93 Fundoplication in Infants and Children

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Introduction

Gastroesophageal reflux is a physiologic phenomenon in infancy before the lower esophageal sphincter matures. In otherwise healthy infants, it rarely causes more than an inconvenience for the caregivers in the form of frequent spit-ups after feeds. As long as the child is thriving and otherwise asymptomatic, no specific treatment is necessary. When gastroesophageal reflux is severe enough to compromise normal growth, cause respiratory symptoms, or lead to inflammation of the esophagus, treatment is indicated. Nonoperative therapies such as thickened feeds, promotility agents, H2-receptor blockers, proton pump inhibitors, or elevating the head of the bed were all found to have only marginal benefit in the treatment of gastroesophageal reflux in young children [1–3]. Complications of untreated pathologic gastroesophageal reflux include failure to thrive, respiratory compromise, and esophageal peptic strictures [4].

There are three physiologic mechanisms to prevent gastroesophageal reflux in humans (Fig. 93.1). First, the lower esophageal sphincter (LES) is a concentration of circular muscle fibers at the lower end of the esophagus proximal to the gastric cardia [5]. The LES is a dynamic barrier that relaxes at the end of an esophageal peristaltic wave to allow a food bolus to pass into the stomach. At other times, it maintains a certain resting tone to prevent gastric content to backflow into the esophagus. Second, the esophagus joins the stomach at a sharp angle, the angle of His [6]. This angle acts as a one-way valve, allowing food to pass from the esophagus into the stomach, but closing when the fundus of the stomach is distended. A corresponding mechanism is found in other organ systems such as the urinary tract, in which vesicoureteral reflux is avoided by the ureter entering the bladder at a physiologic angle. Finally, the most distal portion of the esophagus is normally located within the abdominal cavity. This decreases the pressure gradient across the gastroesophageal junction, because the pliable wall of the esophagus transmits the ambient pressure to its lumen. Thereby, the physiologic pressure gradient between the abdominal and the thoracic compartment is not applied to the gastroesophageal junction, but proximal where it cannot exacerbate gastroesophageal reflux. All surgical fundoplication procedures aim to favorably influence the factors above.

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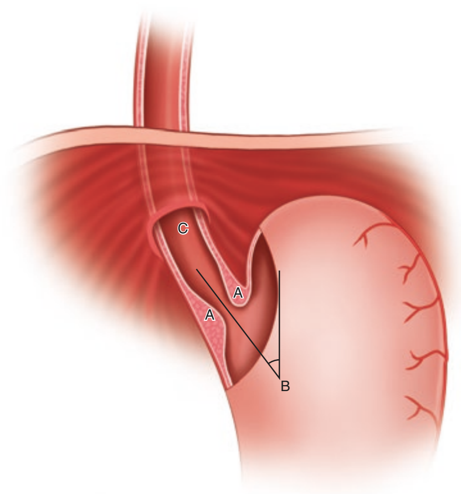

Fig. 93.1 Physiologic and anatomic anti-reflux mechanisms. The lower esophageal sphincter (*A*) is a dynamic concentration of circular muscle that usually remains closed in the resting state but opens up at the end of a peristaltic wave. The normal esophagus joins the stomach at a sharp angle, the angle of His (*B*), creating a vale-like configuration. Usually, the most caudal portion of esophagus is located in the abdomen (*C*), lowering the pressure gradient across the gastroesophageal junction due to the pliable nature of the esophagus

The first surgical intervention for gastroesophageal reflux was the hiatal hernia repair described by Allison in Leeds, England, in 1943 [7]. The recurrence rate was high, prompting the development of many different techniques of actual fundoplication over the following decades. Nissen's first fundoplication was performed in 1937 while he was the chief of surgery in Istanbul to reinforce the esophageal anastomosis he performed after resecting an ulcer [8]. Only later was this technique adapted for the actual treatment of gastroesophageal reflux disease and published by Nissen in 1956 [9]. Toupet described the posterior fundoplication in 1963 [10], and Thal proposed an anterior fundoplication in 1968 [11], to mention only the most popular procedures currently performed in children.

In 1991, the first laparoscopic fundoplication in adults was described by Dallemagne in Liege, Belgium [12]. Georgeson in Birmingham, Alabama, and Lobe in Memphis, Tennessee, published the first series of pediatric laparoscopic Nissen fundoplication independently in 1993 [13, 14].

This chapter describes the indications, techniques, and outcomes of fundoplication for the treatment of gastroesophageal reflux disease in children.

Indications for Fundoplication

As mentioned above, the main indications for a fundoplication in children are emesis of enteral feedings precluding the ability to thrive, aspiration of refluxed gastric content into the airways, persistent inflammation of the esophagus despite medical management, peptic stricture, and apparent life-threatening events found to be correlating with gastroesophageal reflux episodes.

Several patient groups have been shown to be at higher risk of gastroesophageal reflux. Based on the clinical presentation, some authors recommend early fundoplication in these children. For example, up to 80 % of patients who underwent esophageal atresia repair are at risk of developing symptomatic gastroesophageal reflux [15]. Therefore, the pediatric surgeon's threshold for performing a fundoplication in such patient may be lower, particularly because prophylactic proton pump inhibitors have not been shown to reduce stricture formation [16].

Patients with congenital diaphragmatic hernia are another target group in this regard. In one study, congenital diaphragmatic hernia (CDH) patients with an intrathoracic liver and patch repair had shorter postoperative hospitalization times and lower incidence of gastroesophageal reflux at 1-year follow-up when a fundoplication was performed concomitantly with the diaphragmatic hernia repair [17]. A similar study confirmed the predictive value of having intrathoracic liver and patch closure at the time of diaphragmatic hernia repair for requiring a later fundoplication [18]. Some surgeons have therefore recommended performing a modified anterior fundoplication in high-risk patients at the time of CDH repair [19].

Children with type I spinal muscular atrophy may be good candidates for laparoscopic fundoplication. Early surgery increased the nutritional status of these patients and was associated with fewer hospitalizations in the year following the procedure compared to the year before the operation [20]. Similarly, laparoscopic Nissen fundoplication at the time of gastrostomy tube placement was shown to improve survival in both type I and severe type II spinal muscular atrophy [21].

Age or weight should not preclude fundoplication in infants with significant gastroesophageal reflux symptoms or sequelae not responding to medical treatment. Laparoscopic Nissen fundoplication has been performed safely in small infants with low complication rates [22, 23]. Previous open surgery should also not be considered an automatic contraindication to laparoscopic fundoplication. In fact, several studies have shown excellent success rates and low conversion rates for laparoscopic fundoplication in children with previous open abdominal operations [24, 25]. Furthermore, fundoplication in general [26] and laparoscopic fundoplication in particular [27] were not found to increase the risk of shunt infection in children with ventriculoperitoneal shunts.

Laparoscopic fundoplication is feasible and beneficial to treat pathologic gastroesophageal reflux in children who underwent lung or heart-lung transplant with acceptable complication rates and outcomes [28]. Although fundoplication generally facilitates weight gain and nutritional status in children with severe congenital heart disease [29], children with hypoplastic left heart syndrome may have a higher morbidity and mortality during and after open fundoplication [30]. In these children, other nutritional options such as transpyloric feedings may have to be considered as an alternative until the patient has developed more stable physiology.

Most studies indicate that a fundoplication should not be added routinely to gastrostomy tube placement in neurologically impaired children [31, 32]. Postoperative morbidity was increased for patients having a routine fundoplication with their gastrostomy, and only 17 % of patients who underwent gastrostomy alone required a subsequent fundoplication at a later date for gastroesophageal reflux symptoms. Therefore, a more tailored approach is advised [33]. It is not clear what preoperative workup is necessary and which abnormal results should prompt a prophylactic fundoplication at the time of gastrostomy placement. Abnormal pH probe study alone was not a good marker to decide which neurologically impaired patients would benefit from a fundoplication at the time of gastrostomy placement [34]. In one study, clinical assessment had a 95 % positive predictive value in identifying patients who would require a gastrostomy [35].

Diagnostic Workup

Before considering a fundoplication, other entities that can mimic the symptoms of gastroesophageal reflux such as *H. pylori* infection, cyclic vomiting, rumination, gastroparesis, and eosinophilic esophagitis should be ruled out by careful medical evaluation.

A fluoroscopic contrast study of the upper gastrointestinal (GI) tract is usually the first step in the workup of gastroesophageal reflux disease. This examination allows the evaluation of the anatomy of the esophagus, the gastroesophageal junction, the stomach, the duodenum, and the ligament of Treitz. It allows the pediatric surgeon to rule out other anatomic reasons for reflux and vomiting, such as webs, stenosis, or malrotation. It also can detect hiatal hernia or peptic strictures of the lower esophagus which may modify the surgical plan or approach. In a study on 656 patients, significant findings other than gastroesophageal reflux or hiatal hernia were found in 4.5 % of upper GI studies performed in the workup for fundoplication [36]. Since it is merely a snapshot in time, and gastroesophageal is a dynamic disease that changes over the course of the day, the upper GI contrast study is not a sufficient examination to rule out or confirm gastroesophageal reflux. Its reported diagnostic sensitivity for gastroesophageal reflux is only about 31 % [36].

Reflux detected on pH probe in infants and children is extremely variable and depends on many factors such as age, feeding pattern, and positioning. It is therefore difficult to interpret the results. Boix-Ochoa proposed calculating the relative time in which a pH below 4 is detected in the lower esophagus and counting reflux episodes lasting more than 5 min [37]. If a pH probe is ordered, it is important to standardize the circumstances as much as possible, discontinuing acid blockers for at least 3 days before the study and recording feeding and positioning as accurately as possible [38, 39].

A pH probe will not detect nonacid reflux due to gastric contents buffered by feeds or bile reflux. This drawback is circumvented by the more novel impedance study, in which the electrical resistance between multiple electrodes on an esophageal probe is measured. When gastroesophageal reflux is present, the electrodes are surrounded by liquid, conductivity increases, and consequently the electrical resistance drops. Therefore, the impedance study detects all types of reflux independent on the pH and has been found to be more sensitive for the overall detection of gastroesophageal reflux in children [40]. Despite these advantages, the interpretation of the results and their clinical significance faces similar challenges as discussed for pH probe above [41].

A pragmatic and low-cost method to assess for pathologic gastroesophageal reflux in children with either a nasogastric tube or a gastrostomy is performing a bolus feeding challenge under controlled condition during hospitalization. Goal bolus feeds are fed into the stomach, and clinical judgment is used to determine the presence of significant gastroesophageal reflux. If the patient vomits or shows other signs of intolerance such as posturing or coughing, a fundoplication may be indicated.

Some have argued that preoperative delayed gastric emptying does not adversely affect outcome of fundoplication, and therefore preoperative workup with a gastric emptying scan is not helpful [42].

Ultimately, the most important question in the workup of a child who may be a candidate for fundoplication is to predict the benefit the patient may have from the procedure. The current literature suggests that preoperative pH probe and even impedance study are poor predictors of surgical outcome after fundoplication [43, 44]. The workup for gastroesophageal reflux and the indication for fundoplication at this time remain a complex decision that should be individualized for each patient and should not be based on one sole study or clinical finding alone. With this in mind, it is not surprising that pediatric surgeons often decide on performing an anti-reflux procedure on nonobjective data such as parent preference, clinical impression, and recommendations by the pediatrician [45].

Techniques

Contrary to widely prevalent belief, the aim of a fundoplication procedure is not to simply create a tight lower esophageal sphincter. Rather, a well-performed fundoplication changes the geometry of the gastroesophageal junction based on the anatomic and physiologic anti-reflux mechanisms detailed in the introduction. It thereby creates a valve allowing the passage of food into the stomach, but preventing its reflux back into the esophagus.

Many different techniques using the same basic principles for this goal have been described (Fig. 93.2), including those by Nissen [46], Toupet [47], Thal [48], Colles [49], Boix-Ochoa [50], and Watson [51].

The type of fundoplication employed depends mainly on the experience and training of the particular surgeon. Some comparative studies have been performed. In a prospective randomized controlled study, laparoscopic Thal fundoplication had a higher recurrence rate (16 % versus 6 %), but a lower rate of severe postoperative dysphagia (2 % versus 12 %, respectively), compared to laparoscopic Nissen fundoplication [52]. Open Nissen fundoplication has been found to have higher long-term success rates than the open Boix-Ochoa technique, in which the fundus is placed anteriorly onto the esophagus and tacked to the margin of the right crus and diaphragm [53].

In the Nissen-Colles fundoplication, a stapler is used to vertically extend the esophagus into the stomach. It has been described for children and may be particularly useful in patients with previous esophageal atresia repair, in which the operation is limited by a short intra-abdominal segment of the esophagus [54, 55].

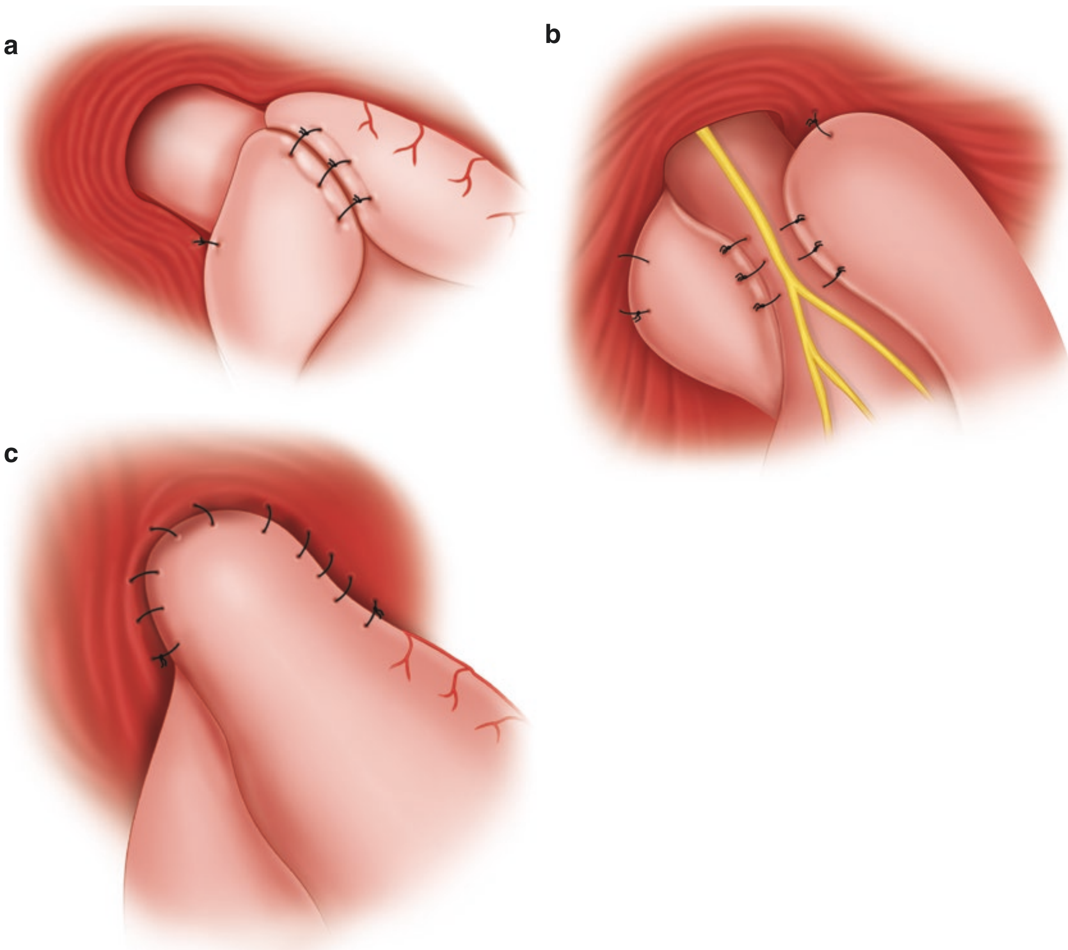

Fig. 93.2 The most commonly performed fundoplications in children are the Nissen fundoplication (**a**), in which a full 360° esophageal wrap is created and sutured around the lower esophagus. In the Toupet fundoplication (**b**), the fundus is pulled through a retroesophageal window and sutured to the anterolateral esophagus and the diaphragm, creating a 270° posterior cuff. The Thal (also called Dor) technique (**c**), consists of a 180° anterior fundoplication

Technically, a laparoscopic Nissen fundoplication is feasible in children without dividing the short gastric vessels (the so-called Rossetti modification) [56].

A complete fundoplication seems to be more effective in the treatment of gastroesophageal reflux, but partial fundoplication may have the advantage of less postoperative dysphagia [57]. This is still an ongoing debate. In a comparison of partial versus complete fundoplication, there were no differences in postoperative symptoms or complications, but more children achieved long-term medication-free recovery in the partial fundoplication group [58].

Regardless of technique, many surgeons place an esophageal bougie for calibration of the wrap before Nissen fundoplication. Recommended bougie size varies from 20F in patients around 2.5 kg to 40F for larger children around 15 kg. Wrap length generally varies between 1.5 and 3 cm [59].

Open Versus Laparoscopic

Since first described two decades ago, laparoscopic fundoplication has become the standard of care in many pediatric centers. In a large analysis of 33,533 children, laparoscopic fundoplication was associated with less in-hospital mortality, shorter length of stay, and lower hospital charges, as well as decreased rates of decubitus ulcers and postoperative sepsis compared to open fundoplication [60]. Similarly, in a retrospective comparison of 50 laparoscopic versus 50 open fundoplication, the advantages of laparoscopic fundoplication included shorter length of stay, quicker feeding, and lower equipment, hospital room, and pharmacy charges. The main advantage of open fundoplication was shorter operating times and associated charges, while total charges were the same [61].

Recently, evidence has surfaced that minimal dissection of the esophagophrenic ligaments during laparoscopic fundoplication may decrease the rate of wrap migration into the chest [62]. This finding was confirmed by a subsequent prospective randomized controlled trial [63].

Gastric Emptying Procedures at the Time of Fundoplication

In the past, the question was posed whether a pyloroplasty or pyloromyotomy should be performed during fundoplication, either as a routine procedure or in cases where the preoperative workup shows delayed gastric emptying [64]. While some studies have shown improved gastric emptying with these types of procedures [65, 66], others have argued that preoperative delayed gastric emptying does not adversely affect outcome of fundoplication anyway [42] and that fundoplication promotes gastric emptying per se, making a synchronous gastric drainage procedure unnecessary [67].

Laparoscopic Nissen Fundoplication: Technical Description

The following is a description of the author's technique for laparoscopic Nissen fundoplication. The patient is positioned at the foot of the operating table. In small children, the legs are taped in a crossed configuration with padding. In older children, a modified lithotomy position in stirrups is preferred. A preoperative dose of prophylactic antibiotics is given, and an esophageal bougie of age-appropriate size [59] is placed. The first trocar is placed in the umbilicus and the capnoperitoneum is insufflated. Additional trocars are placed under laparoscopic vision in the mid-epigastrium, entering the abdomen just to the left of the falciform ligament, and in the left flank area anterior and inferior to the lower spleen tip. A liver retractor is introduced through a stab incision from the right upper quadrant and lifts up the left lobe of the liver, exposing the hiatus (Fig. 93.3a). The 30° camera can be changed to an additional trocar in the future gastrostomy site to give a more direct view onto the hiatus. The gastrohepatic ligament is then divided using the monopolar hook cautery up to the hiatus (Fig. 93.3b). The right esophagophrenic ligament is divided, and a retroesophageal space is dissected bluntly just posterior to the esophagus, respecting the posterior vagus nerve and leaving the hiatus as intact as possible without deliberate dissection toward the chest. The fundus of the stomach is then rotated medially anterior to the esophagus, exposing the gastrosplenic ligament and the short gastric vessels on the left (Fig. 93.3c). Only the most superior gastrosplenic attachments are taken down using the monopolar hook to expose the left esophagocrural ligament. The ligament is divided and at this time the retroesophageal space is completely patent. Only if the hiatus is open, one or two crural stitches are placed to approximate it posteriorly (Fig. 93.3d). All stitches are performed using 2-0 silk sutures and a ski-shaped needle. At this time, an instrument is passed through the retroesophageal space from right to left, and the esophagus is lifted gently anteriorly. Usually, the fundoplication is visible when the camera is oriented to look through the retroesophageal window from the patient's right side. The fundus is grasped, pulled through the space behind the esophagus, and the anteriorly remaining fundus is sutured to the transposed fundus using three silk sutures. A small portion of the lower esophageal muscle fibers is incorporated into the stitch (Fig. 93.3e). The suture line of the fundoplication should be

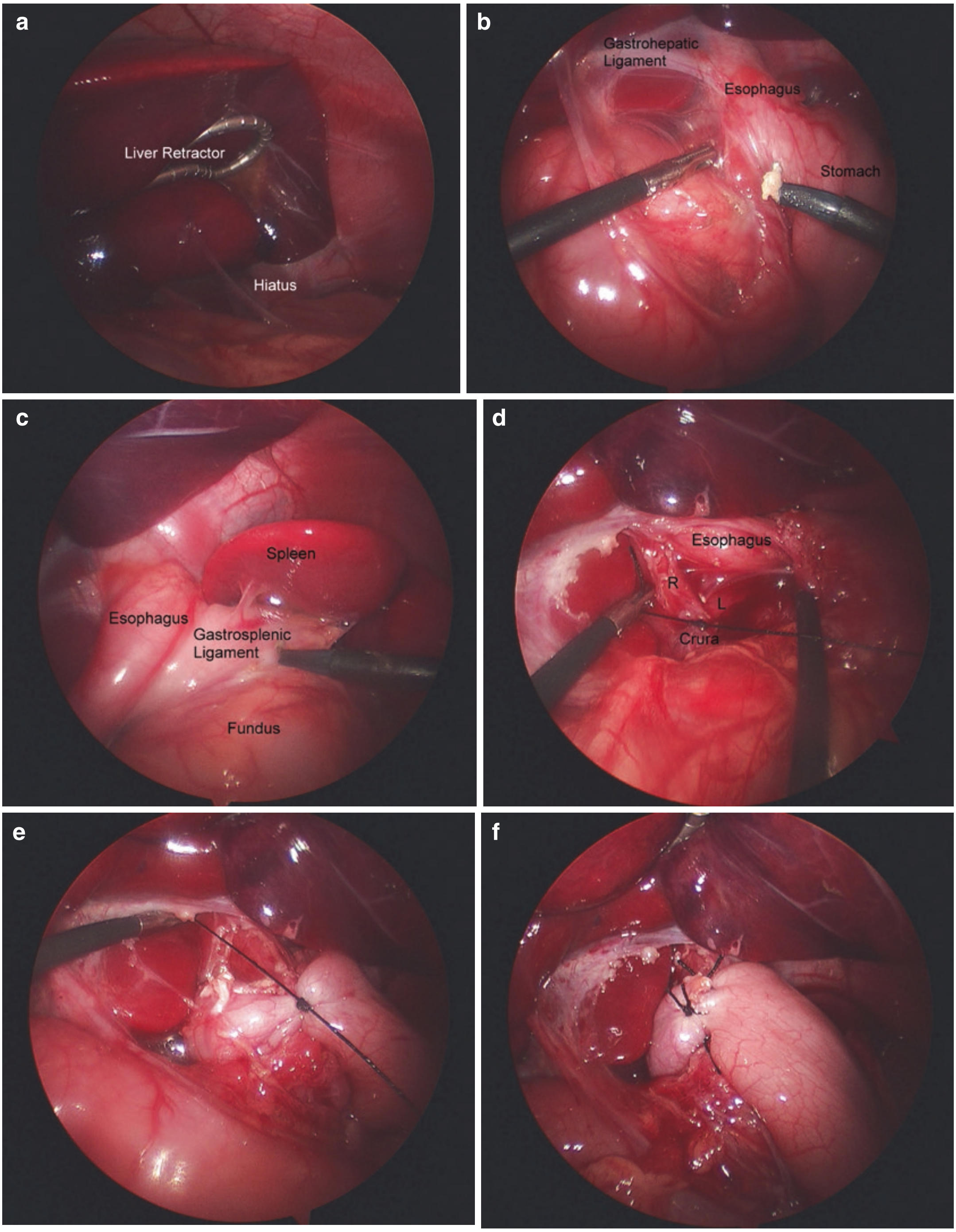

Fig. 93.3 Intraoperative images of laparoscopic Nissen fundoplication (see text for detailed explanation). The liver is retraced anteriorly, exposing the hiatus (**a**). The gastrohepatic ligament is opened to allow dissection of the space between the right crus and the esophagus (**b**). On the left, the superior part of the gastrosplenic ligament is divided as well (**c**). In this case, a crural stitch was placed posteriorly between the right (*R*) and left (*L*) crura (**d**). The posterior fundus is stitched to the anterior fundus around the lower esophagus (**e**). When completed, the suture line of the fundoplication is slightly medial and anterior (**f**)

located at the 10–11 o'clock position on the esophagus (anteromedially, Fig. 93.3f). Once completed, the bougie in the esophagus is withdrawn by anesthesia under vision. The capnoperitoneum is then desufflated and the endoscopic equipment is removed. Patients are allowed to have clear liquid diet when awake and advance to a no-chunk diet as tolerated. The no-chunk diet is maintained for approximately 3–4 weeks after the procedure, at which time regular diet is resumed.

Combination with Gastrostomy Tube

Laparoscopic gastrostomy tube placement can easily be performed along with laparoscopic fundoplication using the T-fastener or U-stitch technique [68]. Also, a percutaneous endoscopic gastrostomy (PEG) tube can be placed at the time of laparoscopic Nissen fundoplication with good results. Laparoscopic observation of the PEG placement may lower the procedure's complication rate [69].

Laparoscopic fundoplication in children who already have a gastrostomy tube in situ is feasible without increased complications [70]. Some surgeons prefer to take down the gastrostomy before fundoplication and perform a new gastrostomy thereafter, while others place the trocars around the gastrostomy site and leave it untouched. In this case, removing the gastrostomy tube before the sterile preparation and placing a sterile Foley catheter or similar into the gastrostomy site during the procedure are advisable.

Robotic and Innovative Approaches

Series of robotic-assisted fundoplication have been reported in children [71]. While it is more expensive, no clear benefits of the robotic approach have been shown in the clinical setting [72]. Operating times for the entire procedure were similar, although the dissection phase was about one third shorter with the robot. This temporal advantage was counteracted by a prolonged setup time for the robot [73]. The robotic approach has also been reported for redo Nissen fundoplication and fundoplication after gastrostomy tube placement in neurologically impaired children with acceptable perioperative complication rates and outcome [74]. One case-match control study comparing laparoscopic versus robotic versus open fundoplication including 50 pediatric patients in each treatment arm demonstrated longer operating times for robotic (160 ± 61 min) and laparoscopic (107 ± 31 min) compared to open fundoplication 73 ± 27 min, $P < 0.05$) with similar complication rates [75]. In an experimental study on infant pigs, conventional laparoscopic and robot-assisted fundoplication was equally effective, and there was a lower incidence of hemorrhage and pneumothorax in the robotic approach [76].

A single-incision laparoscopic approach for Nissen fundoplication has been described in ten children with complication rates and outcomes comparable to the conventional multi-trocar technique [77]. With the single-incision laparoscopic technique, all instruments and the laparoscope are brought in through a single incision in the umbilicus. When a synchronous gastrostomy is performed, the later gastrostomy incision is used as an additional access site, allowing for some ergonomic triangulation during the procedure. The most challenging part of the single-incision laparoscopic fundoplication is knot tying.

Inpatient admission and postoperative hospitalization for several days after a fundoplication are the current standard of care, although same-day outpatient laparoscopic Nissen fundoplication has been reported in a highly selected group of 19 children without any reported perioperative complications [78].

Recently, laparoscopic cardiaplication has been described as an alternative in patients with anatomic variants precluding formal fundoplication [79]. The technique entails a limited dissection along the most cranial greater curvature and subsequent imbrication of the cardia. It needs more formal evaluation before being universally recommendable.

The use of pledgeted mattress sutures rather than simple sutures for both the hiatal closure and the fundoplication reduced postoperative recurrent reflux from 23.4 % to 5.7 % in a study of 384 children [80]. In another longitudinal study of a single surgeon using different methods to perform a Nissen fundoplication, additional sutures of the wrap to the diaphragm did not lessen the chance of failure, which was as high as 26 %, but reinforcing the actual fundoplication sutures with a second suture line eliminated wrap failure in 21 patients [81].

Radio-frequency application to induce circular collagen (scar) tissue in the area of the lower esophageal sphincter (Stretta procedure) has been reported in children, but has yielded only mediocre short-term outcome [82].

Results of Fundoplication

Fundoplication has made a tremendous difference in the lives of countless pediatric patients over the last half century. Studies show clear improvement in the children's symptoms and quality of life, particularly in those with neurological impairment [83, 84]. In a follow-up study of 40 patients who underwent a laparoscopic fundoplication, the parameters for growth, respiratory symptoms, proton pump inhibitor use, and global gastrointestinal quality-of-life index improved significantly after the operation. In this study the positive changes were similar in the 21 neurologically impaired and 19 healthy patients [85]. Furthermore, fundoplication leads to objectively measured improvement of gastroesophageal reflux measured by pH probe without adversely affecting esophageal motility [86].

The documented effects of fundoplication on respiratory symptoms are less striking. While 87 % of gastrointestinal reflux symptoms resolved in 151 children after Nissen fundoplication, only 45 % of patients with reactive airway disease had improvement in asthma symptoms or episodes of pneumonia postoperatively [87]. However, children with apparent life-threatening events (ALTEs) benefited from fundoplication, decreasing the readmission rate for ALTEs from 78 % before to 4 % after fundoplication in a cohort of 81 patients and follow-up times between 4 and 6 years [88].

Despite the unquestionable benefits of fundoplication, some pediatricians are concerned of inadvertent sequelae such as dysphagia, retching, dumping, and gas-bloat syndrome. In a systematic review of 15 studies of open and laparoscopic fundoplications, these complications were as high as 50 % in open procedures [89] and much higher than in the more recent laparoscopic studies. When counseling patients, it is important to take into account these advances. The reduction in morbidity due to the shift from open to laparoscopic technique may be one of the driving forces behind the increase in referrals for fundoplication in children over the last several decades [90].

The outcome of 385 open anti-reflux surgeries has been assessed by postoperative pH probe measurements, showing excellent efficacy and an immediate failure rate of just 2.9 % [91]. However, in a follow-up study on 176 children who underwent open fundoplication, dysphagia was recorded in 30 % and dumping syndrome in 3 % of the patients postoperatively [92]. Similarly, high rates of postoperative dumping (11.5 %), recurrent reflux (12.2 %), and dysphagia (12.8 %) were recorded in 148 patients who mostly underwent open fundoplication [93]. Of note, even with mortality rates as high as 13 % and major complications in 11 % of cases after open fundoplication in a cohort of 93 children, most parents were subjectively satisfied with the postoperative results on long-term follow-up [94].

In one of the first comparative retrospective studies on 120 patients, Collins et al. found a significantly shorter mean postoperative hospital stay (6.8 versus 10.7 days) and earlier time to full feeds (2.3 versus 4.8 days, respectively) for laparoscopic versus open fundoplication with similar complication rates [95]. The outcome of Nissen fundoplication in the laparoscopic era has dramatically improved. In a large analysis of 1,050 planned laparoscopic fundoplications in a single center, there were only two conversions to open technique. In this cohort, average operating times decreased from 109 min at the beginning of the observation period to 38 min in the last 30 procedures. The wrap failure rate was 4 %, and intraoperative complications occurred in only 0.26 % [96]. Another 5-year follow-up study of 238 neurologically normal children who underwent laparoscopic Nissen, Toupet, or Thal fundoplication demonstrated a 5 % intraoperative and 5.4 % postoperative complication rate. The incidence of dysphagia was 2.9 %, and only 2.5 % underwent a redo fundoplication during the observation period. At the 5-year follow-up mark, 96.3 % were free of reflux symptoms and without medications [97].

Although the postoperative cytokine response was found to be no different between open and laparoscopic fundoplication in a randomized trial of 40 children, postoperative immunosuppression measured by monocyte class II MHC was less pronounced in the laparoscopic group [98]. The same authors found no difference in postoperative analgesic requirement between open and laparoscopic Nissen fundoplication. However, fewer children retched, and there was a more pronounced decrease of insulin levels as an indicator of lower cortisol levels after laparoscopy [99].

In an analysis of 7,083 pediatric fundoplications across the United States between the years 2005 and 2008, 56 % were performed laparoscopically. Laparoscopic fundoplication was associated with much shorter length of stay (4 days versus 10 days) and lower cost (US$ 13,000 versus 22,000) when compared to open fundoplication. Furthermore, the laparoscopic group had a 21 % lower wound infection rate and a 51 % lower overall complication rate [100].

A recent systematic review of 17 prospective trials on fundoplication for gastroesophageal reflux disease including a total of 1,280 children found a median success rate of 86 % in providing complete relief of reflux symptoms without medication [57]. The surgical mortality rate was well below 1 %, and there were no cases of gas bloating reported in any of the included trials. Some studies reported less dysphagia with techniques that employ a partial wrap, with no other significant differences in outcome between techniques. Similar findings of shorter hospital stay, earlier feeding, and less morbidity with the laparoscopic approach were obtained in a meta-analysis of five studies [101]. Interestingly, robotic fundoplication was also associated with shorter postoperative stay compared to laparoscopic or open fundoplication in a study on 150 children [75].

Mortality after fundoplication does not usually result from the procedure, but rather from the comorbidities that prompted referral for the procedure in the first place. In a prospective observational study on 244 children who underwent Nissen fundoplication, 20 % died at a median follow-up time of 2.8 years [102]. The risk factors associated with mortality were cerebral palsy, female gender, and concomitant gastrostomy placement. Patients with cerebral palsy and gastrostomy placement had a particular high mortality rate of 41 % at 5 years follow-up, underlying the fact that many of these children have multiple morbidities contributing to the increased mortality.

Complications, Risks, and Alternatives

Despite the advances discussed above, fundoplication still has a relatively high failure rate (3–10 %) compared to other routine procedures in pediatric surgery in which the complication rates are usually around 1 %. Consequently, a detailed discussion about possible wrap dislocation, disruption, or migration and the potential need of a redo procedure is advisable with the patient and family before scheduling the operation. As discussed in the chapter on redo fundoplication, some patients may be predisposed to wrap failure, particularly those that exhibit preoperative retching with feeds.

Unfortunately, there is no reliable method to avoid postoperative retching. Some surgeons advise decreasing the feeding rate or venting the gastrostomy between feeds and when retching occurs. According to one study, a pureed gastrostomy tube diet in lieu of the more conventional formula feeds may reduce the incidence of postoperative gagging and retching after fundoplication by modulating stomach emptying [103].

At times, the intraoperative findings preclude the completion of a planned fundoplication. Severe adhesions may increase the risk of the hiatal dissection, or the stomach may not be large enough to perform the desired loss wrap. In these cases, a Roux-en-Y feeding jejunostomy may be an alternative [103], although the complication rate was found to be as high as 51 % [104]. Placing a gastrostomy for later gastrojejunostomy tube placement is another option [105]. In an observational study, this approach had similar outcome to fundoplication in terms of survival or postoperative pneumonias [106].

Conclusions

Fundoplication has conferred immense benefits to countless children suffering from gastroesophageal reflux disease. When performed laparoscopically and using contemporary technique, outcome is usually excellent, and the morbidity and mortality from the procedure are low.

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