel on these teams are able to obtain vascular access on unstable patients.[14] Depending on the unit workload, these team members also may be part of the airway team. This allows a small group of experts to be exposed to a patient during times of high potential risk of viral aerosolization. Team members who are in a high-risk category for SARS-CoV-2 infection due to age or comorbidities should not be expected to participate in these COVID-19 teams but encouraged to support the team in other ways by taking care of patients at low risk of viral infection.

Conclusion

The pediatric cardiac anesthesiologist is in a unique position to play a significant leadership role in the current rapidly changing COVID-19 pandemic. This freestanding editorial has highlighted the important hospital and regional initiatives in which the assistance of the pediatric cardiac anesthesiologist can help guide medical decision- making. In addition, considerations for the anesthetic care in the catheterization laboratory and cardiac operating room of COVID-19 patients have been reviewed.

Conflict of Interest

None.

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