Minimal Access Surgery in Infants and Children

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"Surgery is always invasive; it is only the access that is minimal in the endoscopic approach"

14.1 Introduction

The application of Minimal Access Surgery (MAS) in pediatric surgery has gained a progressively increased interest and application over the last 20 years (Saxena and Hollwarth 2009). Thanks to the development of smaller size instruments as well as the improvement of specialized pediatric anesthetic techniques, MAS has almost become the gold-standard approach for the vast majority of pediatric surgical conditions including the neonatal ones (Table 14.1).

Table 14.1 Minimal access surgery in pediatric surgery (organs and pathologies)

Upper GI tract:
Gastroesophageal reflux—Fundoplication (Nissen, Toupet, Thal)
Heller's myotomy procedure
Esophageal/gastric duplication
Splenectomy
Liver and biliary tract pathologies, choledochal cyst
Pancreatic pathologies
Cholecystolithiasis
Nutrition and feeding issues—Gastrostomy and Jejunostomy
Lower GI tract:
Hirschsprung's disease
Anorectal malformations
Appendicectomy
Meckel's diverticulum
Intussusception
Inflammatory bowel disease: Chron's disease and ulcerative colitis
Pilonidal sinus—Endoscopic treatment—EPSiT* (* external)
Thoracic procedures:
Congenital pulmonary airway malformation
Recurrent pneumothorax
Hyperhidrosis
Tracheomalacia—Aortopexy
Bronchogenic cyst
Diaphragmatic eventration
Empyema
Pulmonary sequestration
Pediatric Urology and Gynecology:
Pyeloureteric junction pathologies
Cystoureteric pathologies
Ovarian cysts
Renal pathologies
Undescended testes

(continued)

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P. Puri, M. E. Höllwarth (eds.), *Pediatric Surgery*, https://doi.org/10.1007/978-3-030-81488-5_14

Table 14.1 (continued)

Pediatric Oncology:
Mediastinal masses
Lung lesions
Thymic pathologies
Abdominal masses
Retroperitoneal masses (adrenal, renal)
Ovarian masses
Neonatal Surgery:
Esophageal atresia
Chylothorax
Congenital diaphragmatic hernia (CDH)
Inguinal hernia repair
Pyloric Stenosis
Duodenal atresia
Malrotation—Ladd's procedure

14.1.1 Laparoscopic and Thoracoscopic Surgery: Technical Considerations

The introduction of laparoscopic instruments for either thoracic, abdominal, or pelvic cavity in pediatric surgery should be performed under direct vision (Hasson's technique). Although popular with adult surgeons, the use of the Veress needle is discouraged among the pediatric population, mainly due to a high risk of life-threatening complications, especially due to the shorter distance between the abdominal wall and the underlying structures and major vessels. Once the abdominal/thoracic access is established safely under direct vision, the ancillary working port(s) are introduced according to the demands of the specific surgical procedure.

Ports used for minimal access procedures can be disposable or re-usable; however, most of the 3 mm options are available in re-usable forms. Whereas, the disposable instruments are considered to be more reliable since they have not been subjected to previous depreciation, their main disadvantage is related to cost. Of note, some instruments will only be available in disposable options specifically based on the type of function performed. Ports currently available are various sizes that range from 2 mm (fragile and with limited application) to 3–5–11–12–15 mm. The latter larger sizes are often necessary even in pediatrics because some instruments, such as staplers and retrieval bag, are not commonly available in smaller sizes. Besides the diameter, the choice of the length of the port is also important, the choice of which largely depends on the age and weight of the child. The current available lengths are 60–75–100 and 110 mm.

Table 14.2 Trocar tip options

Sharp pyramidal: traumatic. Easy leakage of gas
Sharp conical: less traumatic, dilate the tissue
Eccentric
Blunt conical
Devices with a small blade of a knife
Versa Step
Multiport trocar—SILS

Ports are presently available with a variety of trocars that aid in the insertion and secure placement of the ports (Table 14.2). Fixation of ports at the site of insertion is another issue that has been addressed by the industry in designing variations in the sleeve of the ports to enable secure placement. However, straight sleeve ports will require fixation techniques to the abdominal wall, mostly during neonatal procedures where the thickness of the abdominal wall is less compared to a school going child or teenager and chances of displacement are much higher due to their minimal lengths within the abdominal cavity.

MAS requires the creation of a working space. This is obtained by the use of carbon dioxide (CO_2), which has the advantage of being reabsorbed by blood, not being toxic, cost-effective, and is also non-combustible in the presence of electrosurgical devices. Insufflation pressures used in the pediatric age group ranges between 8 and 12 mmHg and these are even lower in neonates and infants. When thoracoscopy is performed, a pneumothorax can be created with 3–5 mmHg CO_2. The flow rate is preferably kept less than 1 L/min at least at the beginning of the procedure after which it can be safely increased if required up to 2 L/min. A higher flow rate may lead to scapular pain and also cause hypothermia.

A variety of scopes are available and can be chosen depending on the requirements of the type of procedure. Telescopes are available in 2–3–5–10–12 mm with angles ranging from 0° to 70°. The 30° scope is used most because it allows

to look behind structures, around corners, and below the surface of the abdominal wall. Newer scopes are available which allow three-dimensional visualization of the internal structures.

In terms of work port placement, this will follow either the rule of ***sectorization*** (when the target organ is on one side so that the optical port comes to lie on one side and the working ports on the other side of the target organ), or the ***triangulation*** (when the optical port is placed about 10 cm from the target organ with two further working ports on the same 10 cm arc on either side of the optical port, allowing a working space at a 60°–90° angle).

14.2 Thoracoscopic Procedures

For thoracoscopy to be applied in children, appropriate anesthetic techniques play a central role. General anesthesia and positive pressure ventilation can impair visualization inside the pleural space during thoracoscopy due to lung expansion. Single lung ventilation by intubation of the contralateral mainstem bronchus is the most common technique used by pediatric anesthesiologists to partially collapse the ipsilateral lung for pediatric thoracoscopy. Double lumen tubes are not available in appropriate sizes for neonates and small children. Bronchial blockers, such as a Fogarty catheter passed through or beside an endotracheal tube, can be used to block ventilation in the ipsilateral lung. Low flow and low pressure (<6 cm H_2O) infusion of CO_2 into the ipsilateral pleural space can help to partially compress the lung and to increase the visualization of intrathoracic structures. This technique is well tolerated in most neonates. Potential complications of the technique, such as CO_2 embolism and hypotension due to impaired venous return, have not been reported in significant numbers. Stopping insufflation and relieving the pneumothorax can readily reverse hypercarbia and hypoxia due to intrapleural infusion of CO_2.

14.2.1 Diagnostic Thoracoscopy

Thoracoscopy for diagnostic purposes is used infrequently due to the advances in diagnostic imaging. In carefully selected patients, however, the visualization of obscure structures or lesions in the thoracic cavity can be achieved using thoracoscopy. Additionally, biopsies of intrathoracic lesions are commonly performed thoracoscopically.

14.2.2 Biopsies for Pulmonary Pathologies

One of the most common indications for thoracoscopy in children is to perform lung biopsies. In fact, interstitial lung disease in immunocompromised patients, parenchymal lung disease, pulmonary masses associated with malignancies and refractory pleural lesion disease will benefit from lung sampling. Patient positioning will depend on the position of the lung mass. Generally, lateral positioning is the most common; however, lung biopsies might also require prone positioning (posterior pleural lesions) or supine (anterior lesions). The camera port is usually positioned within the midaxillary line at the level of the fourth or fifth intercostal space, below the tip of the scapula. Further ports are inserted according to the baseball field positioning criteria. Thoracoscopic biopsies are performed by using endoloops, endoscopic stapling or sealing devices. There are a few relative contraindications such as previous pleurodesis, advanced empyema, pleural thickening of unknown etiology, cardiovascular instability, hypoxemia despite oxygen therapy, bleeding diathesis, pulmonary arterial hypertension, refractory cough, drug hypersensitivity, and reduced general health status with short suspected survival. It is important to remember that in suspected malignancy, the use of endobag is mandatory to retrieve the specimen, in order to avoid seeding of tumor at the port site.

14.2.3 Pleural Empyema

The treatment of empyema using thoracoscopic debridement has become a standard of care. Children with a diagnosis of empyema should be examined by either ultrasound or CT scanning. Children with obvious fibrinous septi and loculation of the empyema should be treated by thoracoscopic debridement of the intrapleural space. This technique is started using a chest tube to access the pleural space of an anesthetized child. If the chest tube does not sufficiently drain the purulent material in the chest, the next step should be thoracoscopic access of the pleural pace followed by thoracoscopic debridement of the fibrinous septi within the pleural space. Once the pleural space has been accessed with a port, a suction device is used as a probe to separate the lung from the parietal pleura. CO_2 is infused to further develop this space. A scope is then placed through the original port and other ports are sequentially introduced under vision. The fibrinous material within the pleural space is removed using grasping forceps. Usually, most of the fibrinous debris can be removed within 1 hour. The pleural space is irrigated with saline and aspirated using a suction device. One or two chest tubes are left in place to drain the pleural space. Using this technique, recovery from the empyema is usually much more rapid than following chest tube drainage alone or chest tube drainage with fibrinolytic agents to break up the fibrinous septi. The chest tubes are usually left in place for 3 or 4 days and then removed when drainage becomes minimal.

14.2.4 Congenital Pulmonary Airway Malformations and Pulmonary Sequestration

Congenital Pulmonary Airway Malformations (CPAM) including bronchogenic cyst, bronchopulmonary sequestrations, and congenital lobar emphysema (CLE) are conditions that benefit from the thoracoscopic approach since this approach significantly improves the postoperative recovery time. Generally, 3–5 mm ports are used and the application of 3–5 mm sealing devices is gaining popularity for these procedures. In older children, where it is possible to insert 5–12 mm ports, endostapler application is possible. Usually, the lungs are freed using sealing energy sources followed by stapling or ligation of the bronchus and major vessels. Depending on the size, the specimens are generally removed through in an endobag or in a piecemeal fashion through a slightly enlarged 5 mm port site. The chest drain is usually left following lobectomies.

In pulmonary sequestrations, the first step of the procedure is to identify the systemic artery feeding the sequestration, which usually originated below the level of the diaphragm. Depending on the size of the vessels, sutures, clips, or sealing device are used for ligation.

14.2.5 Primary Spontaneous Pneumothorax

Most primary spontaneous pneumothorax (PSP) patients show apical emphysematous-like changes such as bullae or blebs which can be demonstrated by high-resolution chest computed tomography (CT) scans. Indications for the thoracoscopic approach to primary spontaneous pneumothorax are simultaneous bilateral PSP, recurrent PSP, failed conservative management with persistent air leak >3–5 days or significant hemopneumothorax. The procedure involves atypical lung resections using endoscopic staplers.

14.2.6 Mediastinal Masses

Mediastinal masses detected in pediatric age will generally be related to either congenital anomalies or neoplasms. The most frequent indication for thoracoscopy is the presence of a mediastinal lesion such as bronchogenic cyst, esophageal duplication, thymic lesions, or tumors (neuroblastoma). Thoracoscopic resection of foregut duplication and bronchogenic cyst in present times is

considered safe and the preferred approach. Bronchogenic cysts usually have no discrete connections to other important structures in the chest. Esophageal duplications, on the other hand, have a common wall with the esophagus and sometimes have a luminal communication. All mediastinal dissections are performed with a bougie in the esophagus. If there is a luminal communication between the esophagus and the esophageal duplication, the mucosa and muscle of the remaining esophagus is closed using sutures placed thoracoscopically. Great care must be taken not to compromise the esophageal lumen during the closure of the esophagus. Thoracoscopic biopsy of undefined mediastinal masses is a simple technique that avoids the large thoracotomy wound and commonly employed for such biopsies.

14.2.7 Patent Ductus Arteriosus

Thoracoscopic clipping of a patent ductus arteriosus (PDA) is performed using three or four ports. The patient is placed in a semi-prone position to allow the lung to fall away from the posterior thorax. The ductus is carefully dissected, preserving the recurrent laryngeal nerve, which loops around the PDA. A clip applier is passed directly through a small incision in the chest wall. The clip is then applied under endoscopic vision. The recurrent laryngeal nerve is observed while the clip is being applied to avoid injury to the nerve. Placement of a chest tube is optional, depending upon the surgeon's preference.

14.2.8 Esophageal Atresia

Esophageal atresia with or without tracheoesophageal fistula is now being commonly approached by the thoracoscopic approach (Iacona and Saxena 2020). The patient is positioned in the Cuschieri modified lateral decubitus position (side depending on the aortic arch), and the initial camera port is placed below the tip of the scapula. Two further ports are placed in the midaxillary and the posterior axillary line. The Azygos arch is recognized and may or may not be divided. If divided, clips, diathermy, or suture are the options that can been employed. The distal trachea-esophageal fistula is then visualized, ligated, and divided. Both upper and lower esophageal pouch are then approximated and the anastomosis is performed hand-sewn with 10–15 sutures tied intracorporeally. If an anastomosis is not possible, an approach with traction sutures is preferred; this is followed by a delayed anastomosis in a few days. Suturing in this setting is tedious because of the very small working space in the posterior chest. The procedure should be performed by experienced pediatric endoscopic surgeons comfortable in performing thoracoscopic surgery in a small thoracic space.

14.2.9 Congenital Diaphragmatic Hernias and Diaphragmatic Eventration

Both Bochdalek and Morgagni diaphragmatic hernias are repaired using endoscopic techniques. Thoracoscopic repair of Bochdalek diaphragmatic hernias is performed in stable patients but is not usually attempted in infants with pulmonary hypertension and severe pulmonary hypoplasia. Bochdalek diaphragmatic hernias are repaired using a primary closure technique as well as by the application of a patch graft. Repair of Bochdalek diaphragmatic hernia is performed both thoracoscopically and laparoscopically; however, the author favors the thoracoscopic approach. The reconstruction of the diaphragm usually starts at the medial portion of the defect. In larger left-sided defects, care must be taken not to include the esophagus into the first stitch. The tension should be assessed step-by-step, since excessive tension will be the main cause of recurrence. In case of doubt, either a patch or conversion into open repair should be considered.

Morgagni diaphragmatic hernias, on the other hand, are better approached by laparoscopy (Alqadi and Saxena 2019). Laparoscopy enables the visualization and the confirmation of a bilateral defect. The defect is repaired by an extra-

abdominal suturing technique, in which the posterior rim of the hernia tis sutured to the full thickness of the anterior abdominal wall using the port closure needle without the need for a mesh. In case of a large defect or tension in the sutures, a mesh is necessary to avoid recurrence.

Eventration of the diaphragm and a high-riding paralyzed diaphragm are also plicated with a thoracoscopic technique. If CO_2 infusion is used for the enhancement of intrathoracic visualization, there is the added benefit of the diaphragm being pushed down by the pressure of the infused pneumothorax. This pressure enlarges the involved pleural space and aids the plication of the hemidiaphragm. The plicating sutures are placed and tied thoracoscopically.

14.3 Laparoscopic Procedures

Successful laparoscopy depends on adequate expansion of the peritoneal cavity for clear visualization of intra-abdominal structures achieved through a pneumoperitoneum. Although many gases have been utilized for maintaining a pneumoperitoneum, carbon dioxide (CO_2) is the standard gas that is used for procedures. The physiological effects of CO_2 pneumoperitoneum may be more pronounced in infants and children than in adults. Neonates have a higher level of end-tidal CO_2 during carbon dioxide pneumoperitoneum. This enhanced absorption of CO_2 pneumoperitoneum can result in hypercapnia and respiratory acidosis.

Hypercapnia is usually overcome by increasing the minute ventilation and by evacuating the CO_2. Postoperatively, there is a risk that the child may be unable to maintain the increased ventilatory effort needed to ventilate off the CO_2.

Increased intra-abdominal pressure also has cardiovascular effects in the child. The younger the child, the greater the potential cardiovascular compromise. Pressures within the peritoneal cavity above 10 mmHg can lead to the compression of the inferior vena cava with a reduced venous return to the heart and to secondary hypotension. The infants' sensitivity to intraperitoneal pressures greater than 10 mmHg must be carefully considered for safe laparoscopy.

14.3.1 Inguinal Hernia

Laparoscopic inguinal hernia repair and the evaluation of a patent contralateral processus vaginalis is commonly performed around the world. Once a pneumoperitoneum is established, the patency of the patent processus vaginalis can be identified and the repair is performed. Placement of a purse-string or figure-of-eight suture laparoscopically or transabdominally under laparoscopic vision is used to close the internal ring. Variants in pediatric closures include simple closures of the inguinal ring or dissection of the peritoneum at the level of the internal ring and closure of the ring. Non-absorbable monofilament or braided sutures are used in laparoscopic repairs. A potential advantage of the laparoscopic-assisted inguinal hernia repair includes the avoidance of injury to the cord structures and testicles, and also closure of a patent contralateral side without any further incisions in the same session. The procedure is performed as a standard in neonates using 3 mm instruments (Walsh et al. 2020). In the classic open hernia repair, the hernia sac is stripped away from the vas deferens and testicular vessels; many studies have suggested that this stripping of the cord structures may produce unintended permanent changes in the vas deferens and testicles.

14.3.2 Pyloric Stenosis

The principles of the extramucosal pyloromyotomy described by Fredet and Ramstedt still remains the standard management for the treatment of pyloric stenosis also in the laparoscopic approach. In the laparoscopic approach, a 5 mm port is inserted under direct vision to accommodate a 30° scope. Two further abdominal access points are established with or without work ports. The author's preference is to grasp and secure the stomach using the left access work point. Using the right access point, a sleeved retractable laparoscopic knife is inserted to perform the pyloromyotomy, after which the muscle is spread using a pyloromyotomy spreader also inserted from the right side (Saxena 2013). Completion of the

procedure involves administering of air in the stomach and confirming the integrity of the mucosa; after which the air is evacuated though the nasogastric tube. The procedure has a learning curve to become proficient in order to avoid complications such as incomplete myotomies or mucosal perforations.

14.3.3 Duodenal Atresia

Laparoscopic management of duodenal atresia is becoming popular amongst pediatric surgeons since the first reports of successful application of this technique 2 decades ago (Mentessidou and Saxena 2017). The neonate is positioned supine at the end of the table and a 5 mm 30° scope placed in the umbilicus is preferred for this procedure. Abdominal inspection is performed to exclude associated anomalies, such as malrotation. Two further 3 mm ports are inserted under direct vision within the right and left iliac fossa. Once the duodenum is identified, a stay suture is used to suspend the proximal pouch to the abdominal wall. The proximal and distal segments of the duodenum are mobilized and approximated. The proximal pouch is incised transversely and distal segment longitudinally using laparoscopic scissors; avoiding electrocautery. A nasogastric tube is passed through the distal segment to rule out a second atresia or a possible web. The anastomosis is performed intracorporeally with interrupted sutures or with a running suture; both these suturing techniques have shown comparable outcomes. Alternatively, a duodeno-jejunostomy is an option which is easier to perform laparoscopically than duodeno-duodenostomy and has similar outcomes.

14.3.4 Malrotation

Malrotation, with or without mid-gut volvulus, can be managed laparoscopically. The malrotation is detorsed, and a Ladd's procedure performed using three or four access ports (Chacon and Saxena 2019). Appendectomy in neonates and infants is performed by exteriorizing the appendix through a port site and performing the procedure conventionally. Performing a laparoscopic Ladd's procedure in the presence of a volvulus may be challenging as it may be difficult to achieve sufficient visualization in the presence of dilated bowel. There is some controversy in reports emerging as to whether all the steps of Ladd's procedure are being followed or being achieved in the laparoscopic approach besides the detorsion of the volvulus and the division of peritoneal bands attached to the cecum; these include widening of the mesenteric root, appendectomy and positioning of the small bowel to the right and the colon to the left. Conversion rate is high for this procedure and mainly related to the degrees of volvulus, age of the patient, and learning curve.

14.3.5 Gastroesophageal Reflux and Gastric Feeding

Fundoplication, with or without gastrostomy, is a frequent procedure performed in children. Common indications include: primary aspiration, gastroesophageal reflux, profound neurologic impairment, and severe pulmonary and cardiac disease with failure to thrive or recurrent aspiration. Most infants and children needing fundoplication are excellent candidates for a laparoscopic approach. The fundoplication is performed using 3 mm instruments. The distal esophagus is mobilized and secured in the abdomen, and the crus are approximated behind the esophagus. The fundal wrap is formed loosely around the newly created intra-abdominal esophagus. Laparoscopic fundoplication can be achieved using the Nissen, Toupet, or Thal technique with comparable outcomes depending on the volume of cases and experience of the surgeon performing these procedures.

Laparoscopic gastrostomy is usually performed by placing a gastrostomy button. If the gastrostomy is performed without fundoplication, an effort is made to site the gastrostomy at an appropriate distance from both the gastroesophageal junction and the pylorus. Adequate

distance from the fundus is important, in case a fundoplication is needed at a later date. The technique involves securing the stomach by a laparoscopic grasper passed through an abdominal incision (predetermined site of the gastrostomy) and passage of the needle alongside into the stomach under laparoscopic vision to progress the Seldinger wire. The gastrostomy button is then positioned in the same steps as the percutaneous endoscopic gastrostomy. Many pediatric surgeons now prefer the laparoscopic-assisted gastrostomy to percutaneous endoscopic gastrostomy tube placement, as with the laparoscopic approach, the visualization of the entire left upper quadrant allows for the selection of the site of gastric entry, helps in avoiding nearby structures such as the colon, and can easily be combined with the performance of other laparoscopic procedures.

If a percutaneous gastro-jejunostomy tube (PEG-J) is required, the stomach is insufflated by the endoscope and under laparoscopic and endoscopic vision, T-fastners or U-sutures passed through the abdominal wall into the stomach and back out through the abdominal wall to secure the stomach. A Seldinger technique is used to obtain access to the gastric lumen, followed by the dilation of the tract over a guide wire; after which the PEG-J tube is inserted, with the jejunal limb correctly positioned beyond the pylorus under endoscopic vision.

14.3.6 Achalasia

The treatment of choice still remains the extramucosal longitudinal modified Heller cardiomyotomy with the anterior Dor fundoplication to avoid the onset of gastroesophageal reflux, maintaining the myotomy open and protecting the mucosa. Endoscopic myotomy limited to esophageal rosette or the perusal endoscopic myotomy technique (POEM) utilizing a submucosal tunnel to reach the inner circular muscle bundle of the lower esophageal sphincter are recent options to achieve the myotomy. POEM is a safe, effective, and feasible technique for the pediatric population.

14.3.7 Gall Bladder Pathologies

The main indications for laparoscopic cholecystectomy are the presence of symptomatic gallstones followed by gall bladder polyps and biliary dyskinesia. The minimal access approach with the use of four ports involves the retraction of the gall bladder by grasper positioned in one port. After the identification of Calot's triangle, ligation of the cystic artery and duct is performed. Cholecystectomy is performed using a monopolar hook employed in the liver–gallbladder interface, while the gallbladder is retained under traction. It is mandatory to stay close to the gallbladder wall to avoid the injury of the duct of Luschka, which, if present will connect the gallbladder fossa entering the right/left hepatic duct or either the cystic duct and if not seen can cause postoperative bile leak. The gallbladder is retrieved within an endobag to avoid spillage of gallstones in the abdomen. Reported complications of cholecystectomy include cystic duct leaks, duct of Luschka leaks, bleeding, infection, herniation and deep vein thrombosis and injury to the biliary tree.

14.3.8 Splenic Pathologies

Splenectomy in pediatric age found is mainly performed for hematologic disorders. Laparoscopic splenectomy involves a 4-port technique. The spleno-colic ligaments are dissected to release the lower pole attachments. This is followed by the dissection of the splenophrenic ligament. Once the spleen is released from its attachments the splenic vessels are ligated using suture ties, endoscopic titanium clips, vessel sealing devices, or vascular endoscopic staplers. The spleen after resection is placed in an endobag and piecemealed to extract it from the umbilical port site. Morcellators should be avoided as they risk serious and fatal injuries to the underlying structures. Also, the introduction of sharp objects into the endobag risks breaching of its integrity and spillage of the splenic pulp into the abdominal cavity risking splenosis.

14.3.9 Pancreatic Pathologies

Pancreatic tumors are rare in children. The most common pancreatic tumors in pediatric population are: pancreatoblastoma, solid pseudo papillary tumors, and islet cell tumors. Among these, insulinomas are insulin-secreting tumors arising from pancreatic beta cells with 10% associated to the multiple endocrine neoplasia (MEN) type 1. Congenital hyperinsulinism of infancy (CHI) is a condition characterized by the inappropriate secretion of insulin causing persistent hypoglycemia and leading toward serious neurologic sequelae. However, recent advancements in minimally access surgery have enabled surgeons to perform laparoscopic pancreatectomy safely. Most of these reports involve the adult population with distal pancreatectomies. Few reports have described the role of laparoscopic approach for the treatment of these pathologies in children.

14.3.10 Meckel's Diverticulum

The surgical technique consists in Meckel's diverticulum utilizes the capability of diagnostic laparoscopy and management at the same time. Though over the past 3 decades multiple laparoscopic approaches have be advocated, the authors' preference is for a laparoscopic-assisted resection of Meckel's diverticulum. Once the diverticulum is identified, the diverticulum is exteriorized through the umbilical port site and the resection and anastomosis are performed. The umbilical port site is enlarged especially with the extension of the linea alba so as to accommodate safe reduction of the anastomosis and prevent its forced reposition. The enlarged skin incision within the umbilical port site incision can be concealed at the time of port site closure.

14.3.11 Intussusception

Laparoscopic approach is indicated when attempts at enema reduction have failed or where enema reduction is contraindicated; it can be also useful as a diagnostic tool when other modalities of investigations like ultrasound and contrast enema were inconclusive like intussusception of small bowel. This approach is contraindicated in hemodynamic unstable children and when there is evidence of small bowel obstruction with marked abdominal distention and dilated bowel loops. Laparoscopic reduction involves grasping the intussusception and the intussuscepiens, and pulling back the intussuscepiens while holding the intussusception; this generally helps avoid tears during the reduction. In case of multiple presentations of intussusception and the absence of lead points, a laparoscopic ileo-cecopexy can be performed using non-resorbable sutures to secure part of the terminal ileum approximated to the cecum.

14.3.12 Appendicectomy

Laparoscopic appendectomy has taken its place as the primary technique used to treat appendicitis. In pediatric surgery centers, converting to an open operation after attempting laparoscopic appendectomy is a very uncommon event. It is performed with three ports using the sectorization or the triangulation port placement. The authors prefer the latter approach, as suprapubic port placements in sectorization have been reported to be associated with injuries to the bladder during port placement. The appendix is identified and separated from any attachments using blunt and sharp dissection. The mesoappendix is divided with bipolar forceps cautery and scissors sequentially till the base of the appendix is reached. The appendiceal stump is ligated with 3 endoloops ligatures (and resected between the 2 proximal and the distal endoloops) or with a stapling device. The appendix is delivered through the umbilical port site.

Usually a urethral catheter is inserted at the beginning of the procedure in order to empty the bladder and decrease the risk of bladder injury. Single-port appendicectomy is also performed in some centers as well as the transumbilical laparoscopic-assisted appendicectomy (TULAA). The laparoscopic approach has shown a decrease in morbidity with reduced length of

hospital stay and rate of wound infections. The incidence of a postoperative intraperitoneal abscess is about the same as after open appendectomy. Morbidity seems to be diminished with a more rapid discharge from the hospital being reported in several very large series. Laparoscopic appendectomy has become the standard of care for children with appendicitis.

14.3.13 Anorectal Malformations

High imperforate anus is usually repaired by a posterior sagittal anorectoplasty (Georgeson et al. 2000). The alternative laparoscopic repair of a high imperforate anus starts by the dissection of the rectourethral or rectovesicular fistula transabdominally. The muscle complex is identified by muscle stimulation on the perineum. A tract is developed through the muscle complex by identifying the appropriate landmarks from both the perineal and abdominal aspects. This tract is sequentially dilated using a radially expanding trocar. The fistula is pulled down to the perineum through the tract and secured to the perineal skin with sutures. The laparoscopic repair of a high imperforate anus mimics the repair of a low imperforate anus where the fistula to the perineum is mobilized and pulled through the external sphincter. Continence after laparoscopic pull-through has not been fully assessed although the early results appear to be promising.

The laparoscopic approach is mainly deemed to treat high prostatic or bladder neck fistula in males and congenital high rectovaginal fistula or cloaca with high rectum in girls. The laparoscopic approach offers performing of the abdominal part of the surgical procedure using the minimal access route, thereby avoiding the morbidities associated with laparotomy. The goals of laparoscopic-assisted pull-through for high anorectal malformations include precise placement of the rectum inside the sphincter complex without dividing and weakening the muscles and the diminished soft tissue scarring around the rectum leading to improved rectal compliance.

14.3.14 Hirschsprung's Disease

The management of Hirschsprung's disease has been radically changed by minimally invasive techniques (Georgeson KE 1995, 2002b). A pull-through is utilized after laparoscopic identification of ganglion cells proximal to the transition zone. Although the pull-through can be performed using a Duhamel or Swenson technique, the most common procedure performed endoscopically is an endorectal pull-through. Hirschsprung's disease is now managed by a single primary pull-through as opposed to the two- or three-stage procedures formerly used to correct the disorder.

Laparoscopic-assisted trans-anal endorectal pull-through is a versatile and effective technique for all left and transverse colon aganglionic segments. A laparoscopic-assisted Duhamel procedure is however preferred in case of ascending colon and total colonic ganglionosis. Contraindications to primary laparoscopic-assisted endorectal pull-through are associated life-threatening anomalies, deteriorating general health, severe enterocolitis, and severe dilatation of the proximal bowel.

14.3.15 Inflammatory Bowel Disease

Surgical procedures available for the management of these conditions include total colectomy, subtotal colectomy, ileocecal resection, ileorectal anastomosis with or without the creation of pouch (Georgeson 2002a). Four ports are used: 12 mm port is placed in the umbilicus, one 5 mm port in the right upper quadrant, one in the left flank region, and one 12 mm in the right iliac region where the ileostomy is to be fashioned. A fifth port may be used in the epigastric region, if needed. Generally, the colon dissection starts at the sigmoid colon by creating a mesenteric window, after which an endostapler is employed to create a rectal stump. Mobilization of the colon continues up to the hepatic flexure, always close

to the bowel wall in order to avoid injuries to surrounding structures. Once the colon is entirely mobilized, it is extracted from the right iliac region by extending the incision. Ileostomy is created also at this port site.

A three-port technique is preferred for the laparoscopic right colectomy. Two 12 mm and one 5 mm ports are used (one port in the suprapubic area and other in the right iliac fossa). Following the mobilization of the right lateral peritoneal attachments by sharp dissection, the mesocolon is dissected by using sealing devices. The colon is dissected intracorporeally using a linear endostapler. The anastomosis is finally performed either intracorporeal or extracorporeal suturing method.

14.4 Genitourinary System

14.4.1 Vesicoureteral Reflux

Different techniques are available for the surgical treatment of vesicoureteral reflux (VUR). Minimal access techniques were recently developed in order to reduce postoperative pain, avoid postoperative hematuria, and shorten hospitalization. They include endoscopic treatment (not covered in this chapter), vesicoscopic reimplantation, and laparoscopic reimplantation. When laparoscopic Lich-Gregoir reimplantation is performed, a cystoscopy precedes the laparoscopic phase in order to gain access to the bladder. Usually, a transperitoneal approach is preferred using 3 ports, a 5 mm umbilical port and two 3 mm ports on the right and left flanks, respectively. The ureter is identified at the level of the iliac vessels, the peritoneum is breached at the vesicoureteral junction and mobilized to achieve sufficient freedom for a tension free reimplantation. The bladder dome is suspended to the abdominal wall with a stay suture. After bladder filling, the detrusor muscle is split to expose the bladder mucosa. After placement of the ureter in the muscle cleft, the detrusorrhaphy is performed.

The vesicoscopic approach involves the insertion of a 5-mm step-port inside the bladder under cystoscopic vision. Following this the urethral catheter is inserted to deflate the bladder and allow the insufflation of CO_2. Under direct vision, further 2 ports (3-mm) are inserted. A 3–4 Fr catheter is then inserted to cannulate the ureter and secure it during its mobilization. Once adequate length is gained, a submucosal tunnel is created and the reimplantation is performed. Limitations however with this technique are small bladder capacity, surgeon's skills in intracorporeal suturing and knot-tying and previous failed endoscopic treatment or thick bladder wall.

14.4.2 Ureteropelvic Junction Obstruction

Ureteropelvic junction obstruction (UPJO) is the most common cause of hydronephrosis in infants and children. The patient is positioned in lateral decubitus or supine position with the affected side slightly elevated. The three-port technique is employed using a 5 mm 30° scope introduced through the umbilicus and two ports triangulated to reach the ureteropelvic junction. A transabdominal stay suture is placed to suspend the pelvis in order to facilitate suturing. The anastomosis is performed with either continuous or interrupted suturing. A double J stent is passed through one of the ports and advanced with the pusher. If the UPJO is related to an external obstruction such as a crossing vessel, a vascular hitch can be performed.

14.4.3 Benign Renal Pathologies

Minimal access surgery is one of the best applications for nephrectomy in benign conditions. The approach can be either transperitoneal or retroperitoneal according to surgeon preference and skills. The patient is positioned in a prone lateral decubitus will be required for the retroperitoneal approach. A 10 mm 30° scope is preferred for the transperitoneal approach while a 0° for the retro-

peritoneal approach. Three ports are needed in both approaches. Due to the smaller space, retroperitoneoscopic approach is considered technically more demanding. For the retroperitoneal approach, a single 5 mm incision is sufficient to access the retroperitoneal renal space. This first incision is placed midway between the 12th rib and the iliac crest at the lateral border of the sacro-spinal muscle, and the initial working space is created with the use of a balloon (80–120 ml air instillation) or swab to create the working space. The camera port is then inserted, and a 5 mm work port is inserted under direct vision laterally to the camera port between the 11th rib and the iliac crest. The second work port is placed in a medial position to achieve triangulation. Ligation of the renal vessels for nephrectomy can be achieved by sutures or vessel sealing devices.

14.4.4 Ovarian Pathologies

Ovarian pathologies that can be approached by laparoscopic surgery include ovarian cysts, benign ovarian neoplasms, ovarian torsions, streak gonads, and giant para-ovarian cysts. Open surgery is the preferred option in malignant neoplasms to avoid the risk of spillage and tumor upstaging. Simple ovarian cysts are punctured and evacuated under laparoscopic vision. In case of large hemorrhagic cysts, a cyst fenestration is performed and the contents evacuated by aspiration. Ovarian torsions are a good indication for laparoscopic surgery, with the present recommendation to salvage necrotic ovaries in children. Oopheropexy is performed on the ipsilateral affected ovary and prophylactically on the contralateral normal ovary based on the surgeon's preference. The authors' preference is to perform oopheropexy using a non-resorbable braided suture with a 2-point fixation of the ovaries. Streak gonads can be resected using vessel sealing devices, with a preference for salpingo-oophorectomy in this pathology. Giant para-ovarian cysts are evacuated through the initial port site incision to offer space in the abdomen to perform the laparoscopic procedure. The cyst wall resection can be performed using vessel sealing devices. Benign teratomas can be safely managed laparoscopically as an ovary-sparing procedure without rupturing the tumor cysts and mass (Raicevic and Saxena 2019). Careful dissection after breaching the capsule enables step-by-step enucleation of the entire mass leaving the residual ovarian tissue in situ.

14.4.5 Impalpable Testis

In case of impalpable testis, laparoscopy offers both a diagnostic and a management option. Once the lie of the testis is determined, four options are possible: (1) The presence if the testis inside the inguinal ring warrants the management with an open orchidopexy in the same setting.

Abdominal testis that cannot be mobilized for scrotal fixation can be managed by one of the following first stage options: (2) Performing a laparoscopic first-stage Fowler-Stephens procedure in which the testicular vessels are cauterized by bipolar forceps and dissected. During the second-stage laparoscopic Fowler-Stephens procedure, a large peritoneal flap is created around the testicle before it is mobilized into the scrotum via the Prentiss maneuver, in which a port is introduced through the scrotal incision and passed directly into the abdomen through the external inguinal ring to retrieve the testis for orchidopexy. (3) Vessel-sparing technique-I: Laparoscopic application of a traction suture on the testis and securing it to the abdominal wall on the contralateral port site. In the second stage that is also performed with, the testis is released from its abdominal wall attachments and due to sufficient length gained, an orchiopexy is performed either using the Prentiss maneuver or by routing the testis through the inguinal canal. (4) Vessel-sparing technique-II: Laparoscopic application of a traction suture on the testis and passing the suture through the ipsilateral inguinal canal for traction fixation in the scrotum. Since the testis is placed in the inguinal canal with this

technique, the second stage does not involve laparoscopy, but only an incision in the inguinal canal and orchidopexy.

14.5 Pediatric Oncology

The use of laparoscopy, thoracoscopy, and robotic techniques in pediatric oncology is being increasingly reported; however, controversies regarding its application in specific tumors remain. Although minimal access undoubtedly improves postoperative morbidity (pain, length of hospital stays, and cosmesis), uncertainty toward its compliance with the oncologic principles remain. Minimal access approach is employed for the management of abdominal and thoracic tumors such as adrenal tumors (adrenocortical carcinoma, pheochromocytomas, adrenal adenomas, sarcomas, ganglioneuromas, ganglioneuroblastomas, and neuroblastoma), pancreatic tumors (pancreatoblastomas and pseudo papillary tumors), liver tumors, ovarian tumors, sacrococcygeal teratoma (Altman type 4 or to ligate the feeding vessel in Altman type 1–3).

Irrespective of the minimal access approach, the following criteria should be respected in minimal access tumor surgery: (1) optimal exposure of the operative field both in the abdomen and thorax (with preference for single lung ventilation for thoracic masses), (2) dissection should proceed from the periphery to the central located vital structure with instruments familiar to the surgeon, (3) safe and secure removal of the tumor in endobags after resection and extending incisions if necessary, and (4) a clear plan to manage intraoperative bleeding.

14.6 Conclusion

Minimally invasive surgical techniques are playing an expanding role in pediatric surgery. Despite the growing use of endoscopic surgery in children, the current literature supporting the safety and efficacy of thoracoscopy and laparoscopy in children is based on relatively small numbers of patients. It seems clear, even with these small numbers, that children tolerate minimal access techniques well but have specific issues that must be recognized and respected to achieve safe results.

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