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Recommendations for developing clinical care protocols during pandemics: From theory and practice



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In 2019, a novel coronavirus called the severe acute respiratory syndrome coronavirus 2 led to the outbreak of the coronavirus disease 2019, which was deemed a pandemic by the World Health Organization in March 2020. Owing to the accelerated rate of mortality and utilization of hospital resources, health care systems had to adapt to these major changes. This affected patient care across all disciplines and specifically within the perioperative services. In this review, we discuss the strategies and pitfalls of

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how perioperative services in a large academic medical center responded to the initial onset of a pandemic, adjustments made to airway management and anesthesia specialty services – including critical care medicine, obstetric anesthesiology, and cardiac anesthesiology – and strategies for reopening surgical caseload during the pandemic.

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Introduction

In 2019, a novel coronavirus called the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) led to the outbreak of the coronavirus disease 2019 (COVID-19), which was deemed a pandemic by the World Health Organization in March 2020 [1]. Consequently, the pandemic led to an accelerated rate of death and severely limited hospital resources. With the initial limitation of personal protective equipment (PPE) and uncertainty of disease burden and treatment, hospitals across the globe had to adapt to the unprecedented changes. In this review, we discuss the strategies and pitfalls of how perioperative services in a large academic medical center responded to the initial onset of a pandemic, adjustments made to airway management and anesthesia specialty services, and strategies for reopening surgical caseload during the pandemic.

Initial hospital response to the onset of the pandemic

By early March 2020, it was clear that the increase in COVID-19 infections and lack of concrete knowledge with respect to the virus' transmission necessitated reviews of the health system's capacity and development of a plan. It was important for leadership that as COVID-19 infections increased, patients were not disenfranchised and continued to receive top rate care, and that their healthcare workers (HCW) remained safe. For this to be achieved, it was advised that separate task forces be put into place to manage in-patient factors and to oversee surgical and procedural volumes. The surge plan for in-patients needed to consider both COVID-19 positive patients, as well as integrate anticipated seasonal hospital volume. Such protocols included indications for intensive care unit (ICU) admission, room choice, patient cohorting, guidelines for donning and doffing PPE, nursing ratios, and the mandate that an anesthesiologist perform all intubations. Owing to the initial unknown risk of viral transmission, the anesthesiology attending or most experienced anesthesiologist intubated any patient suspected to have or who had COVID-19. It has been shown that anesthesiologists were at the leading front in the treatment of COVID-19 patients [2,3]. Initially, anyone caring for a COVID-19 suspected or confirmed patients was asked to comply with standard, contact, droplet, and airborne precautions.

In order to successfully manage procedures and operations in a large academic medical center during a pandemic, there were many variables that warranted consideration (Table 1). In the event that the hospital neared full ICU capacity, a tiered plan for increasing ICU availability was required. This included the use of the preoperative and preprocedural areas, the post anesthesia care unit, and the operating rooms. It was critical that the overall census of the health system was consistently evaluated daily in order to safely manage all patients. Research shows that predictive models using epidemiological parameters may prove beneficial in these situations [4]; therefore, collaboration with an epidemiological team forecasting COVID-19 projects was deemed essential [5]. This type of collaboration was utilized to get a more strategic sense when it was best to accept patient transfers to assist other health systems that were overloaded.

At the onset of the pandemic, PPE was one of the most difficult items to initially manage since the mode of transmission was not clear and rapidly changing guidelines were leading to the overuse of PPE, as seen in many places [6]. Additionally, the concern from HCW about reports of in-hospital transmission at other institutions further complicated this delicate situation. Leverage of information technology was key, for example, the creation of a dashboard that was updated daily from the

Table 1
Specific concerns during pandemic and recommendations for considerations.

COVID Concerns	Considerations	Review system
Overall Census	<ul style="list-style-type: none"> • Surgical volume interference with ICU bed capacity • Use of preoperative and post-operative space or the ORs for ICU patients • COVID positive patient trends 	<ul style="list-style-type: none"> • Daily Calls • Dashboard • Weekly discussions with epidemiologists • Weekly Calls
Medications	<ul style="list-style-type: none"> • Cut procedural and operative volumes if shortages prevent care of ICU patients • Determine alternative drugs to use in anesthesiology • Manage overall health system supply by moving medications between locations 	
Personal Protective Equipment	<ul style="list-style-type: none"> • Areas of the hospital needing PPE • Providing specialty carts with intubating equipment • Managing PPE requirements based on guidelines • Creating policies to allow reuse 	<ul style="list-style-type: none"> • Daily Calls • Dashboard
Health Care Workers	<ul style="list-style-type: none"> • HCW with symptoms were tested and remained at home • HCW out with COVID • HCW needed to stay home to care for family • HCW afraid to contaminate family • Crowding of workspace • Visitors bringing in virus 	<ul style="list-style-type: none"> • Daily Evaluations with nursing management • Weekly evaluation of percentage positive infections among HCW • Worked with facilities and leadership to decrease risk at work • Local hotel rooms for HCW after shifts

Abbreviations HCW = health care worker, ICU = intensive care unit, OR = operating room.

purchasing department for PPE to keep up with the demand. The usual practice prior to the pandemic for face masks in the operating suite was to dispose masks after every use. However, because supplies became too low due to pandemic, new policies were developed; including surgical masks were not replaced between seeing patients and a policy implemented that allowed the reuse of N95 masks. To ensure that the necessary PPE was available to those who were intubating patients or taking care of COVID-19 positive patients in the operating room, specialty “COVID carts” were set up and placed in the ICU and outside the designated COVID-19 operating rooms. These carts contained intubating equipment, gloves, protective gowns, a powered air purifying respirator (PAPR), N95 masks, and instructions on how to properly don and doff PPE [7–9].

Monitoring Disease Spread Among Healthcare Workers. The health of those providing care and their families was of utmost importance. Different healthcare systems approached thresholds for quarantining among their healthcare providers. Owing to the initial uncertainty with respect to the way in which COVID-19 was transmitted and the lack of tests at the beginning of the pandemic, anyone with symptoms was asked to remain at home until they felt better. To preserve the health of their workers, the health system arranged for hotel rooms to be provided post-shift, placed more tables for outside dining, separated in-door furniture, and limited visitors. Once testing sites affiliated with the healthcare facility expanded, routine testing of healthcare providers was key in maintaining a healthcare workforce during the pandemic. These test sites were drive-by and similar to many others around the country [10]. At our institution, our ability to provide testing rapidly increased as the laboratory capacity improved and turnaround time for test results rapidly decreased. By the third week of August, 2020, unlimited testing was available for all HCW with symptoms or possible exposure and anyone who was not feeling well was required to stay home [11].

Response to the pandemic in the Perioperative Setting

Identifying Essential Surgeries. Early in the pandemic, many healthcare systems mandated the cancellation of all elective surgeries. Such reduction in surgical volume placed a large financial toll on hospital systems. Healthcare systems had to rapidly transition to performing “essential surgeries” only; however, the definition of essential surgeries was not clear-cut. Our institution used the definition of any surgery in which a 4–6 week delay would result in adversely affecting prognosis or quality of life [11]. Since there was great variation in this interpretation, we asked surgical chairs and division chiefs to assess their cases and postpone those not meeting essential criteria. Those cases left on the schedule were then approved by perioperative leadership consisting of a surgeon, anesthesiologist, and hospital administrator.

COVID-19 testing for all surgical patients. Within two weeks of ramping down surgeries, our health system had put into place COVID-19 testing for all preoperative patients within 72 h of surgery. Any positive results warranted a call from a trained nurse on the infectious disease team. At that time, the nurse would go over quarantine guidelines with the patient, as well as assist with triaging the patient if they had symptoms. If the patient had a condition that could be delayed, then on the advice from infectious disease, they were retested 14 days later. The decision about optimal timing to proceed with future surgeries depended on the urgency of the surgical procedure and the nature of the COVID illness, as there was concern over increased morbidity and mortality in the perioperative period in patients infected with COVID [12]. Patients were allowed to proceed to surgery after 14 days in the case of urgent procedures. If the procedure could not be delayed, then the procedure was done in an operating room specifically set up for COVID-19 patients.

Dedicated Operating Rooms for COVID-19 patients. In our large healthcare system, it was strategic to designate operating rooms only for COVID-19 patients. These rooms were set up with minimal supplies and equipment to minimize the number of things that needed to be cleaned or thrown out after a case. Prior to entry to a COVID-19 OR, donning guidelines were closely followed. A recommended setup for utilization of a dedicated COVID-19 operating room included two nursing teams – one that was in the operating room, and one that was outside of the operating room. These teams communicated through phone to minimize the opening of the OR doors. The fewest number of people possible took part in the surgery and the surgical attending performed the case so that the time in the operating room was limited. From an anesthesia standpoint, every effort should be made to not mask ventilate the patient due to the fear that it could spread the virus through aerosolization [12]. After the surgery, if the patient was extubated, they recovered in the operating room, while those who remained intubated went directly back to the ICU.

Personal Protective Equipment in the Perioperative Setting. It is recognized that much has changed and our knowledge has broadened since the initial days of the pandemic. The Centers for Disease Control and Prevention now advise that to protect from COVID-19, HCW should take contact and droplet precautions, and they have removed airborne precautions. When in the presence of COVID-19 positive patients, the following PPE is now recommended: a medical mask, goggles or a face shield, gloves and a clean, nonsterile surgical gown [13]. However, until there is mass vaccination, most HCW still prefer to wear an N95 or PAPR, especially during aerosolizing procedures, for patients with known or suspected COVID-19, and our health system has fully supported this so as to allay any fears.

Airway management of patients with or suspected COVID-19

Severe hypoxemia is one of the prime manifestations of COVID-19-related deterioration. In contrast to other forms of hypoxic respiratory failure, a majority of patients with COVID-19-related hypoxemia often do not show clinical signs of overt respiratory failure [14]. In milder forms, supplemental oxygen might be sufficient to keep the oxygen saturation rate above 92%. It has been reported that “self-proning” might further improve oxygen saturation in some but not all patients [15].

Especially in the beginning of the COVID-19 crisis, there was controversy about the use of oxygen delivery via high flow nasal cannula. While high flow nasal cannula has been shown to significantly improve oxygenation and avoid intubation, there was significant concern about its use in COVID-19 patients due to potential aerosolization and infection of healthcare providers. However, the

aerosolization risk has been shown to be relatively low and the wide availability of PPE further minimized the risk to healthcare providers [16]. Therefore, supplemental oxygen therapy with high flow nasal cannula is now widely used in our institution.

While noninvasive ventilation has been shown to prevent intubation in mild to moderate ARDS [24,215,648] it has also been demonstrated in earlier pandemics that noninvasive ventilation increased nosocomial infections [17]. However, with the rigorous use of PPE this seemed not to hold true during the current COVID-19 pandemic. In a single-center study, the use of noninvasive ventilation avoided invasive mechanical ventilation in over 50% of patients [18].

Based on the available literature the following algorithm was adapted in our center and is recommended. Patients with COVID-19 were supported with supplemental oxygen to maintain saturation >92%. At this stage, self-proning was encouraged. If a patient was unable to maintain oxygen saturation >92%, the next step would be high flow nasal cannula oxygen and/or noninvasive ventilation would be attempted. If the patient showed physical signs of respiratory distress or the oxygen saturation fell below 90% for longer periods of time despite these noninvasive steps, we proceeded with intubation and invasive mechanical ventilation (Fig. 1).

Endotracheal intubation in patients with COVID-19 occurs for two reasons: persistent hypoxemia despite noninvasive ventilation or need for secondary surgical procedures. The goals for intubation remained the same regardless, but the degree of hypoxemia in these patients and the disease progression significantly altered our approach to airway management. In March 2020 much remained unknown regarding the SARS-CoV-2 virus and the risk of transmission during aerosol-generating procedures, such as intubation. The 2003 SARS epidemic demonstrated that HCW participating in aerosol-generating procedures were at increased risk of contracting the virus [19] and early data from Wuhan, China supported this finding in this current pandemic [20]. Protecting both patients and HCW was critical when approaching patients that required intubation. In order to achieve these goals, we focused on optimizing the patient prior to intubation attempts, minimizing aerosolizing the virus, maximizing first-attempt intubation success and reducing the exposure to HCW caring for patients with COVID-19.

To protect the HCW caring for the patient with COVID-19, the goals for intubations were to reduce the potential for aerosolization and to reduce the number of individuals who might be exposed. For these reasons, we limited the number of people in the room during intubation to three: the anesthesiologists, the bedside nurse, and a respiratory therapist (during out-of-operating room intubations). All of these individuals wear protective gear, including N95 facemasks or PAPR, eye protection and protective gowns and gloves.

The approach to intubation in patients with COVID-19 infections differed from our approach in non-COVID patients. As described above, the goal was to minimize the amount of aerosolization during the intubation process to prevent potential exposure to those caring for the patient. For this reason, the most skilled anesthesiologist/anesthetists performed the intubation to increase the success rate on the first laryngoscopy. This has led to the anesthesiology team performing all intubations of COVID-19 patients throughout our hospitals. A rapid sequence induction is the preferred method for ensuring that the patient is adequately anesthetized and not coughing during laryngoscopy. However, a true rapid sequence induction can lead to profound hypoxemia in these patients. Adequate pre-oxygenation is thus all the more paramount. Pre-oxygenation can significantly prolong the time until desaturation in all patients [21]. In patients receiving high-flow oxygen the preferred pre-oxygenation technique is to use a Mapleson system so as to be prepared in the event bag-mask ventilation is necessary following induction. For patients already receiving Bilevel positive airway pressure support (BiPAP), this noninvasive technique is maintained to enhance pre-oxygenation in critically ill patients [22]. Although the goal was to avoid bag mask ventilation, if hypoxemia occurred prior to successful endotracheal intubation, bag mask ventilation was utilized.

The use of video laryngoscopy as the primary technique for endotracheal intubation was recommended by many early in the pandemic. This technique may provide increased distance from the person performing laryngoscopy and the airway, potentially offering additional protection. At our institution, we identified many reasons that the use of video laryngoscopy might be preferable but did not insist on its use as the rate of first pass intubation success does not differ between the two techniques [23]. For those who preferred direct laryngoscopy this technique was used. Finally, it is

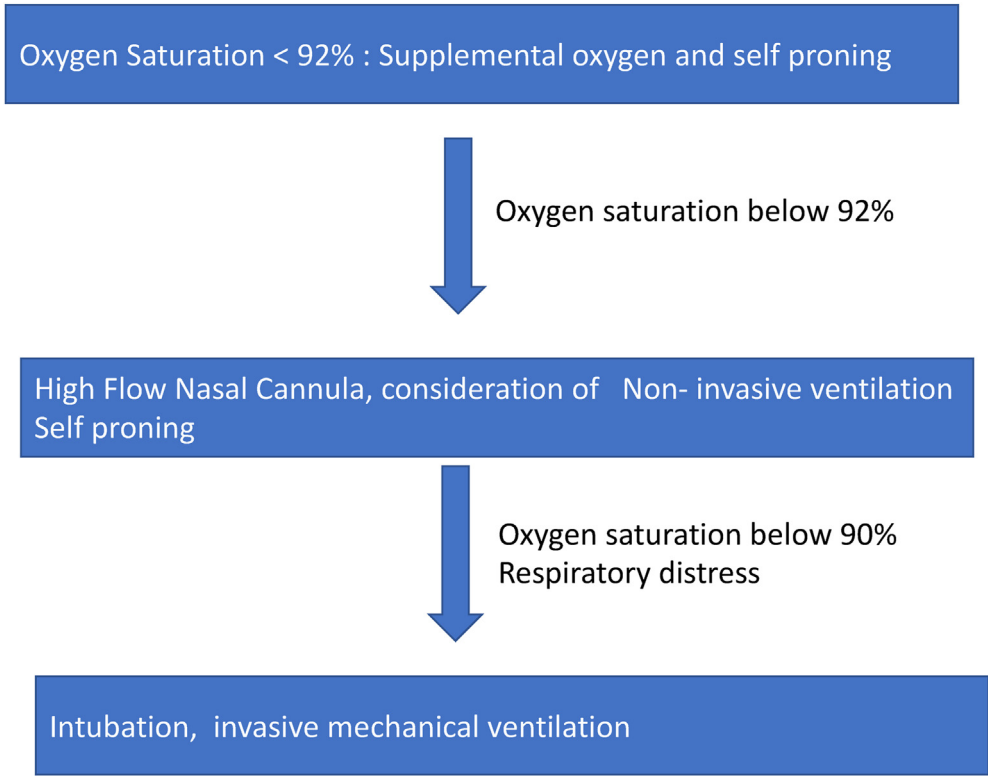


Fig. 1. Recommendations for management of hypoxemia in the COVID patient.

important to note that our institution did not focus on the use of the “Aerosol” intubation box. Dr. Lai created the “Aerosol” intubation box to potentially reduce the spread of virus during intubation [24]. Conflicting data exist about the potential for these intubation boxes to reduce the amount of aerosolization of virus [25]. More importantly, the time to successful intubation is prolonged with such a device [26]. A recent analysis of available studies has revealed that intubation boxes do not negate the need for adequate PPE. Furthermore, the authors concluded that these boxes should be avoided until adequate validation studies can be reported [27]. Given the goal of protecting both HCW and the patient, as well as the fact that we had sufficient PPE, maintaining normal intubation techniques was our priority.

Difficult Airways. The unanticipated difficult intubation during the COVID pandemic presented unique challenges. The COVID airway cart holds all supplies that could be needed for a difficult intubation, including supraglottic airways that could accommodate subsequent intubation, a disposable fiberoptic bronchoscope, and cricothyrotomy kits. For unanticipated difficult intubations, there was a preference to move quickly toward supraglottic airway placement. Supraglottic airways do not eliminate the potential for aerosolization, but when these devices are positioned well with a good seal, ventilation can occur more optimally with lower airway pressures, reducing significant hypoxemic events. Supraglottic airways can also act as a conduit for successful endotracheal intubation via a fiberoptic bronchoscope.

The anticipated or known difficult airway posed a larger concern. Topicalization for awake fiberoptic intubations or awake tracheostomies can result in significant aerosolization of SARS-CoV-2 virus. Every attempt was made to avoid these techniques. However, safety of the patient was an equal concern. If appropriate, awake techniques were used. The same PPE was utilized during these awake intubation attempts, number of personnel was minimized, and use of a negative pressure room was preferred.

Airway Management in the Operating Room. Regional anesthesia, either via peripheral nerve block or neuraxial technique, is an attractive option for surgical anesthesia in the COVID-19 patient. Neuraxial and peripheral techniques are not aerosol-generating procedures and carry less risk of nosocomial infection. For appropriate surgical procedures, they can serve as the sole anesthetic, decreasing use of sedatives that may be in short supply due to intensive care demands. [28] COVID-19 infection has been associated with thrombocytopenia, which may correlate with the severity of respiratory disease [29]. Laboratory evaluation for thrombocytopenia should be considered before proceeding with neuraxial or deep peripheral nerve blocks. The threshold for an adequate platelet count prior to procedure varies by individual practitioner, with recent data suggesting that platelet counts greater than $75,000 \times 10^6/L$ lower the risk of epidural hematoma in neuraxial procedures [30]. For a procedure done under sole regional or neuraxial block, there may be no need for further airway management. The patient should wear a standard surgical face mask to reduce contamination of the operating room [31].

For procedures done utilizing Monitored Anesthesia Care (MAC) and some regional anesthetics, supplemental oxygen may be required, especially if intravenous sedation is administered. Supplemental oxygen may increase operating room contamination, depending on the route of delivery and flow rate. As previously reported, simple face masks at lower flow rates (i.e., 4 L/m) likely have the lowest travel of an exhalation jet (0.4m) [32]. Nasal cannula at moderate to higher flows has a longer exhaled jet, up to 1m caudally at 5 L/m flow [33]. It is important to note that the exhalation jet does not necessarily correlate with dispersal of infective droplets. However, it is prudent to use the lowest oxygen flows required to maintain oxygen saturation. Simple oxygen masks at low flows may present the lowest risk of operating room contamination, although this has not been specifically proven. Regardless of the route of administration, the patient may wear a surgical mask over the oxygen delivery device to reduce respiratory droplet spread. Monitoring of end-tidal carbon dioxide has been brought up as a potential source of contamination of the anesthesia machine during a procedure under MAC anesthesia. However, the water trap typically has a filter adequate for the isolation of infective particles and may be changed between cases. Care with level of sedation and airway management during MAC and regional anesthesia is critical. The worst outcome may be the need for emergent intubation due to patient or sedation factors during the surgical procedure, impairing the ability to adequately prepare for the intubation and increasing the risk of transmission. If there are preoperative concerns about the potential need for intraoperative airway manipulation, consider definitive airway management in a controlled fashion at the start of the case.

The use of laryngeal mask airways (LMA) for operative room airway management in COVID-19 patients has not been significantly studied. In general, most LMAs are able to provide an airway seal at low airway pressures. First generation LMAs were found to have a more significant leak than an endotracheal tube (12% vs 1.7%) in controlled low-flow ventilation [34]. However, second generation devices may demonstrate a better seal and less significant leak [35]. The Pediatric Difficult Intubation collaborative published guidelines suggesting a supraglottic airway with a good seal was adequate in some cases, and that a cough with a supraglottic airway device in place was relatively contained. [36] The LMA certainly remains an important airway rescue device in case of unexpected difficult intubation or mask ventilation. Use in a nonemergency setting in the operating room is at the discretion of the anesthesiologist, but an adequate seal and ability to deliver positive pressure ventilation without significant operating room contamination is a prerequisite. If a supraglottic airway is used, the inserter should not place their ear close to the patient to determine leak in order to prevent unnecessary exposure but should instead rely on stethoscope for confirmation to avoid exposure to respiratory droplets.

Endotracheal intubation remains the gold standard for operating room airway management for certain procedures, including many emergency operations. Description of safe intubation practices for the COVID-19 patients was discussed previously. In the operating room during any aerosol generating procedures, staff should be reduced to the minimal safe number. A skilled assistant should be available should an unexpected difficult intubation be encountered. Full PPE should be maintained in the room until 1 h after the aerosol generating procedure. Protocols surrounding endotracheal intubation are encouraged to ensure precautions are followed. Extubation and recovery are an additional source of potential aerosol creation. Insufficient evidence exists to suggest protocolizing deep vs awake extubation in COVID patients. In pediatric patients, deep extubation may decrease the risk of cough but

does not appear to affect the risk of laryngospasm and breath-holding [37]. The benefit of reduced cough must be balanced with the risk of laryngospasm or need for positive pressure mask ventilation. If needed, mask ventilation at low pressures with a 2-hand mask seal may help reduce room contamination. Post-extubation, the patient may be recovered in the operating room, or may be transported to a negative pressure isolation room for recovery depending on institutional preference. Once stable, a surgical mask may be placed on the patients, covering any oxygen delivery devices.

Considerations in critical care management

Designating Teams for COVID-19 Patients. It is likely strategic to physically separate COVID positive and COVID negative ICU patients, as cohorting of patients decreases the risk of cross-contamination [38–40]. Nursing, support, and physician teams should, therefore, also be divided into COVID and non-COVID teams, which switched periodically in order to decrease burnout and fatigue. At our institution, the hospital decided that the medical ICU teams should first take care of COVID positive patients, followed by anesthesia critical care teams once that team census became saturated. Surgical, neurosurgical, and cardiovascular critical care teams would focus on non-COVID patients and were enlisted in the care of traditionally medical ICU patients. It was decided to keep the nursing ratios (one provider to two patients) in the ICU as long as possible and only get out of ratio if absolutely needed, which would require an emergency plan approved by the county. Additional critical care experienced staff were identified within the health system (including anesthesiologists, surgeons, certified registered nurse anesthetists, and PACU nurses amongst others) and these providers were given refresher training should they need to be reallocated to the ICU. Staff surveys about education, experience, and willingness to cross train aided in this effort.

Potential Danger to Non-COVID-19 Patients. One of the dangers of focusing on the care of COVID patients is to sub-optimally treat non-COVID patients. It has been suggested that when ICU capacity is strained, patients may receive sub-optimal care overall and their susceptibility to adverse events may be modified. Clinician behavior and patient care processes may be altered [41]. Additionally, sustained strain may have negative consequences for ICU clinician well-being. ICU leadership focused additional training to mitigate these effects, including the sharing of workload by various ICU services and the routine switching of COVID teams as described previously. Additionally, there have been reports from our health system related to adverse patient outcomes, presumably from patients delaying seeking care because of COVID-19. In response, hospital leadership created an outreach program to the community to emphasize the importance of timely treatment of non-COVID illnesses.

Considerations in obstetric anesthesia

Owing to the unpredictable and time-sensitive nature of pregnancy and delivery, a majority of procedures for the obstetric patient population are nonelective. Consequently, the obstetric anesthesia provider must be prepared to care for confirmed COVID positive patients and patients under investigation (PUI) at any time. The following section covers policies and strategies designed to minimize the risk of infection of HCW while simultaneously providing prompt, safe care to parturients with known or suspected COVID-19 infection [42].

Patient Screening and Testing. The pregnant population is unpredictable in that many deliveries cannot be carefully planned. With the exception of scheduled labor inductions and Cesarean deliveries, a majority of women present in labor without much warning. Identifying women at high risk for exposing providers to COVID-19 is important but difficult, given the prevalence of infected individuals with mild or no symptoms. Thus, all patients and partners *presenting unexpectedly* to labor and delivery were screened in this way:

- Asymptomatic patients that require extended triage or admission for obstetrical reasons were swabbed for a standard, nonrapid, COVID-19 test, and treated with standard precautions until test results.

- Symptomatic patients were given a rapid COVID-19 test when available and categorized as PUI. As such, they were subject to droplet and full contact precautions.
- Known COVID + patients and those who rule in with testing were treated as the symptomatic PUI patients, with isolated rooms and strict adherence to full PPE for providers.

Labor analgesia for the COVID + and PUI parturient. Labor analgesia is considered an important part of peripartum care and should not be withheld or delayed secondary to COVID positive status. Owing to the assumed risk of droplet aerosolization, inhaled nitrous oxide may not be considered for labor analgesia. Epidural analgesia is the standard of care for labor analgesia and is a good option for patients with respiratory symptoms, as it does not contribute to respiratory depression. An advantage of encouraging epidurals for COVID positive women is that functional epidural catheters provide a smooth transition to Cesarean section anesthesia when dosed with more concentrated local anesthetic. Having a good epidural in place may prevent the need for urgent general anesthesia with endotracheal intubation. Avoidance of intubation is important from both a patient and provider safety perspective. COVID-19 patients with respiratory symptoms desaturate more rapidly with general anesthesia induction or be at higher risk for hypoxia and atelectasis with mechanical ventilation.

When entering an isolation room for a procedure, one must consider not just provider safety, but also equipment contamination – thus it is important to consider the idea of creating “COVID Epidural packs.” Our pack included one epidural kit, epidural infusion pump tubing, Tegaderm and tape for securing the catheter, and a Duraprep stick for skin prep. Once an epidural is requested, the anesthesiologist grabs a COVID epidural pack and adds their preferred sterile gloves, loading dose syringe, phenylephrine, and ephedrine, prior to heading into the patient room. Anesthesia providers don full PPE with N-95 mask prior to entering the patient’s room. Once inside, the COVID pack has everything needed to place the epidural and treat potential hypotension without leaving the room or bringing an entire medication/supply cart into the contaminated space.

Cesarean Section Anesthesia for the COVID + Patient. It may be important to designate an operating room in a labor and delivery suite for COVID patients. Such room should be stocked more sparsely, containing only the anesthesia supplies and equipment needed to safely do one case. Additional equipment is located immediately outside the operating room, so that a runner can quickly bring the anesthesiologist items as needed (passed into the room with brief door opening). This operating room also contains a standard obstetric anesthesia medication Pyxis with all drugs needed to perform safe neuraxial or general anesthesia. As with labor epidurals, anesthesia providers wear full PPE and do not exit and re-enter the operating room during the case.

Cesarean deliveries are most frequently done with spinal or epidural anesthesia. Given the physiologic changes associated with pregnancy, general anesthesia carries an increased risk of aspiration, oxygen desaturation, and potentially difficult airway management. These risks of general anesthesia hold true for the COVID positive population. Further, tracheal intubation is an aerosolizing procedure, placing the anesthesiologist at risk of droplet exposure during induction of general anesthesia. Post-operatively, patients frequently cough vigorously at the time of extubation, making emergence from general anesthesia a high-risk event for virulent droplet dissemination. For these reasons, spinal or epidural anesthesia is *strongly* preferred in the COVID patient requiring cesarean section. Neuraxial anesthesia has the added benefit of allowing the patient to continually wear a mask to minimize spread of respiratory tract droplets.

The obstetric patient population provides unique challenges during the COVID-19 pandemic. The time sensitive and unpredictable nature of labor and delivery inevitably exposes providers to patients who have not been pre-screened for symptoms nor tested for COVID. Our institution attempts to identify high-risk patients through symptom screening and performs preemptive COVID testing for scheduled inductions and Cesarean deliveries. COVID positive patients and PUI are placed in isolated rooms with full contact and droplet precautions. Labor analgesia is an important consideration for COVID positive patients and has several potential benefits for patient comfort and safety. To minimize the number of exposed staff members, the most experienced anesthesia provider should place these epidurals when possible. Patients are also encouraged to request epidurals early in the labor course to avoid the heavy breathing associated with severe pain. Patients requiring Cesarean delivery should be

cared for by the most experienced anesthesia provider available, in an operating room reserved for COVID-positive and PUI patients. Spinal or epidural anesthesia is preferable to general anesthesia when time and circumstances permit. It is essential for obstetric, nursing, and anesthesia providers to communicate frequently to avoid the need for urgent delivery whenever possible.

Considerations in cardiac surgery

Similar to policies and practices adopted in any main OR, cardiac surgery should abide by patient screening prior to proceeding with any cardiothoracic surgical case. Further, as with any surgical subspecialty, cardiac surgery is subject to urgent and emergent cases such as Type A dissections. As such, any cardiothoracic anesthesia provider must be prepared to care for COVID positive/PUI patients that may present for surgery.

Patient screening and testing. During the height of the pandemic, most cardiac surgery was restricted to urgent and emergent cases [43]. This is related to often a multi-day ICU stay that is required postoperatively in cardiac surgery patients, which can impact hospital capacity and resources. Once deemed necessary to proceed, all patients presenting for cardiac surgery should be screened for symptoms of COVID-19, such as fever, dry cough, fatigue, loss of smell or taste, myalgias or any other flu-like symptoms, and specifically for recent outside exposures. This is particularly important in the elderly population, who has been shown to exhibit higher mortality from COVID-19 than younger age groups. [44] In addition to routine symptom screening, all patients presenting for nonemergent cardiac surgery should have a preoperative COVID test performed within 3 days of the surgical date. For all patients with a negative test within the designated time frame, symptom and exposure screening should still be performed the morning of surgery. For patients with a negative test and absence of symptoms, they can safely be managed with standard precautions. For patients testing positive or those who are symptomatic, which were identified as a PUI, we discussed further with the surgical team regarding necessity to move forward or if delaying would be within the best interest of the patient and HCW.

Preoperative Assessment of COVID+/PUI Patients. COVID 19 is known to cause myocarditis, which may manifest as heart failure, nonspecific ST-T changes, arrhythmias, or cause release of myocardial enzymes. This may or may not be associated with classical respiratory symptoms. Inflammation of the pericardial sac may result in a pericardial effusion significant enough to cause tamponade physiology. In addition, it is not uncommon to encounter vasoplegia and shock stemming from either sepsis or dysregulation of the renin-angiotensin system. Right ventricular dysfunction secondary to pulmonary vascular abnormality, hypoxia, and subsequent mechanical ventilation is commonly encountered. All these factors negatively influence the carriage of cardiac surgery and its outcome [45].

For any known COVID-19 positive/PUI patient undergoing cardiac surgery in our institution, rigorous safety precautions were implemented. This started with direct admission to the OR so as to eliminate the need of additional exposures in the preoperative holding area. Additionally, any patient already admitted to a hospital room or ICU, was directly transported to the OR. A dedicated OR was assigned for any cardiac surgery case that was done for a COVID positive/PUI patient and clear signage of caution was placed on all doors entering that OR. Ideally, line placement was performed after arrival in the OR, and not prior.

All HCW interacting with the patient wore appropriate PPE, including a disposable surgical cap, gown, two sets of gloves, fit tested N95, and eye protection or face shield. Alternatively, depending on hospital availability and need of the HCW, PAPR was sometimes appropriate. All PPE was worn throughout the case duration with appropriate doffing upon completion [46].

Intraoperative Management of COVID+/PUI Patients. Prior to induction, a discussion took place regarding the necessary number of anesthesiologists needed for successful intubation. At teaching institutions, policies to reserve COVID-positive intubations for faculty only may be considered as a means to reduce trainee exposure; therefore, at our institution, the faculty made the decision as to whether or not it was appropriate for the trainee to intubate. Additional staff with appropriate PPE were available outside of the room should extra help be needed. Rapid sequence induction was considered standard for these patients to minimize any mask ventilation and additional aerosol generation. Video-laryngoscopy has become standard use for COVID positive intubations as this may yield

a success rate that would reduce the need for multiple direct laryngoscopy attempts; however, use of this tool was subject to the attending anesthesiologist's preference. [47] In academic centers, it would be appropriate to have any attending anesthesiologist only cover one OR when managing a COVID-positive case, as this would reduce the cross-contamination when going between rooms during the day.

In the case of COVID-positive/PUI patients, a discussion with the surgical team was needed to decide on the necessity for the use of transesophageal echocardiography (TEE) during the case. If absolutely necessary, placement and use should proceed with caution. Prior to TEE probe placement, suctioning of the stomach to remove air content can be omitted. Despite a lack of confirmatory evidence, TEE probe placement and manipulation is considered by experts as an aerosolizing procedure. It follows that probe manipulation should be kept to a minimum, and the exam should be performed by an experienced clinician. At the end of the case, removal of the TEE probe should be done with caution.

Placement of any additional lines including central venous catheters and pulmonary artery catheters should all be performed using ultrasound/TEE guidance to reduce procedure time and increase first pass success. Minimal disconnection of the ventilator circuit is needed to reduce exposure. One consideration here is the occasional need for inhaled nitric oxide (iNO) for RV support. In a case where iNO may be needed, the insertion into the ventilator circuit should be done at the start of the case. If there is a need for cardiopulmonary resuscitation in the OR, chest compressions should ideally be done by one provider, while one other provider administers medication. Prolonged resuscitation in the face of anticipated futility should be avoided to mitigate risk [48].

It is also important to note that both hydroxychloroquine and azithromycin, which COVID 19 patients may be on, can cause QT prolongation. This can predispose to serious arrhythmia during cardiac surgical procedures. Fortunately these drugs are no longer considered frontline therapies, but it is possible to come across patients who have been on them. The data on drug interactions with remdesivir are scant as of now, but vigilance is needed for what could be an interaction in a multi-drug-use situation as is the cardiac OR [49].

Steps for preparing Re-Opening of surgical volume and maintaining safety

Once state and local regulations allowed for nonessential surgeries to resume, the operating room volume was ramped up in an incremental manner, with the recognition that the health system must be prepared to respond and adjust to fluctuating COVID-19 patient volumes and other critical resource needs. In addition to complying with county and state regulations, our decision and implementation plans aligned with best practices as outlined by the Centers for Medicare and Medicaid Services, the American College of Surgeons, and other professional societies. Additionally, we recognized the importance of clear and effective communication to our personnel and the community at large regarding safeguards that were in place, so that patients and healthcare teams felt safe in our institution. As an example, we developed scripting for our surgery and procedural scheduling teams to use during phone calls, which outlined these aforementioned measures.

Screening of patients and employees for symptoms of COVID-19 was integral to maintaining a safe working environment. All scheduled surgical and procedural patients were required to undergo COVID-19 testing 48–72 h prior to surgery, as well as symptom screening over the phone and prior to entry to the medical center. After testing, patients were advised to quarantine at home until the day of surgery. Patients coming in for urgent surgery who did not have COVID-19 testing were immediately placed on isolation precautions and tested for COVID-19 via rapid assay. All peri-operative staff were tested for active COVID-19 infection and antibodies prior to reopening the ambulatory surgical center and employees had ongoing access to testing via a dedicated employee health phone scheduling system. Employees were screened for symptoms at the entrance to the medical center and those that did not feel well were encouraged to stay home and get tested. Of note, a dedicated COVID-19 officer was appointed for the Department of Anesthesiology to assist in this process. Since the initial reopening of surgical volume, employee screening has evolved to a required daily online “symptom checker,” as well as required weekly COVID-19 testing.

Prior to re-opening of surgical volume, perioperative leaders drove planning efforts that included meetings with department and division leadership to review postponed cases, and to reassess cases

that had become more time-sensitive during the COVID-19 shutdown. There had to be a careful balance in the surgical schedule between current volume and rescheduling those cases that had been postponed. To aid in proper rescheduling, department and division leadership were asked to identify cases that could be shunted to our outpatient facilities, as well as cases that were consistent with low resource intensity within the inpatient environment. During the case resumption period, a new block schedule was created and published and block time released at seven days (rather than the pre-COVID-19 72 h) This time was released to preoperative services and used for scheduling of postponed cases. Many factors were considered in determining the appropriate allocation of surgical block time to services including the proportionate amount of time they had pre COVID-19, the volume and utilization of time by the service pre COVID-19, as well as the service-specific backlog generated by eliminating nonessential cases during the initial surge of the COVID-19 pandemic. All of this was done in an effort to maximize efficiency and conserve resources.

Post-surgical discharge location was closely monitored because of COVID-19's effect on the community. For example, patients needing post-operative placement in a skilled nursing facility were not always allowed to proceed, as many of the facilities had outbreaks that prevented patients from having a guaranteed discharge bed post-operatively. Any patient who was admitted under the category of "outpatient in a bed" had expedited evaluation of their discharge readiness in order to minimize time in the hospital. While normally not done, some patients were transferred between the institution's campuses in order to manage the surgical flow, so that the efficiency of the OR schedule could be maintained.

Conclusions

Though the pandemic has caused many alterations in the way that HCW wear PPE, the management of the ICUs and the ORs, and the way in which symptomatic patients are approached, it has been through the careful implementation and adherence of protocols and testing that has allowed us to continue to provide healthcare to our patients, as well as assist other health systems in managing their patient populations. Our routine testing for our HCW and patients has instilled a level of confidence that our clinics and hospitals are safe and allowed surgical volumes to increase rapidly after the initial surge. With the current surge, the focus is less on whether or not COVID-19 will infect HCW or other patients, but on how the overwhelming number of patients is flooding the system. Therefore, surgical cases are often curtailed secondary to a lack of ICU beds or due to an overflow in the Emergency Department. It is our hope that the roll out of the vaccines will be the next step in curtailing the pandemic and setting us on a path back to normalcy.

Practice points

- During a pandemic, healthcare systems need to quickly establish a strategy to optimize hospital bed availability while maintaining optimal care
- It is crucial to establish a plan to determine what constitutes essential surgery to optimize perioperative services
- Algorithms need to be developed for airway management during a pandemic
- When reopening a healthcare system during a pandemic, it is crucial that a well-developed plan is implemented in a timely manner

Research agenda

- We need national studies looking at varying responses to a pandemic and how that either positively and negatively affected patient care
- We need more studies on the cost-effective analysis of preserving hospital capacity in the setting of limiting nonessential surgeries
- More studies are needed to aid healthcare systems to intelligently predict resource utilization based on regional patterns during a pandemic

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RW helped conceptualize the project, writing the original draft, and editing/reviewing the subsequent drafts.

AB helped conceptualize the project, writing the original draft, and editing/reviewing the subsequent drafts.

KR helped conceptualize the project, writing the original draft, and editing/reviewing the subsequent drafts.

BF helped conceptualize the project, writing the original draft, and editing/reviewing the subsequent drafts.

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LW helped conceptualize the project, writing the original draft, and editing/reviewing the subsequent drafts.

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SS helped conceptualize the project, writing the original draft, and editing/reviewing the subsequent drafts.

RG helped conceptualize the project, writing the original draft, and editing/reviewing the subsequent drafts.

Declaration of competing interest

None.

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