

The Perioperative Services Response at a Major Children's Hospital During the Peak of the COVID-19 Pandemic in New York City

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Running Head: Transformation of Children's Perioperative Services

INTRODUCTION

In March, 2020, New York City (NYC) and the surrounding boroughs and counties became an epicenter of COVID-19 infections with a rapid rise in critically ill and ventilated adult patients, many of whom were treated in New York Presbyterian (NYP) system hospitals. Surge capacity strategies were rapidly employed, more than doubling ICU capacity in NYP facilities. In the face of accelerating numbers of COVID-19 admissions, and impending critical shortages of personal protective equipment (PPE), ICU beds, and ventilators, NYP made the decision to halt all elective surgery across its campuses with only the most emergent and urgent cases allowed.

The Morgan Stanley Children's Hospital (MSCH) is a quaternary 284 bed facility located in the Washington Heights neighborhood of NYC. It is freestanding by virtue of its separate buildings but is part of a large 10 campus health care system. It is the only hospital dedicated solely to pediatric and obstetrical care within the NYP system as well as in NYC.

This report documents the many swift changes made within the first weeks of the NYC pandemic by MSCH perioperative services in order to facilitate our entire health system's response to a massive influx of critically ill adult patients, as well as to care for the COVID-19 positive children at MSCH.^{1,2} Table 1 summarizes the changes in roles, processes and facilities at MSCH. In addition, we outline processes used to expand OR activities for semi-urgent (time-sensitive) patients while the ban on elective surgery was still in effect. The new pediatric COVID-related multisystem inflammatory syndrome is briefly described.

REDEPLOYMENT OF PERSONNEL AND EQUIPMENT

1. Anesthesia and Surgical Faculty

Since many COVID-19 patients require intubation, it was critical to have the most experienced provider(s) performing this high risk aerosol-generating procedure. Thus, the Division of Pediatric Anesthesiology created a 24 hour/7 day dedicated airway management team for all pediatric and young adult patients. The on-site team consisted of one pediatric anesthesia faculty member and a pediatric anesthesia fellow. For all intubations, the airway team carried a "COVID airway backpack" with PPE and all necessary supplies for intubation in COVID-positive or suspected patients.

As the COVID-positive patient cohort surged in NYC, the ORs at the adult hospital of the NYP-Columbia University campus were repurposed to care for critically ill adult COVID-positive patients requiring mechanical ventilation (OR-ICU). Three pediatric anesthesiology faculty and three of the six pediatric general surgery faculty redeployed to serve on the adult critical care teams caring for patients in the newly created 78 OR-ICU beds that reside in the adult hospital that is across the street from MSCH.

Pediatric general surgery faculty also took multiple shifts as attendings for the novel surgical workforce activation teams (SWAT), a combination of acute care surgery and procedure-focused (ie. venous and arterial access, chest tube insertion) response teams. These teams included surgical housestaff.

2. Operating Room Nurses/Technicians/Support Staff

Beginning March 17th and continuing for the next six weeks, an average of 16 MSCH OR staff (~60% of a daily MSCH Perioperative Services team) were redeployed each day and night shift to care for the adult patient surge in the OR-ICU and at other NYP facilities. This daily infusion of our skilled nurses and support staff to care for adult patients was instrumental in maintaining adequate patient care ratios in the OR-ICU. The children's hospital redeployed nursing and support staff members have provided more than 700 work-shifts in adult care areas over six weeks. Additional OR staff were redeployed to the pediatric ICU and Labor & Delivery (L&D) units which were operating at full census.

3. Anesthesiology Housestaff and CRNAs

At the inception of the OR-ICU in our adult hospital, all of the frontline health care providers consisted entirely of providers from the Department of Anesthesiology. They included anesthesiology faculty, anesthesiology fellows from various subspecialties, and large number of anesthesiology residents and CRNAs. During normal operations in our pediatric ORs before the COVID pandemic, five CRNAs and nine residents were assigned to the children's hospital. During the COVID pandemic period, we redeployed two CRNAs and all nine anesthesia residents to staff the adult OR-ICU. To staff the pediatric ORs and non-OR procedural areas during this period, anesthesiology staffing consisted of two CRNAs, and two fellows, and all available anesthesiology faculty.

4. Anesthesia Machines

In the adult OR-ICU, anesthesia machines needed to be used as ventilators for COVID patients. A total of 23 adult ORs were converted to OR-ICUs. At its peak, there were 90 patients in the OR-ICU receiving mechanical ventilation using the anesthesia machine ventilators. Anesthesia machines throughout the different NYP clinical areas (e.g. catheterization labs) were transferred to the OR-ICU as ventilators for the COVID patients. From the pediatric ORs and procedural areas, a total of 11 anesthesia machines were deployed to adult OR-ICUs.

REDISIGN OF CHILDREN'S HOSPITAL PERIOPERATIVE SERVICES

1. Conversion of One Operating Room to Negative Pressure

As the first COVID-19 positive patients began populating the children's hospital, the need for a negative pressure room within the operating suite was recognized. This room would provide a means to safely access the airway in COVID-19 positive patients coming for surgery, as well as provide a location to perform other aerosol generating procedures such as bronchoscopy, tracheostomy, emergent otolaryngology surgery and endoscopy, regardless of COVID-19 status. Our facilities team recommended using a room at the end of the corridor with nearest access to

a window for ease of installation. Overnight, the team placed a negative pressure HEPA-filtered venting system and ran temporary ductwork across the ceiling and out through the wall towards the window that was isolated by sealed heavy plastic sheeting.

2. Conversion of One Operating Room to a COVID-19 Dedicated Room

To minimize the risk of viral transmission between patients, one operating room was designated for major surgical procedures in known COVID-19 positive patients. This room was emptied of all but the most basic of equipment and goods. A designated “runner” was available outside the room to procure any goods or equipment that might be needed during the case and a nearby, unused operating room was stocked with additional OR and anesthesia supplies. All anesthesia machines throughout the OR were fitted with HEPA-filters on the expiratory limb of the circuits. We found that placement of the filter closer to the endotracheal tube in infants resulted in unacceptable levels of dead space ventilation and excessive CO₂ retention. The anesthesia machine, monitors and computer screens and keyboards were all draped in thin disposable plastic sheeting. The anesthesia workstation, containing equipment and medications, was similarly draped and all efforts were made to remove the necessary items for the case prior to patient entry. The goal was to avoid entering the machine during the case, potentially contaminating all contents. Postoperatively, patients were transported to negative pressure rooms either in the ICU or post-anesthesia care unit (PACU). The endotracheal tube was clamped prior to transfer to a HEPA-filtered ambu-bag or portable transport ventilator for ICU bound patients. Intubated neonatal patients were transported from their ICU to the OR using their neonatal ventilators, thus obviating the need to disconnect the closed system which would aerosolize gases and potentially contaminate the environment.

3. Conversion of One Operating Room for Scheduled Cesarean Section Procedures

An ongoing surge of COVID-19 patients was occurring at one of our neighboring NYP hospitals. They needed to create additional surge beds for COVID-19 positive patients using their postpartum beds. To do this, they would need a place to decant their obstetric and neonatal patients as there were no candidate places on-site. MSCH was the best place to move these patients as both locations shared a common faculty from the Department of Obstetrics and Gynecology at Columbia University.

Initial steps were taken to safely transfer inpatient postpartum mother and newborn dyads in an effort to vacate the postpartum unit on April 4, 2020 while planning was quickly undertaken to be able to consolidate all obstetric services (e.g. triage and labors & delivery) at MSCH. We recognized that to assume the volume we would need additional space to safely accomplish this goal. Multidisciplinary discussions were held and the option of caring for low risk, COVID negative patients scheduled for cesarean deliveries in the MSCH perioperative areas was explored.

Ultimately, one general surgery operating room and 2 PACU bays at MSCH were dedicated to Obstetrics and equipped with fetal monitors, newborn equipment and all necessary instruments and supplies. This was in addition to the 3 OB ORs and 4 PACU bays on the existing labor unit. The

referring OB service closed on April 9. Small teams were maintained there for obstetric or gynecologic emergencies. Beginning on April 9, we performed one scheduled cesarean delivery in the dedicated pediatric operating room. Between April 10 and May 8, 33 C-section deliveries were performed in the MSCH OR in the first two weeks of activity with healthy outcomes for moms and newborns. This helped to facilitate safe care for these patients while allowing continued safe operations on our busy labor and delivery unit.

4. Implementation of a Rapid COVID-19 Test in the Perioperative Area

The reverse transcription polymerase chain reaction (rRT-PCR) test for the qualitative detection of nucleic acid from SARS-CoV-2 in nasopharyngeal swabs was performed using Cepheid technology which provides results within one hour. We initiated same-day SARS-CoV-2 testing in the perioperative area in an effort to maximize safety and reduce patient and family stress. By implementing same-day testing, patients and families avoided potential exposures of additional travel and visits to the hospital for testing. Beginning April 8, MSCH perioperative services initiated rapid rRT-PCR swabbing on all outpatients, same day admits, and inpatients so that all patients had testing within 24-hour of their procedure when clinical urgency allowed. Our trained perioperative nurses performed the test using full PPE precautions. Swab samples were processed in real-time and not batched. While waiting for test results, the patient and family stayed in their designated partitioned bay.

SURGICAL VOLUME AND CASE ADJUDICATION

During the moratorium on elective procedures, we performed 303 pediatric subspecialty surgical procedures from March 17 – May 8, 2020 (Table 2), a 77% reduction in surgical volume at MSCH compared to the same interval in 2018 and 2019. In addition, 49 neonatal and pediatric cardiac catheterization procedures and 99 pediatric interventional radiology procedures were performed during the same time period. Of note, since MSCH is the only ACS-designated level I pediatric trauma center in NYC, we staffed and kept open and ready one OR for emergencies.

Emergency procedures were reviewed by MSCH's surgeon-in-chief and chief of pediatric anesthesiology. All urgent (within 48 hours) procedure requests were reviewed by a larger multi-disciplinary committee with rapid turnaround to facilitate scheduling and resource planning.

Given the historical high volume of extremely complex pediatric cardiac surgery at MSCH, these cases required special attention and were initially prioritized by the chief of pediatric cardiac surgery based on the following:

- 1) clinical status of the patient and risk of delaying surgery,
- 2) resource-utilization, such as anticipated ventilator duration, intensive care unit stay, blood product usage, perfusion needs,
- 3) risk of exposure for the patient, family, and healthcare staff,

- 4) co-morbidities and complexity of the procedure with implications on the usage of hospital resources,
- 5) the safety of the patient's social and clinical situation if surgery is delayed.³

Subsequently, the candidate cardiac patients were reviewed by aforementioned multi-disciplinary committee. Patients were labeled as urgent (category I) if they were at risk of dying or serious harm without surgical repair within 24-48 hrs. Semi-urgent cases were those that needed to be done within 2 weeks (category II). In-house patients who could not be discharged without surgery, Status IA transplants and neonates with ductal-dependent lesions were also labeled as urgent.

For the seven-week period from March 17 to May 8, 2020, the pediatric cardiac surgery service performed the second highest number of surgeries, 71 (Table 3). Forty in-patients (category I) had cardiac repairs, of which 22 were neonates. Another 17 patients in category II had open heart surgery during that time period as well. Some patients were admitted from home such as those with a tetralogy of Fallot lesion with very high right ventricular outflow tract gradients, Blalock-Taussig shunt-dependent patients with increasing cyanosis, and complete atrioventricular canal patients with severe failure to thrive despite maximal medical therapy. One heart transplantation was performed on a patient while supported on ECMO. Several babies with congenital heart defects were born during this period from COVID-positive mothers. Of those who required surgery, none tested positive for COVID-19.

During the six weeks covered by this report, the highest number of procedures (85) was performed by the pediatric general surgery service (Table 4). The majority of children with acute appendicitis presented to the hospital with signs and symptoms of perforated appendicitis and most had interval treatment. Patients meeting criteria for early acute appendicitis were treated with surgery if COVID-19 negative and IV/oral antibiotics if COVID-19 positive. In order to minimize the escape of potential aerosolized particles from laparoscopy, we implemented the use of closed-circuit devices that filter the released carbon dioxide, such as the Conmed Airseal[®] device with Smoke Evacuation and the Lexion Insufflow[®] device with Smoke Evacuation. These devices are able to filter particles as small as 0.01 microns. COVID-19 particles measure on average 0.12 microns (0.06-0.14 microns). Indeed, some authors actually recommend laparoscopy over open surgery as the evacuation of smoke and aerosolized particles is more feasible with current laparoscopic smoke evacuating systems than open smoke evacuation systems, where containment of the surgical smoke is challenging, if not impossible.⁴

Expanding the OR Schedule for Delayed Semi-Urgent Patients

Once we were confidently on the downslope of COVID-19 infections, plans began to “slowly open the aperture” and address the patients who had their surgical treatment postponed during the pandemic. These patients did not fall into the emergency/urgent category that received care during the entirety of the pandemic but were deemed semi-urgent. They were not, however, elective cases. Our aim was to

weigh individual patient benefits and risks against the ongoing public health concerns. All pediatric surgical and medical subspecialists who treat patients in the MSCH OR submitted prioritized case logs to an internal NYP perioperative leadership group. In addition, pediatric subspecialty surgeons from other NYP hospitals also submitted their cases as all pediatric care continued to be provided solely at MSCH. Factors that influenced prioritization included treatment of patients with proven or suspected malignancies, alleviation of pain, improvement of function and quality of life, and prevention of potentially serious complications or disease progression. Of the 727 postponed patients, 89 (12.2%) were scored as semi-urgent (needing to be performed within 2 weeks of increased OR activity).

Operating room block time was assigned to subspecialty services based on several factors: 1. Number of semi-urgent cases (those needing to be performed within 2 weeks of increased OR activity) on their log; 2. pre-COVID allocation of OR blocks; and 3. pre-COVID utilization data. During the first week of expanded activity, we utilized six of our ten main ORs; four rooms were block scheduled, one room was "open time" used at the discretion of the perioperative leadership committee for unassigned services, one room used for emergency and add-on cases (Table 5). We assigned block time in two rooms on both Saturday and Sunday to further facilitate reducing the queues. One of two Endoscopy suite rooms were also re-opened. This plan allowed the Obstetrics service to continue using the MSCH OR for overflow C-sections and maintained an additional MSCH OR as a negative pressure room for aerosol-generating procedures and one room was reserved for known COVID-positive patients needing major surgery.

During the first six days of expanded activity, 48 (53.9%) of the 89 semi-urgent procedures were completed. All procedures were vetted by the MSCH OR leadership group. No procedures deemed purely elective were performed during this interval. Valuable information was gathered during this expanded schedule regarding optimal patient throughput, COVID testing, social distancing in perioperative waiting areas, environmental services and PPE. Rapid assimilation of new processes and infrastructure adjustments, influenced by the pandemic, should allow return to our full ten room main OR and two endoscopy suite capabilities in the near future. Monitoring for COVID recrudescence and regulatory guidance will be required for all elective surgery to resume.

Pediatric COVID-Related Multisystem Inflammatory Syndrome

Acute COVID-19 in children has been less severe than in adults. However, on April 27, 2020 clinicians in the United Kingdom reported the emergence of a COVID-related multisystem inflammatory syndrome (CMIS). Since then, physicians at MSCH and other children's centers have noted patients from infancy to adolescence admitted with a constellation of symptoms including fever, tachycardia, raised rash, diffuse abdominal pain, diarrhea and hypoperfusion. As opposed to primary COVID-19, most children affected with the newly emerging constellation of symptoms have no significant underlying medical conditions. This new syndrome appeared a month or so after the surge of COVID-19 in our region suggesting a post-infectious etiology. Many patients have had a preceding illness consistent with COVID-19. At the time of their CMIS symptoms, patients have either tested positive for SARS-CoV-2 viral RNA by PCR testing or had positive serology tests demonstrating antibodies to SARS-CoV-2 suggesting they have been infected weeks earlier. Nearly 100 patients have been admitted with pediatric CMIS in New York State with several deaths. Some features are similar to Kawasaki Disease, however, pediatric CMIS can cause hypotension and shock, typically requiring intensive care management, features not often seen in Kawasaki Disease.

Pediatric surgeons have evaluated many of these children with pediatric CMIS for diffuse abdominal pain. Imaging findings include transmural enteritis, gallbladder wall thickening and ascites. Treatment begins with IV fluids, steroids and immunoglobulin. No abdominal surgical procedures have been performed on the first 20 patients with pediatric CMIS at MSCH.

SUMMARY

NYP's ten hospital health care system flexed rapidly and aggressively to meet the surge of critically-ill, ventilated COVID-19 positive adult patients. All elective procedure were postponed and adult ICU capacity was more than doubled within days. The children's hospital aided this effort by becoming the sole provider of pediatric care in the health system freeing pediatric beds for adult patients. The children's hospital supplied equipment (anesthesia machines), redeployed personnel (faculty, residents, nurses, staff) and created process and facilities to safely support the care of children with COVID-19. This report captures specific steps taken by perioperative leadership to best utilize the children's operating rooms in the overall strategy against the pandemic while maintain a safe environment (for staff and patients) for emergency, urgent and time-sensitive operative procedures. In addition, processes were developed which facilitated initial expansion of OR activities.

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Table 1. People, Process and Facilities Changes of the MSCH Perioperative Services

WEEK	ACTION STEPS
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1	<ul style="list-style-type: none"> - Suspend elective surgery - Multi-disciplinary committee organized for case request adjudication - -Pediatric emergent/urgent cases performed in only 3 ORs - 4th OR reserved for emergency cases (e.g. trauma) - Negative pressure OR room established for aerosol generating procedures - Dedicate one OR for COVID-19 positive patients - Unused pediatric anesthesia machines sent to adult hospital - Pediatric airway team created - Deployment of excess pediatric perioperative nurses, faculty and housestaff to the adult hospitals
2	-Day-of-surgery rRT-PCR rapid nasal swab testing site created in the perioperative area
3	-Neighboring NYP system hospital's OB and neonatal services were brought to MSCH and merged with the existing programs
4	-5th MSCH OR and two PACU bays dedicated for surge C-Sections

Table 2.

Pediatric OR Procedures at MSCH from 3/17/20 – 5/8/20

Service	Procedure Type				Total
	Emergency	Outpatient	Inpatient	Same Day Admit	
General Surgery	11	8	63	3	85
Cardiac Surgery	8	0	40	23	71
Oncology	0	24	14	3	41
Orthopedic Surgery	4	9	14	1	28
Ophthalmology	2	13	0	0	15
Otolaryngology	0	3	9	0	12
Gastroenterology	2	4	8	0	14
Medicine-Neurology	0	3	1	0	4
Urology	3	1	1	1	6
Medicine-Nephrology	0	2	1	0	3
Neurosurgery	0	1	11	0	12
Other	4	2	2	4	12
Total	34	70	164	35	303

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Table 3.

Pediatric Cardiac Surgery Procedures at MSCH from 3/17/20 - 5/8/20

Procedure Type	# of Procedures
Cardiac Repair/Shunt	53
Chest washout/closure	8
ECMO/Assist Device	6
Heart Transplant	2
Insertion Pacemaker	2
TOTAL	71

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Table 4. Pediatric General Surgery Procedures at MSCH from 3/17/20 - 5/8/20

Procedure Type	# of Procedures
Laparoscopic Appendectomy	20
Esophagoscopy for dilation or foreign body	8
Feeding access +/- Fundoplication	8
IV Access-related	9
I&D Abscess	6
Trauma	3
ECMO	3
Incarcerated inguinal hernia repair	2
Midgut volvulus exploration	2
Congenital diaphragmatic hernia	2
Tracheo-esophageal fistula repair	1
Kasai Portoenterostomy	1
Intestinal atresia repair	1
Laparoscopic Pyloromyotomy	4
Intestinal perforation repair	1
2 nd look laparotomy	2
Lymph node biopsy	2
Anterior mediastinal tumor resection	1
Resect thigh sarcoma/vascular reconstruction	1
Laparoscopic ovarian cystectomy	1
Hirschsprung's rectal biopsy	1
Other	6
TOTAL	85

Table 5. Initial room assignments during first week of expanded OR activity.

Room	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	
1	Ortho/Spine	Urol	Ortho/Spine	Eye	Ortho/Spine	Urol	ENT	
2	Cardiac	Cardiac	Cardiac	Cardiac	Cardiac	Cardiac	Cardiac	
3	Gen Surg	Gen Surg	Gen Surg	Gen Surg	Gen Surg			
4	Neuro	Open	Neuro	Open	Neuro			
5	Open time							
6	Emergency + Urgent add ons							
7	Known or suspected COVID-positive patients requiring major open surgery							
8	Negative Pressure Room (aerosol-generating procedures)							
9	closed							
10	Obstetrics	Obstetrics	Obstetrics	Obstetrics	Obstetrics			

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