Aim: Working practices in pediatric surgery underwent enormous changes during the era of the COVID-19 pandemic. While certain surgical conditions in children can be managed temporarily with nonsurgical options, most neonates with congenital surgical malformations require emergent operations. We discuss the challenges faced; measures adopted in dealing with surgical emergencies and analyze the diagnoses and outcomes of patients with COVID-19 infection in our institute during the pandemic era.

Materials and Methods: When the lockdown was imposed, it was mandated that all elective procedures should be put on hold. We formulated criteria for triaging procedures as emergent, urgent, and elective. A standard operating protocol was devised regarding admission, pre and postoperative management. Protocols for surgical procedures were established in a separate Covid-designated operation room including a specified sequence of donning and doffing personal protective equipment.

Results: In the COVID era, from March 23, 2020 to mid-July 2021, 1282 surgeries have been done in our department, 344 emergencies and 461 planned procedures, which include 31 COVID-19 positive cases, with overall good outcomes. 103 emergency surgeries were done during the first wave (March-end to June 2020), and 103 during the second wave (April to mid-June 2021). Moreover, not a single healthcare worker in the department has been infected.

Conclusion: Pediatric Surgeons are adapting to the new guidelines to continue to provide emergency services with safe and effective care to their patients during the COVID-19 pandemic. Simultaneously, focus on personal and staff protection is ensured to keep the healthcare workers healthy and able to discharge their duties adequately.

Keywords: COVID-19, pediatric surgeries, protocols, working practice
is likely to be high, they may be an important source of asymptomatic infection in the pediatric population and good nursing care. Moreover, as the incidence of COVID-19 positive children emerged, concerns surrounding the vulnerability of the children to the virus itself and its possible complications were raised. Pediatric surgical patients with COVID-19 infection required multidisciplinary management by neonatal and pediatric intensives, pediatric surgeons, anesthetists, and good nursing care. Moreover, as the incidence of asymptomatic infection in the pediatric population is likely to be high, they may be an important source of undetected transmission, as asymptomatic or undiagnosed carriers.

The goal of pediatric surgical services during the pandemic is to provide timely surgical care to children with emergent surgical issues while optimizing patient care resources and preserving the health of caregivers. Multidisciplinary shared decisions are essential for the management of children with COVID-19 infection undergoing surgery. Surgical scheduling should be made in the context of available institutional resources that will be constantly changing.

**Aims**
This manuscript discusses the challenges faced by the pediatric surgical department during the COVID-19 pandemic and the measures adopted in dealing with neonatal and pediatric surgical emergencies.

It outlines the criteria and methods we followed for planned surgeries in pediatric patients.

It also analyses the diagnoses, management, and outcomes of neonatal pediatric surgical patients with COVID-19 infection in our institute.

**Materials and Methods**
When the lockdown was imposed on March 23, 2020, it was mandated that all elective procedures should be put on hold so that resource management for the pandemic could be adequately arranged. The department of Pediatric Surgery also implemented this order; however, we still had emergency surgical neonates and children coming in 24 × 7. As the only pediatric surgical department in the public sector in the state of Gujarat, we have always had a heavy patient inflow, including many from neighboring states.

We formulated criteria for triaging the patients as emergent (have to proceed), urgent (weigh risks and benefits before deciding whether to proceed), and elective (can postpone) procedures [7,8] [Table 1]. During the lockdown, the inflow was naturally quite low, with mostly only emergency cases coming in. All patients who were dated for planned procedures were postponed and telephonically informed.

A standard operating protocol for surgical patients was devised regarding admission, pre and postoperative management. The ward and neonatal intensive care units (NICU) were reorganized to increase the space between patients, create separate areas for suspected patients, and a designated area to examine and evaluate patients when they were first brought in. For a patient who was hemodynamically stable, a medical officer/resident doctor would initially take a detailed history from the relatives about symptoms suggestive of COVID-19, family/neighborhood history of COVID-19 or exposure, area of residence, travel history, and special attention to symptoms in mother (in case of neonates and breast-fed infants). If the patient was clinically unstable, primary resuscitation was done by staff and doctor on duty taking full precautions with complete personal protective equipment (PPE) kit, then history was elicited.

All suspected patients were kept in the designated area and staff caring for them maintained protocol of using PPE kits. There was no cross-caring of non-COVID and suspected patients. All patients who tested positive were shifted to the 1200-bedded designated COVID hospital in the campus after surgery.

**Protocols for surgery**
Dire emergencies such as vascular accidents (volvulus/torsion testes), intussusceptions, trauma, and male anorectal malformations requiring intestinal diversion were taken for surgery without awaiting the results of the reverse transcriptase polymerase chain reaction (RTPCR) test for COVID-19. These patients were operated in a separate COVID-designated operation room (OR). There was a separate team of OR staff, anesthetists, and helpers attending these cases, fully equipped with PPE. Induction and intubation were done by senior anesthetist with one assistant. This would ensure rapid induction with minimal exposure. Only the minimum numbers of essential personnel were inside the OR with operating team entering after intubation and exiting before extubation. Measures to decrease aerosol generation
such as minimum and cautious use of diathermy and constant suction of smoke were used.\[8\]

Before induction, we made it a point to have a group discussion with all personnel involved, regarding shifting, positioning, induction, plan of surgery, protocols to be followed, and possible complications. This ensured a smooth and fast process with minimum confusion and accidents. A specified sequence for PPE donning and doffing was established to ensure personnel protection and prevent environmental contamination [Chart 1].\[1\]

Thorough disinfection and sterilization of the OR were conducted immediately after surgery and at the end of every day. The sterilization included routine disinfection of the anesthesia machine, whole OR disinfectant spraying and mopping.\[1\]

For other surgical emergencies such as trachea-esophageal fistula, congenital diaphragmatic hernia, intestinal obstruction, and pyloric stenosis, we waited for the result of the RTPCR test for COVID-19 and then operated accordingly in the respective OR. In these cases, time was necessary for resuscitation and stabilization, so we could take them as planned emergencies. Again, theater staff was kept to a minimum. Universal precautions were taken in these cases also; plastic gown, double gloves and masks, shoe covers, and face shields.

| Emergent            | Urgent                  | Elective                  |
|---------------------|-------------------------|---------------------------|
| Ischemia            | Abscess requiring I and D| Reconstruction            |
| Torsion             | Biliary atresia         | Enteroctomy closure       |
| Limb threatening ischemia | Symptomatic cholelithiasis | Cholecystectomy for biliary colic |
| Trauma              | Uncontrolled bleeding   |                           |
| Penetrating trauma  | Intussception           |                           |
| Acute intestinal obstruction | Malrotation     |                           |
| Incarcerated inguinal hernia | Congenital malformations |                           |
| Congenital malformations | Uncontrolled bleeding   |                           |
| Anorectal malformation or Hirschsprung’s disease requiring diversion | Oncologic surgeries | Splenectomy for hematologic diseases |
| Atresias            | Ischemia                |                           |
| Symptomatic congenital diaphragmatic hernias | IBD exacerbation requiring surgery | Asymptomatic choledochal cyst excision |
| Upper airway/GI foreign body | Insertion of vascular access | Removal of uninfected vascular access |
| Acute appendicitis  | Symptomatic inguinal hernia | Asymptomatic inguinal hernia |
| Hollow viscus perforation | Asymptomatic choledochal cyst excision | Orchiopexy |
| Any diagnosis requiring ECMO | Any diagnosis requiring ECMO | Fundoplication |

ECMO – Extracorporeal membrane oxygenation, IBD – Inflammatory bowel disease, GI – Gastrointestinal

Table 1: American college of Surgeons: Classification of procedures in pediatric surgery according to their urgency\[7,8\]

| Emergent            | Urgent                  | Elective                  |
|---------------------|-------------------------|---------------------------|
| Ischemia            | Abscess requiring I and D| Reconstruction            |
| Torsion             | Biliary atresia         | Enteroctomy closure       |
| Limb threatening ischemia | Symptomatic cholelithiasis | Cholecystectomy for biliary colic |
| Trauma              | Uncontrolled bleeding   |                           |
| Penetrating trauma  | Intussception           |                           |
| Acute intestinal obstruction | Malrotation     |                           |
| Incarcerated inguinal hernia | Congenital malformations |                           |
| Congenital malformations | Uncontrolled bleeding   |                           |
| Anorectal malformation or Hirschsprung’s disease requiring diversion | Oncologic surgeries | Splenectomy for hematologic diseases |
| Atresias            | Ischemia                |                           |
| Symptomatic congenital diaphragmatic hernias | IBD exacerbation requiring surgery | Asymptomatic choledochal cyst excision |
| Upper airway/GI foreign body | Insertion of vascular access | Removal of uninfected vascular access |
| Acute appendicitis  | Symptomatic inguinal hernia | Asymptomatic inguinal hernia |
| Hollow viscus perforation | Asymptomatic choledochal cyst excision | Orchiopexy |
| Any diagnosis requiring ECMO | Any diagnosis requiring ECMO | Fundoplication |

ECMO – Extracorporeal membrane oxygenation, IBD – Inflammatory bowel disease, GI – Gastrointestinal

| Donning                                      | Doffing                                      |
|----------------------------------------------|----------------------------------------------|
| Hand disinfection→Cap→Medical protective mask→Goggles/face screens/eye-protective surgical Masks→Isolation gowns/protective suits→Shoe covers→Gloves→Hand disinfection→Hand disinfection→Goggles/face screens→Hand disinfection→Goggles/face screens→Hand disinfection→Goggles/face screens→Hand disinfection→Medical protective masks→Hand disinfection→Disposable skull caps→Hand disinfection/hand washing→Change personal clothing |

Wherever possible (e.g., appendicitis, Hirschsprung’s disease), nonsurgical management was followed as long as there were no adverse consequences.

**Postoperative management**

The patients were kept isolated in the suspect ward till the Covid test results came. Till then, all handling was done with due precautions with masks, face shields, gloves, and PPE. Positive patients were shifted to the COVID hospital where care was undertaken by neonotologists, pediatricians, and pediatric surgeons. Hence, there was multidisciplinary management including treatment protocols for symptomatic
COVID-19 infection. This included antibiotics according to blood cultures, steroids, oxygen support, and/or low molecular weight heparin.

Those patients who were operated after a negative COVID test were cared for in the Pediatric surgical ICU and NICU.

A strict protocol of one patient-one relative was maintained in the ward with entry barred to all visitors and unnecessary people. While staff maintained protocols of sanitizing before and after attending each patient, the patient attendants were also advised to use masks, frequently wash hands, and maintain hygiene for themselves and their children.

**Planned procedures**

When the lockdown eased, and we started outpatient services and planned surgeries, it was necessary to ensure smooth flow of patients and avoid cross-infection. One patient with single relative during consultation with the doctor and nurse using appropriate protection with face shields and gloves was mandated. Examination was done by senior faculty wherever necessary. Sanitization after each consultation was done. The number of planned surgeries per day was limited to ensure effective utilization of available resources and workforce and adequate cleaning of the OR in between cases. It also helped prevent overcrowding in the wards and cross infection. In all cases, RTPCR test for COVID-19 was done preoperatively. If the result was positive, the case was postponed, and the patient referred to the COVID hospital for further management if required.

**RESULTS**

Working practices in the Pediatric Surgical Department saw a lot of changes in the era of the COVID-19 pandemic. Our hospital became the largest center in the state treating over 84,000 COVID-19 patients between March 2020 and Mid-June 2021. With the concerns of the pandemic and the severe resource and human resources restrictions, we followed a protocol of performing only emergency surgeries by the attending consultants on a rotational basis during the first wave from March end to June 2020 and again between April and mid-June 2021 (second wave).

Overall, in the period from the last week of March 2020 to Mid-June 2021, 1282 surgeries and procedures were done in the department. The numbers have been divided into three phases, first wave, intermediate period, and second wave [Table 2]. For a department performing an average of 180–200 surgeries a month, this was a drastic decrease to <40 a month during the peaks of the pandemic.

| Time period               | March end to June 2020 (first wave) | July 2020 to March 2021 | April to mid June 2021 (second wave) | Total     |
|---------------------------|-------------------------------------|-------------------------|-------------------------------------|-----------|
| Emergencies               | 103                                 | 482                     | 103                                 | 206       |
| Planned                   | -                                   | 461                     | -                                   | 461       |
| Minor emergency procedures| 34                                  | 52                      | 52                                  | 138       |
| Total                     | 137                                 | 990                     | 155                                 | 1282      |

During the first and second wave, we operated only surgical emergencies. In the intermediate period, we did many of our long pending planned procedures. There was also a rise of emergency cases with the easing of the lockdown. There were 206 emergencies, 461 planned surgeries, and 138 minor procedures, with 103 emergencies during the first wave and 103 during the second wave. Neonatal emergencies outnumbered those in older children; 625 and 557, respectively [Table 3]. The most common neonatal emergencies were tracheoesophageal fistula and Anorectal malformations [Table 4].

**Surgical patients with COVID-19 infection**

During the period from the end of March 2020 to mid-June 2021, our department operated 31 surgical patients who tested positive for COVID-19. These included 19 neonates and 12 patients aging between 1 month to 7 years. There were 15 male and 16 female patients. Most of the neonates had congenital anomalies requiring emergent procedures. In older children, there were usually inflammatory/obstructive conditions. The table shows the different diagnoses [Table 5]. Other than one patient, all were primarily admitted with surgical emergencies. There was one case which turned out to be post-Covid syndrome manifesting as primary peritonitis. On exploration, this patient had severely inflamed intestines without any hollow organ perforation. Postoperatively he had raised inflammatory markers and IgG antibody levels. He improved after he was put on pediatric management protocol for post Covid Multisystem Inflammatory syndrome in children.

**Outcome**

Twenty-four patients had a good surgical outcome and no adverse sequelae of COVID-19 infection. We lost seven patients, all of whom were neonates.

Of special note is the fact that none of the health-care workers caring for these patients in our department was infected with COVID-19. This was a result of the stringent protocols and precautions which were diligently followed every time.
**Discussion**

The coronavirus pandemic has thrown up a tremendous challenge to human health care, with significant impact on surgical practice, triaging the urgency of surgical procedures, and considering nonsurgical management options wherever possible.\[8\] Surgical services have to be prioritized, balancing patient needs and resource availability. The European Association of Urology Guidelines Office proposed the following suggestions for factors that must be taken into account: \[9\]

1. The impact of delay on primary surgical outcomes
2. Feasibility of alternative procedures that have fewer requirements for an OR
3. Comorbidities and/or increased risk of complications

| Table 3: Neonates and children operated during the pandemic |
|----------------------------------------------------------|
| Time period      | March end to June 2020 (first wave) | July 2020 to March 2021 | April to mid June 2021 (second wave) | Total |
|------------------|-------------------------------------|------------------------|-------------------------------------|-------|
| Neonates         | 82                                  | 465                    | 78                                  | 625   |
| Older children   | 55                                  | 425                    | 77                                  | 557   |

| Table 4: Various emergency procedures done during the pandemic |
|---------------------------------------------------------------|
| Type of emergency                                           | Number of patients |
| Tracheoesophageal fistula                                      | March end to June 2020 (first wave) | July 2020 to March 2021 | April to mid June 2021 (second wave) |
| Intestinal atresia                                           | 29                                     | 131                     | 33                     |
| Anorectal malformation                                       | 3                                      | 26                      | 4                      |
| Omphalocele/gastrochisis                                      | 20                                     | 88                      | 4                      |
| Neonatal necrotising enterocolitis                           | 6                                      | 22                      | 7                      |
| Congenital diaphragmatic hernia                               | 2                                      | 3                       | 1                      |
| Posterior urethral valve                                     | 5                                      | 19                      | 1                      |
| Open neural tube defects                                      | 1                                      | 13                      | 3                      |
| Sacrococcygeal teratoma                                      | 2                                      | 18                      | 1                      |
| Colostomy for hirschprung’s disease                          | 1                                      | 14                      | 4                      |
| Infantile hypertrophic pyloricstenosis                       | 4                                      | 10                      | 2                      |
| Liver abscess                                                | 1                                      | 14                      | 3                      |
| Intestinal obstruction                                       | 13                                     | 54                      | 9                      |
| Perforation peritonitis                                      | 5                                      | 16                      | 5                      |
| Torsion testis                                               | 2                                      | 1                       | 1                      |
| Others                                                       | 9                                      | 16                      | 12                     |
| Total                                                        | 94                                     | 477                     | 103                    |

| Table 5: Surgical patients with COVID-19 infection |
|---------------------------------------------------|
| Diagnosis                                         | Number of patients |
| Tracheoesophageal fistula                          | Total | March end to June 2020 (first wave) | July 2020 to March 2021 | April to mid June 2021 (second wave) |
| Intestinal atresia                                | 3      | 1                                      | 0                      | 2                      |
| High anorectal malformation                        | 3      | 1                                      | 2                      | 0                      |
| Omphalocele major                                 | 1      | 1                                      | 0                      | 0                      |
| Neonatal necrotising enterocolitis                 | 2      | 0                                      | 1                      | 1                      |
| Cystic lung lesion                                | 1      | 0                                      | 0                      | 1                      |
| Lumbosacral meningomylocele                        | 1      | 0                                      | 1                      | 0                      |
| Infantile hypertrophic pyloricstenosis             | 1      | 0                                      | 1                      | 0                      |
| Intussusception                                   | 2      | 0                                      | 1                      | 1                      |
| Liver abscess                                     | 3      | 1                                      | 1                      | 1                      |
| Psoas abscess                                     | 1      | 0                                      | 1                      | 0                      |
| Intestinal obstruction                            | 3      | 2                                      | 0                      | 1                      |
| Esophageal stricture                              | 1      | 0                                      | 0                      | 1                      |
| Torsion testis                                    | 1      | 0                                      | 0                      | 1                      |
| Total                                            | 31     | 10                                     | 10                     | 11                     |
4. The threat to patient life if the procedure is not performed immediately
5. The threat of permanent organ dysfunction if the procedure is not performed
6. The risk of rapidly progressing severe symptoms and disease progression if the procedure is not performed.

For pediatric surgeons, the options are limited as many cases are congenital surgical emergencies. The focus is on effective management of emergency cases with elective procedures being postponed wherever possible while minimizing the risk of transmission of infection.

The American College of Surgeons states that the principle of pediatric surgery during the COVID-19 pandemic is to provide appropriate surgical care to children with urgent surgical issues [Table 1] while utilizing patient care resources effectively in addition to protecting health-care workers.[3]

**Challenges and obstacles**

The delivery of emergency surgical services has become difficult due to various concerns, starting from a reduced workforce and shortage of hospital supplies. The need for postoperative supplements including blood products must be carefully considered.

Late presentation due to fear of attending hospitals and hesitation to be admitted in a COVID hospital have a major impact on the overall outcome. These patients are usually dehydrated with associated electrolyte abnormalities and sepsis, which compound the complications.[6]

Another dilemma which we face is how expedient the surgery needs to be. There is a fine line between balancing the risk of waiting for results of COVID test and operating as suspected and exposing potentially uninfected patients.

The logistics of arranging to operate separate or with minimum personnel also need to be addressed. The entire process from shifting the baby to the Covid specific OR, induction of anesthesia, performing the surgery, extubation, and shifting back need to be finely orchestrated using minimum number of adequately protected personnel.

Added to this are the technical difficulties in performing delicate reconstructive surgeries wearing PPE kits; the kits can often be stifling, especially under the glare of the theatre lights. The surgeons and assistants need to be aware and prepared for this and hydrate themselves adequately before the procedure.

There are also concerns about aerosol spray from cautery, intubation, and extubation. Smoke extractors and aerosol boxes are advocated to minimize the risks, but these may not be available universally. Use of bipolar tools and continuous smoke suction are an alternative, as are measures such as avoiding positive pressure ventilation and using regional anesthesia wherever possible.[10]

It is imperative to ensure that all personnel involved are trained beforehand regarding the correct techniques for donning and doffing PPE kits and also that there is a strict, uniform protocol for biohazardous waste disposal.

Triage and prioritizing are needed while starting planned surgeries. Essential reconstructive surgeries, tumors, and cysts, hernias take preference over other surgeries such as hypospadias and colostomy closure. The number of daily surgeries should be limited to prevent overcrowding in the wards and to ensure adequate patient care in view of the existing staff shortage. In the outpatient department, smooth inflow with a single patient and relative at a time and minimum personnel will help avoid cross infection and increase patient confidence in visiting the hospital.

Indeed, these precautions and protocols may become the new normal in health care, as long as the threat of this pandemic continues to hover over us.

**Conclusion**

The pandemic has fundamentally changed the way we function as a hospital and deliver patient care. All surgical specialties have had to triage their daily surgical procedures and consider nonsurgical management options where possible and limit hospital stay.

In the COVID era, from March 23, 2020 to mid-July 2021, 1240 surgeries have been done in our department, 344 emergencies and 461 planned procedures, including 31 COVID-positive cases, with overall good outcomes. Moreover, not a single HCW in the department has been infected as a result of taking adequate precautions.

Pediatric Surgeons are also adapting to the new guidelines to continue to provide vital emergency surgery with safe and effective care to their patients during the COVID-19 pandemic. At the same time, focus on personal and staff protection is being ensured rigorously so that the health-care workers remain healthy and able to effectively discharge their duties. Undoubtedly, the pandemic has highlighted a number of strengths and weaknesses in the health care system. There are times when despair overcomes even the most optimistic care provider. Nevertheless, the incredible efforts and dedication of health-care workers focused on
providing the best care possible to patients, even in these unprecedented conditions, pave the way for positive and encouraging outcomes on the horizon.

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There are no conflicts of interest.

REFERENCES
1. Soneru CN, Nunez K, Petersen TR, Lock R. Anesthetic concerns for pediatric patients in the era of COVID-19. Paediatr Anaesth 2020;30:737-42.
2. World Health Organisation (WHO) Coronavirus Disease (COVID-19) Outbreak Webpage. Available from: https://www.who.int/data/data at WHO/coronavirus (COVID-19) data. [Last accessed on 2021 Jun 25].
3. Al-Jabir A, Kerwan A, Nicola M, Alsafi Z, Khan M, Sohrabi C, et al. Impact of the coronavirus (COVID-19) pandemic on surgical practice – Part 2 (surgical prioritisation). Int J Surg 2020;79:233-48.
4. Rahul SK, Gupta MK, Chaubey D, Kumar D, Keshari R, Kumar V, et al. Pediatric surgery during coronavirus disease lockdown: Multicenter experience from North India. Formos J Surg 2020;53:216-22.
5. Verdoni L, Mazza A, Gervasoni A, Martelli L, Ruggeri M, Ciuffreda M, et al. An outbreak of severe Kawasaki-like disease at the Italian epicentre of the SARS-CoV-2 epidemic: An observational cohort study. Lancet 2020;395:1771-8.
6. Qazi SH, Saleem A, Pirzada AN, Hamid LR, Dogar SA, Das JK. Challenges to delivering pediatric surgery services in the midst of COVID-19 crisis: Experience from a tertiary care hospital of Pakistan. Pediatr Surg Int 2020;36:1267-73.
7. American College of Surgeons. COVID-19 Guidelines for Triage of Pediatric Surgery Patients; 2020. Available from: http://www.facs.org/covid-19/clinical-Issues-guidance/elective-case/pediatric-surgery. [Last accessed on 2020 Mar 24].
8. Dedeiliâ A, Esagian SM, Ziogas IA, Giannis D, Katsaros I, Tsoulfas G. Pediatric surgery during the COVID-19 pandemic. World J Clin Pediatr 2020;9:7-16.
9. Ribal MJ, Cornford P, Briganti A, Knoll T, Gravas S, Babjuk M, et al. European association of urology guidelines office rapid reaction group: An organisation-wide collaborative effort to adapt the European association of urology guidelines recommendations to the coronavirus disease 2019 era. Eur Urol 2020;78:21-8.
10. Brücher BLD, Nigri G, Tinelli A, Lape–na Jr JFF, Espin-Basany E, Macri P, et al. COVID-19: Pandemic surgery guidance. 4Open 2020:3:1. Available from: https://doi.org/10.1051/fopen/2020002.