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SHORT REPORT

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Systems-focused simulation to prepare for COVID-19 intraoperative emergencies

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1 | INTRODUCTION

Although intraoperative emergencies are uncommon,[1] we faced a need to develop evidence-informed and contextualized guidance for intraoperative emergencies involving patients with COVID-19. At our academic pediatric hospital, we assembled a multi-disciplinary team to examine and adapt intraoperative emergency workflows to ensure safety for patients with suspected COVID-19 infection and limit exposure for healthcare providers, with a focus on *system improvement* (rather than individual performance). This was achieved using in situ simulation with experienced clinicians employing a modified Promoting Excellence and Reflective Simulation Framework (RFS)[2] and *pause and reflect* debriefing.[3] We aimed to identify potential failure and success points in our existing practice and establish safe COVID-19-related emergency response procedures.

2 | METHODS

This project was determined to not be human subjects research by the Children's Hospital of Philadelphia Institutional Review Board and therefore exempt from informed consent.

A ventilated high-technology manikin was used for an in situ simulation of a healthy 25 kg, 7 year-old with COVID-19, presenting for an urgent lower extremity fracture repair in a functional negative-pressure operating room (OR). The simulated child developed stable supraventricular tachycardia (SVT) while under general anesthesia. The SVT was unresponsive to vagal maneuvers and intravenous adenosine, and the patient developed hemodynamic instability after a synchronized cardioversion. This patient's cardiac rhythm deteriorated to ventricular fibrillation, which resolved following CPR and defibrillation according to appropriate algorithms.

Two anesthesiologists, a circulating nurse, and a scrub nurse were inside the OR (hot zone) at the start of the simulation. A nurse trained in donning and doffing personal protective equipment (PPE) served as a PPE coach and supervised donning of PPE in the cold zone. This nurse also assisted with transferring additional supplies into the room. A second PPE coach was in the warm zone to help with PPE doffing and to redirect the flow of personnel to the cold zone prior to entering the OR. Two simulation educators, a simulation technician, and a senior patient safety and human factors scientist observed, took notes, and facilitated discussion and debriefing.

TABLE 1 Observations of barriers and successes, with proposed guidance

Observation themes	Barriers	Successes	Proposed workflow
Pre-anesthetic preparation	Lack of clear contingency role assignments. Not all needed medications readily available in the COVID-19 OR.	The existing pre-anesthetic briefing provides an efficient template to discuss deviations from standard practice, to create agreed-upon plans, and to confirm availability of equipment and medications.	Roles in case of an emergency are pre-assigned and discussed during the pre-anesthetic briefing: Circulating nurse calls for help; brings equipment and medications from door to bedside. Senior anesthesia clinician functions as team leader; manages airway and ventilation if necessary Junior/second anesthesia clinician administers medication and defibrillation. Scrub nurse initiates CPR. All medications and intravenous fluids expected to be used for the case should be in the room before the patient's arrival. First-line emergency medications (succinylcholine, atropine, ephedrine and/or phenylephrine, epinephrine), and an extra bag of intravenous fluids should be available in room prior to patient's arrival.
Emergency response activation	Uncertainty about the best method to request additional help or to declare an emergency.	Existing systems (telephone and overhead) deemed effective and appropriate to request help or declare an emergency.	A telephone call to operating suite front desk to request nonurgent additional help. Overhead call stating, “COVID Anesthesia Now in [location]” to obtain emergency help.
Personnel management during an emergency	Concern that responders may inadvertently rush into a COVID-19 OR without appropriate PPE. Emergency responders may not be immediately aware of their roles or expectations. Emergency responders may be unsure when to enter the room.	PPE coaches in warm and cold zones for the duration of the case were effective gatekeepers to the OR. Responding staff readily reverted to core training despite unfamiliar workflow.	Warm zone PPE coach proactively directs responders away from the warm zone and toward the cold zone. Charge nurse helps with crowd control. All responders should stage in the cold zone and await further instruction. The first responding anesthesia clinician establishes communication with the anesthesiologist in the room. An anesthesiologist in the cold zone assigns roles to responding anesthesia clinicians. Charge nurse or PPE monitor assigns roles to responding nurses or other staff. Only staff requested to enter the OR should don PPE. All others should be prepared to do so immediately. Cold zone PPE coach supervises PPE donning and acts as the final gatekeeper to the room. If the staff inside the room become overwhelmed, the team lead should request additional personnel with specific task assignments to enter the room. If CPR is initiated, one additional member may need to enter the OR to assist with chest compressions or other tasks as directed. This person should be explicitly designated and should not be the first responding anesthesiologist.
Information management	Emergency responders may be unclear of the clinical situation inside the OR. Cognitive aids are difficult to handle in PPE, and may not be immediately available in the OR. Paper-based cognitive aids may not be easily sanitized. Cold zone responders are unable to see physiologic monitors; may be unaware of dynamic changes in patient condition.	The standard practice of maintaining cognitive aids, including weight-based emergency medication dosage books, in the cold zone, allows easy access and relay of information into the room. Existing computer quick-link to emergency algorithms on room computers allows algorithms to be displayed on overhead screens inside the room. The ability to display physiologic monitors on overhead screens allowed this information to be visible from the cold zone.	The team leader must clearly relay the patient weight, allergies, relevant history, and current condition being treated to emergency responders in the cold zone. Circulating nurse configures one overhead screen to display emergency algorithms. The team leader requests a specific algorithm. If possible, circulating nurse configures second overhead screen to display physiologic monitors and positions screen to face the cold zone window. Responding cold zone anesthesiologist serves as an additional knowledge resource, in addition to referring to paper-based cognitive aids.

(Continues)

TABLE 1 (Continued)

Observation themes	Barriers	Successes	Proposed workflow
Equipment management	Bringing a cardiac arrest cart into OR risks contamination of contents and drawers. Unclear ability to decontaminate the entire cart within a reasonable timeframe. The process of transferring clean medications into the OR is unclear.	The ready availability of sanitizable metal tables allowed for smooth transfer of contents into room.	Designation of a labeled, two-level metal trolley (defibrillation table) to reside in the cold zone, next to the standard cardiac arrest cart. Upon declaration of emergency, responders to place defibrillator, adult, and pediatric defibrillation pads on the top level. Rigid CPR backboard and collapsible step stool to be placed on the lower level. Defibrillation table to be transferred into the OR at the request of the team leader. First responding anesthesiologist takes charge of emergency drugs in the cold zone from the standard cardiac arrest cart, which remains in the cold zone. Necessary medications are prepared and labeled, then placed into a designated medication transfer bin. PPE monitor places a medication transfer bin on top of medication transfer table that resides inside the OR, adjacent to the cold zone door. Once the cold zone door is shut, the circulating nurse collects medications and brings them bedside.
Technical communication	Difficulty hearing the telephone while wearing PAPR. PAPR and masks muffle Speakers' voices. Masks cover facial expressions. Auditory feedback due to proximity of speakerphones between the OR and the cold zone. Occasional static or signal loss on cordless phone in the cold zone.	Multiple communication modalities (wired phone, cordless phone, baby monitor, tablets with videoconferencing) available, although not usually used simultaneously. Availability of various modalities allowed for the rapid generation of a planned-redundancy communication plan. Dry erase marker boards in OR available in case of technology failure.	Utilize hands-free devices. During emergencies, the telephone in the OR should be placed on speakerphone. All staff should speak slowly, in loud, clear, voices, with voice directed toward the telephone. Employ closed-loop communication to confirm that information is received and interpreted as intended. Implement a planned-redundancy communication system. A two-way baby monitor with one-way video (camera inside the OR) and two tablets with pre-installed videoconferencing software are now dedicated to the COVID-19 rooms. A dry erase board is available.

Note: Anesthesia Now: local terminology for an intraoperative anesthetic emergency.

Abbreviations: CPR, cardiopulmonary resuscitation; OR, operating room; PAPR, powered air-purifying respirator; PPE, personal protective equipment.

We debriefed using three reflection techniques. Reflection-*before*-action encourages participants to think about potential consequences and plan around a clinical scenario. Reflection-*in*-action enables participants to reflect in the moment that a clinical decision is being made. Reflection-*on*-action allows participants to learn from a clinical action that has already occurred.

The scenario was stopped each time a potential failure point or significant success was encountered. A mini-debriefing was performed, and workflow modifications were brainstormed. After each mini-debriefing, the scenario was resumed at a point that required overcoming the previously identified hurdle, implementing the changes discussed, and assessing their success. At the end of the simulation, a final debriefing was conducted to organize discussed actions and concepts into themes and to translate lessons learned into prototype revised policy and procedures for managing intraoperative emergencies.

3 | RESULTS

A summary of the observed barriers, successes, and proposed workflows specific to our institution, related to pre-anesthetic preparation, emergency response activation, personnel management, information management, equipment management, and technical aspects of communication, appears in Table 1.

4 | DISCUSSION

Systems-focused in situ simulation led by an experienced multidisciplinary team helped us identify barriers and success points for optimal performance during emergencies involving patients with COVID-19. We tested our *work-as-imagined* by conducting *work-as-simulated* and modified our workflows in real time based on our

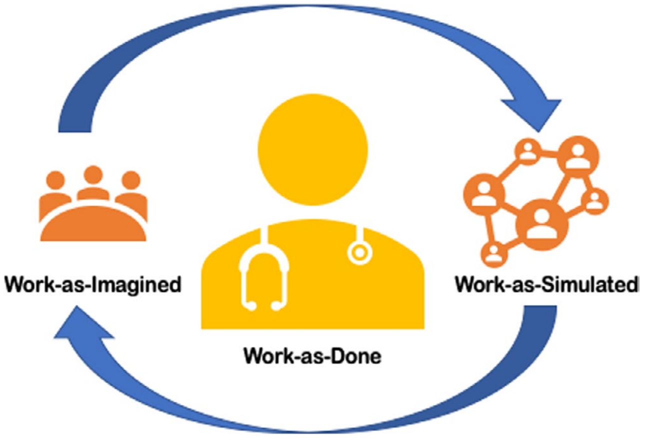

FIGURE 1 Work-as-imagined and work-as-simulated are methods to improve work-as-done through ongoing refinement of understanding and processes. Simulation can help inform the next round of guidance, which can further be refined by subsequent simulation or patient care experience

simulations (Figure 1). During the same session, we tested, modified, retested, and repeated processes as needed until we arrived at acceptable safe workflows.

This effort is not without limitations. While we have a better idea of how to translate our *work-as-imagined* into *work-as-done*, we have continued to adapt our response based on in vivo experience taking care of patients with COVID-19. Further study will likely elucidate additional improvements as the COVID-19 landscape evolves and as institutions and clinicians gain more experience with new workflows.

While our simulations were conducted in a well-resourced pediatric setting with the support of experienced simulation personnel, the overarching concepts can be adapted to individual institutions' capabilities. In all instances of workflow modification, it is vital to identify and preserve success points so that these are not inadvertently excluded from new practices. Involving a diverse group of front-line clinical staff in these endeavors provides useful insight into how work is actually done and may contribute to overall buy-in and successful implementation.

CONFLICT OF INTEREST

Rajeev Subramanyam is Associate Editor at *Pediatric Anesthesia*. None reported by any of the remaining authors.

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