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SURGICAL ENDOSCOPY
and Other Interventional Techniques

The current role of laparoscopic surgery for gastroesophageal reflux disease in infants and children

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Abstract
Background: The benefits of surgery for gastroesophageal reflux disease (GERD) in infants and children have been questioned in the recent literature. The goal of this review was to determine the best current practice for the diagnosis and management of this disease.
Methods: The literature was reviewed for all recent English language publications on the management of GERD in 8- to 10-year-old patients.
Results: In infants and children, GERD has multiple etiologies, and an understanding of these is important for determining which patients are the best surgical candidates. Proton pump inhibitors (PPIs) have become the mainstay of current treatment for primary GERD. Although laparoscopic surgery appears to be better than open surgery, there remains some morbidity and complications that careful patient selection can minimize.
Conclusion: Surgery for GERD should be performed only after failure of medical management or for specific problems that mandate it.

Key words: Gastroesophageal reflux disease — GERD — Laparoscopic surgery

The benefits of surgery for gastroesophageal reflux disease (GERD) in infants and children have been questioned recently in the pediatric literature [20]. There are two main arguments for this. First, many infants and children experienced improved symptoms when placed on proton pump inhibitors (PPIs). Second, and perhaps more important, surgery is thought to be associated with a relatively high failure rate and some complications. This results in the need for many postoperative infants and children to remain on or resume their medications, to undergo redo surgery for recurrent disease, or to require additional treatment for new symptoms resulting from the surgery, some of which are attributable to complications. These arguments are based, in part, on older data, most of which comes from an era in which open surgery predominated.

No prospective randomized trials have compared either open or laparoscopic surgery with medical management in the pediatric population. Nor have any prospective randomized studies evaluated open versus laparoscopic surgery in infants and children. Many of the data used by pediatric gastroenterologists to determine the validity of surgery for this disease are extrapolated from studies performed on adults.

The purpose of this review is to set the record straight, insofar as possible, regarding the best current practice for the management of GERD in infants and children, with an emphasis on the current role of laparoscopic surgery.

Materials and methods

A literature search was undertaken for all English language publications on GERD in patients between the ages of 0 and 18 years. Publications were reviewed for their relevance to the subject, their content, and their methodology. Specific subsearches were performed to review specific aspects of this body of material including etiology, diagnosis, medical and surgical management, outcomes, and complications.

Results

Etiology

The etiology of GERD in infants and children differs that for this disorder in adults. A number of different mechanisms generally are held responsible for GERD in the younger patient, and they vary somewhat with age. The etiologies can be divided into primary GERD, which is a functional disorder of the gastrointestinal tract, and secondary GERD, which is seen more often as a result of dysmotility in systemic neurologic diseases.

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Secondary GERD also can be caused by mechanical factors such as those that occur in chronic lung disease, in systemic and local infections, or as the result of stimulation to the vomiting center in the brain from medications, as in the case of GERD related to chemotherapy [38]. The results of surgery for infants and children with secondary GERD tend to reflect a higher recurrence rate and more complications.

It appears that GERD runs in families, and some pediatric patients seem to be more susceptible to the development of GERD because of genetic predisposition. Indeed, a GERD-related gene has been described [25], although the significance of this has been questioned by others [28]. The lack of mucus and bicarbonate secretion by surface epithelial cells, the lack of defensive enhancement by prostaglandin release, the lack of an effective mucus cap after injury, and an apparent lack of capacity for esophageal erosions to heal rapidly by epithelial repair all may play a role in the development of esophagitis. Ineffective acid clearance, because of either inappropriate salivary pH or poor motility, prolongs exposure and promotes injury. This may be exacerbated when mucosal resistance is impaired, as discussed earlier [25].

The function of the upper esophageal sphincter and its role in the development of GERD in patients with chronic respiratory disease is poorly understood. It may be that the chronic irritation or erosion of the upper airway in some patients with GERD is attributable to dysfunction of the upper esophageal sphincter. Whether the inciting phenomenon may be delayed gastric emptying remains controversial [11]. When there is a delay in emptying, gastric distention initiates a vasovagal mechanism, resulting in abnormal neural regulation of the lower esophageal sphincter by the central nervous system. This causes a transiently lower esophageal sphincter relaxation, resulting in decreased basal tonicity in the lower esophageal sphincter and making the patient prone to reflux. Transient lower esophageal sphincter relaxation, regardless of the stimulus, is thought to be the single most common cause of GERD at all ages [11]. Mechanical factors such as the presence of a hiatal hernia or an obtuse angle of His tend to worsen the reflux symptoms when these phenomena occur. Although these anatomic abnormalities are thought to be familial and genetically predisposed, we have insufficient information about their natural history to make any statement about either their prevalence or the likelihood of their resolution in childhood [18].

Infants with congenital anomalies such as esophageal atresia are known to have esophageal dysmotility and seem more prone to GERD. Those with congenital diaphragmatic hernia probably have GERD for largely mechanical reasons related to the lack of a proper esophageal hiatus or lower esophageal sphincter mechanism. Erosive esophagitis is observed in 20% to 70% of children with GERD, primarily those with chronic illness, neurologic impairment, and 3 to 4 years of symptoms [18].

The patients at highest risk for GERD are those with neurologic impairment, cystic fibrosis, and anomalies such as esophageal atresia (long gap) and Barrett's esophagus, as well as preterm infants with severe pulmonary disease. Some studies suggest a possible pathophysiologic role for *Helicobacter pylori* in the development of GERD that begins in childhood and persists into adulthood [18].

More than 85% of premature infants have GERD. Of these, 3% to 10% have what appears to be supraesophageal or esophageal manifestations such as apnea/bradycardia and worsening of their bronchopulmonary dysplasia. As many as 100% of infants 3 months of age or younger are thought to have GERD. About one-third of these infants seek medical attention, whereas in 80% of cases, the symptoms resolve spontaneously without intervention. By 6 months of age, 20% to 40% of infants have GERD, but at 1 year, fewer than 20% have demonstrable reflux [18]. At 1 year of age, fewer than 20% of infants remain symptomatic. In older children, 3 to 18 years of age, GERD symptoms range from 1.8% to 22% [20].

Symptoms

Symptoms vary somewhat with the age of the patient. Among the premature, GERD should be considered for infants who demonstrate apnea and bradycardia and persistent airway problems. Feeding tubes make the lower esophageal sphincter incompetent, so these infants are likely to have reflux while the tube is in place. It is important that the feeding tube be removed when these infants are evaluated for GERD.

Infants with GERD are apt to present with apnea/bradycardia, reactive airway disease, and recurrent pulmonary infections or pneumonia. Symptoms suggestive of GERD are less frequent in children than in adults. Among 3- to 9-year-olds, heartburn occurs 1.8% of the time, epigastric pain 7.2% of the time, and regurgitation in 2.3% of cases. This varies somewhat in adolescents, who report heartburn 5% of the time, epigastric pain 5% of the time, and vomit more frequently (8% of the time). Children with GERD are more likely to have a previous diagnosis of sinusitis, laryngitis, asthma, pneumonia, or bronchiectasis. Notably, children with GERD are less likely to have a diagnosis of otitis media [32].

Although the prevalence of GERD in the pediatric age group has not been well studied, we do know that the prevalence of regurgitation in infants (one or more episodes a day) reaches a peak of 67% at the age of 4 months and decreases to 21% by 7 months [8]. At the age of 1 year, 14% of patients who had regurgitation report persistent feeding problems. Children 3 to 9 years of age have heartburn and regurgitation, respectively, 1.8% and 2.3% of the time, whereas those 10 to 17 years of age report heartburn and regurgitation 5.2% and8.2% of the time. There appears to be poor correlation between the symptoms reported by the children themselves and the symptoms claimed by the parents for these children.

In the very young patient, particularly the preterm infant, symptoms of reflux are common. These infants present with apnea/bradycardia, emesis, poor

oral intake, or irritability. However, only 63% of infants younger than 32 weeks gestation presenting with these symptoms will have documentable GERD [1]. Only 20% of infants younger than 34 weeks gestation have documentable GERD. Although the evidence is nonconclusive, it appears that most of the support is in favor of continuous intraesophageal pH-metry with a specificity and sensitivity greater than 90% as the best of the diagnostic studies. Intraluminal electrical impedance studies have the extra advantage of being able to detect nonacid reflux in these patients. Younger infants can present with regurgitation or vomiting together with growth failure or indirect symptoms of pain such as abnormal crying, dysphagia, anorexia, sleep disorders, or anemia. Acute life-threatening events resulting from either laryngospasm or reflex bradycardia can be seen in this age group and should be correlated with documented reflux. Chronic respiratory disease and upper airway problems also can be seen in this age group. Generally, 50% to 80% of these patients become asymptomatic by the time they reach 2 years of age.

In older infants and children, vomiting is the predominant symptom. This generally disappears within a year after the diagnosis in most children (90%). When infants fail to grow and no other cause is apparent, GERD should be considered. Erosive esophagitis affects fewer than 5% of thriving children. It manifests as heartburn or dysphagia and may present with anemia or esophageal stricture. Neurologically impaired children are at greater risk for manifesting signs of erosive esophagitis. Approximately 30% to 70% of these children with GERD will show signs of erosive disease. Chronic reactive airway disease or asthma may be caused by unsuspected GERD. This condition is seen in 27% of children with GERD, and upper airway manifestations are seen in 6% of patients [4]. Currently, dystonic contortions of the head and neck (Sandifer's syndrome) rarely is seen.

Diagnosis

As a general rule, evaluation of the infant or child with suspected GERD is not as complex as the workup of an adult patient. Endoscopy offers a sensitivity of 70% and a specificity of 95%. Up to 30% of biopsies diagnosed by the pathologist as reflux esophagitis are thought to be normal at esophagoscopy. Esophageal biopsy in such cases documents the presence of esophagitis and can differentiate GERD-related inflammation from eosinophilic esophagitis by the histologic finding of 15 to 20 eosinophils per high-powered field. This study is essential when Barrett's esophagus is suspected. Barrett's esophagus is suspected only in children in their second decade after years of untreated reflux. The children at greatest risk are those with cystic fibrosis, those with severe mental retardation, and those who have had an esophageal atresia repair.

Ultrasound, used to detect more than five episodes of reflux in 10 min, is commonly performed overseas, but not so often in North America. The "gold standard" pH monitoring, although highly diagnostic, with a sensitivity of 90% and a specificity of 100%, appears to be used only for 33% to 77% of patients. When airway symptoms predominate, bronchoalveolar lavage can provide supportive evidence with the observation of lipid-laden macrophages in the effluent. However, this finding has a sensitivity of only 38% and a specificity of 59%. An otolaryngologic examination, in which acid injury to the pharynx and vocal cords can be documented by erythema of the arytenoid and arytenoid bar and by posterior pharyngeal cobblestoning, also supports the diagnosis of GERD. Moreover, upper gastrointestinal contrast studies have a sensitivity of 40% and a specificity of 85%. Many prefer a radionuclide-labeled ^{99m}Tc sulfur colloid gastric emptying scan. This study can assess for the presence of GERD and quantitate the gastric emptying time. In most settings, 50% of the isotope meal normally leaves the stomach within the first 60 min, with approximately 80% emptying within 90 min after ingestion of the labeled meal. When reflux is present, it can be seen on the images, and if there is aspiration, the isotope can be observed in the lungs [35]. Resolution of symptoms after a trial of PPIs is considered by many to be diagnostic of GERD in symptomatic patients [7, 33].

Clinicians in the United States rarely rely on manometrics or motility studies in infants and children, although some European centers find these studies useful. When manometrics are performed in pediatric patients with GERD, with or without demonstrable esophagitis, esophageal body contractions generally are noted to be decreased in number and abnormal, suggesting that these patients have impaired esophageal body acid clearance [6]. This and the finding of poor gastric emptying in many of these patients probably reflects the fact that GERD in this age group is to some extent a manifestation of a more generalized gastrointestinal motility disorder [29]. In light of this fact, the number of patients who perceive swallowing difficulties after antireflux surgery should not surprise us.

Motility

Patients with central nervous system disorders who vomit have abnormal gastric motility and some degree of delayed gastric emptying as often as GERD. The performance of a fundoplication in these patients may in fact unmask these symptoms and predispose the patient to additional or new symptoms of discomfort. These patients are difficult to evaluate. The normal pH study fails to differentiate between true GERD and the reflexive vomiting that occurs with dysmotility [29]. When these patients undergo surgery for GERD, however, procedures for gastric emptying are rarely indicated [34]. There is some evidence in adults that fundoplication performed for these patients will improve gastric motility [13].

Management

Mild symptoms of GERD without complications in older individuals can be managed well with lifestyle changes such as weight loss, when appropriate; reduc-

tion of fatty foods, caffeinated beverages, and chocolate; and elimination of eating before bedtime. According to the latest Cochrane review, it appears that thickened feedings do reduce GERD symptoms [9].

Histamine-2 receptor blockers

Antacids and histamine-2-receptor antagonists (H_2RA) may give symptomatic relief for children with GERD, and H_2RA therapy still is prescribed commonly for infants. Studies with adults, however, show that 2 weeks of PPI therapy is more effective than 12 weeks of H_2RA administration for the healing of erosive esophagitis [20]. Findings show that H_2RA therapy fails to inhibit meal-induced acid secretion as PPIs do. The PPIs are more potent suppressors of acid secretion and thus reduce the volume of gastric secretions. This facilitates gastric emptying and results in less vomiting. Furthermore, in contrast to H_2RA, the administration of which may result in a tachyphylaxis, the effect of PPIs does not diminish over time.

Proton Pump Inhibitors

In cases of erosive esophagitis in children, the rate of healing with PPI therapy seems to be even faster than in adults [20]. Because PPI therapy is so effective, when it fails, the most likely causes are either that the dose is too low or split into two. The most effective dosing is as a single dose with the first meal of the day. That being said, there are some circumstances in which an additional dose with the evening meal may be beneficial. These include severe esophagitis, peptic stricture, esophageal motility disorders, symptoms of persistent nocturnal reflux, and so-called "atypical" or "extra-esophageal" manifestations of GERD such as otolaryngologic or pulmonary complications.

Younger children often require higher doses of these drugs on a per kilogram basis than adults. Whereas the dosage for omeprazole usually begins at 0.7 mg/kg per day and goes up to 3.5 mg/kg per day, a starting dose of 1.4 mg/kg per day heals severe esophagitis in about 75% of children afflicted with the disorder, relieving them of their symptoms in approximately 2 weeks of therapy. Lansoprazole at a starting dose of 1.5 mg/kg per day, with the dose increased under the guidance of a pH test to assess gastric acid suppression, appears to be effective in both the treatment of GERD and the suppression of gastric acid secretion [14]. Although findings have shown long-term use of omeprazole in adults to be safe for as long as 11 years, our data only demonstrate the safety and efficacy of its continuous use in children for up to 2 years [20].

Prokinetics

There is no clear evidence that cisapride is effective for treating GERD in children. Additionally, this agent is associated with fatal cardiac arrhythmias and sudden death and thus is no longer considered safe [2]. Similarly, although metoclopramide appears to be slightly more effective than placebos in controlled studies, the side effects of this agent outweigh any potential benefits, and we no longer use it as a prokinetic [9]. The literature, however, does currently support the use of low-dose erythromycin as a prokinetic agent in combination with acid suppression when a prokinetic is believed to be beneficial [5]. Erythromycin appears to act in low doses via motilin receptors on cholinergic neurons, and in higher doses more directly on a muscular motilin receptor [10].

Surgery

In recent a Pediatric Health Information System (PHIS) survey of 28 U.S. children's' hospitals, GERD accounted for approximately 4% of all admissions. This number appears to be increasing, particularly in the 12- to 24-month age group. Most of these children (77%) are currently treated with PPIs, whereas approximately 25% to 36% of children undergo surgery for their disease. Interestingly, 14% of hospitalized children who undergo surgery appear to do so without any pediatric or gastroenterologic consultation or input. In the year 2000, approximately $750 million was spent for inpatient care of children with GERD in the United States [18].

Surgery is thought to be indicated when symptoms persist despite maximal medical therapy, when the patient cannot be weaned off medication, or when symptoms recur immediately at cessation of medications. Surgery may be considered when symptoms progress with maximal medical management or when there exist complications of esophagitis such as hemorrhage, pain, stricture, or Barrett's esophagus. Surgery is further indicated when complications of aspiration ensue or chronic "reactive airway disease" persists. Severe cases may present with massive aspiration in the form of a "near miss" sudden infant death episode.

In more subtle cases, patients simply may fail to thrive because of their chronic reflux, or they may have sequelae of their congenital anomaly, such as a tracheoesophageal atresia with esophageal fistula or a congenital diaphragmatic hernia. Also, some patients have anatomic abnormalities that predispose them to GERD, such as a congenital short esophagus or a large hiatal hernia.

For many years, surgery was the mainstay of treatment for the management of severe GERD in infants and children. Surgery for GERD remains among the most commonly performed operations in pediatric surgery worldwide. The surgical approach is very appealing because it has the potential to avoid the use of medications, the long-term effects of which we do not know. The problem is not so simple, however, because of the relatively high documented failure rate and the complications associated with these operations noted in the past. The best candidate for surgery is the neurologically normal patient with GERD documented by esophagoscopy who has responded favorably to PPI therapy.

Most of the problems seem to arise in the difficult-to-treat patients with neurologic impairment or repaired esophageal atresia, and in those with chronic pulmonary disease [19, 20] Some authors note that antireflux sur-

gery in neurologically impaired children results in up to twice the complication rate, three times the morbidity, and four times the reoperation rate within a follow-up period of less than 2 years. In one study, only 40% of children with esophageal atresia had an "excellent" result at 5 years, including those who underwent reoperations [20].

One factor nearly impossible to evaluate in comparisons of studies on antireflux surgery is the lack of consistency in technique. The devil apparently is in the details, and experience is important. Some surgeons divide the short gastric vessels, whereas others do not. Some surgeons fully mobilize the distal esophagus, whereas others do not. Some surgeons make a loose floppy wrap, whereas others make it snug. Some surgeons fix the wrap to the crura or diaphragm, whereas others do not, and some use pledgets, whereas others fail to see the need. There also are a number of different procedures. The choice to perform a Nissen fundoplication, a Nissen-Rossetti fundoplication, a Thal fundoplication, a Boix-Ochoa fundoplication, or a Toupet fundoplication depends more on the surgeon's experience and the location of practice than on the patient's pathology. Most of these modifications have been made because the operation failed in some way. It is difficult to imagine that these factors are irrelevant. In most instances, when there is more than one way to perform an operation or there exist many operations to accomplish the same thing, it means that we have yet to find the optimal solution.

Since I performed the first laparoscopic fundoplication on a child in 1991 and presented a motion picture on the procedure at the Clinical Congress of the American College of Surgeons in 1992, pediatric surgeons around the world have gained quite a large experience with this technique. Since then, Georgeson [15] has performed more than 2,000 fundoplications in infants and children. Rothenberg [30, 31] recently reported the results for his series of more than 1,100 cases.

Reports over the past decade have been more encouraging than those of prior years with open surgery because most pediatric surgeons currently seem to favor the laparoscopic approach. An experienced pediatric laparoscopist will not hesitate to perform a fundoplication even in the smallest of preterm infants.

The rates for conversion to open procedures range from 0% to 7.5%. Most conversions to an open procedure occur either because the surgeon is inexperienced and the procedure is one performed early on the learning curve or because it is a redo procedure after a gastrostomy tube or a previously failed fundoplication. This is the situation in about two-thirds of the cases.

Occasionally, a complication occurs that the surgeon is more comfortable treating by laparotomy. Reported complications range from 0.5% to 11.5%, and the rate of recurrent GERD ranges from 1.4% to 6% [36]. One recent long-term study of laparoscopic Nissen fundoplication in infants and children with a follow-up of 11 months to 19 years showed a recurrence rate of 15.4% [39]. There is a steep learning curve. Most of the complications occur early in the history of any individual series, usually within the first 50 cases. Similarly, the more complex the patient group (e.g., the more neurologic impairments and the more congenital malformations or chronic lung disease in small infants), the greater the likelihood that complications will be observed. The range of complications seen in children is similar to that observed in adults, and the majority of these can be dealt with laparoscopically. Among the common complications seen are bowel or vascular injuries from access, pneumothorax from a diaphragmatic injury, trocar-site hernia, and hemorrhage. Other complications such as pulmonary impairment and late adhesive bowel obstructions that we used to see regularly after open antireflux procedures are rare after laparoscopic antireflux surgery.

Our experience with robotic-assisted antireflux surgery in 30 infants and children is similar in outcome and frequency of complications to our laparoscopic experience. There is a learning curve for getting used to the absence of haptic feedback that requires about 5 to 10 cases. During this period, there is a tendency for surgeons to make the crural repair or the wrap too tight. Once this is remedied, the results are the same.

For patients with difficult-to-manage respiratory symptoms because of GERD, Mattioli et al. [27] emphasize the importance of paying particular attention to the individual's complaints, especially because many infants and children present with atypical symptoms. These authors note that evaluating the response to medical therapy and assessing the results of bronchoalveolar lavage are the best tools for studying patients with confusing symptoms. With careful use of these criteria, they find that only about 8% of their patients require surgery. By carefully selecting their patients, they have been able to demonstrate a 96% reduction in symptoms and have had no evidence of postoperative complications or recurrence of reflux.

Gastrostomy tubes

The technique of gastrostomy tube placement at the time of an antireflux procedure is well described [16]. It does not seem to be an independent factor in the development of complications, except when the tube is brought out through a trocar site for an immune-suppressed patient. In the author's experience, this can lead to severe cellulitis and should be avoided at all costs.

It still is controversial whether a child with no GERD at the time of surgery needs a "protective" wrap simply because a gastrostomy feeding tube is required. These patients are often impaired in some way, neurologically or otherwise, and cannot eat on their own. There are data to suggest that the placement of a gastrostomy tube imparts up to a 10% risk for the development of GERD after a percutaneous gastrostomy, and up to a 39% risk of GERD after a Stamm gastrostomy [3]. It is reasonable to offer a selective approach and to study these patients beforehand. When preoperative studies demonstrate previously undiagnosed GERD, an antireflux procedure probably should be performed. When no reflux is demonstrated, a gastrostomy tube alone can be placed, with the understanding that many of these patients will return with

reflux symptoms. Some of them will respond to aggressive medical therapy. The remainder should undergo a wrap.

Many children referred for surgery because of GERD already have a gastrostomy tube in place. Often, the tube has been placed percutaneously (PEG) by the gastroenterologist. Jesch et al. [22] reviewed their experience with laparoscopic Thal fundoplication in children who had a previously placed PEG and found that the presence of this device rarely presented a problem. In most cases (77%), the procedure took place without event and without disruption of the PEG. The PEG was relocated in 13.5% of cases during the laparoscopic procedure, and in the remainder, conversion to an open procedure was performed for reasons other than the presence of the PEG.

Complications

According to Spitz and McLeod [35], complications are most often observed in infants younger than 4 months of age, in those with esophageal atresia, and in the neurologically impaired child. Disruption of the wrap is seen in 8% to 12% of cases. Dysphagia from an excessively tight wrap (noted to occur more frequently after a laparoscopic antireflux procedure) occurs 2% to 12% of the time, and herniation of the wrap into the chest is not uncommon. Gas bloating, seen in 4% to 10% of cases, appears to be more common in the neurologically impaired child. Adhesive bowel obstruction is seen 2% to 10% of the time, usually after additional procedures such as a gastrostomy, Ladd's procedure for malrotation, or appendectomy have been performed. The incidence of adhesive bowel obstruction appears to be less with the laparoscopic procedure, and there seems to be a higher incidence of paraesophageal hernia after the laparoscopic approach than we used to see after open antireflux surgery [21].

Esposito et al. [12] recently investigated the use of laparoscopic fundoplication in patients with GERD after repair of an esophageal atresia. They noted a 31.2% rate of short-term dysphagia after the procedure, which was most likely attributable to intrinsic esophageal dysmotility. All neurologically normal patients were free of reflux symptoms up to 6 years after their antireflux surgery.

In a recent retrospective review, 198 children were evaluated for the occurrence of postoperative complications and side effects. These were further categorized according to whether they had associated medical disorders (74%) or simply symptoms of GERD. The median age of surgery for the children in this study was just over 2 years of age, and 89% of the patients came for follow-up visits within 2 months of their surgery. Postoperatively, the children with associated disorders had significantly more pulmonary infections (52% vs 22%) and dumping syndromes (2% vs 0%). Most of the children (63%) required evaluation or treatment for symptoms suggestive of recurrent reflux despite the fundoplication [17].

In a similar review of their initial 3 years of experience with laparoscopic fundoplication, Jones et al. [23] reported that 22% of the patients remained symptomatic or required medication for their reflux after their fundoplication. An additional 36% of their patients had some degree of dysphagia, most of which resolved by 6 weeks after the surgery, and 35% of their patients reported increased flatulence.

A clear understanding about the various etiologies of GERD in infants and children guides us in our selection of the best procedure for an individual case. Knowing which patients are subject to the risk of failure because of their condition often prompts us to modify our technique. As an example, we may choose to reinforce our sutures with pledgets in the neurologically impaired patient, whether this is our routine for the neurologically normal child or not. Even so, antireflux procedures for these patients are prone to failure despite our best efforts.

When a wrap fails, we have several possible options depending on the mechanism of failure. In some cases, the simplest option is to treat the patient medically. A redo fundoplication is a consideration. It may be necessary to revise the wrap completely, and to reinforce it with a felt patch or pledgets. When the esophagus is too short for securing sufficient length below the diaphragm to create an adequate wrap, a Collis gastroplasty can be performed either laparoscopically or as an open procedure, depending on the experience of the surgeon. As a last resort, in the case of severe reflux, an esophagogastric disconnection or Bianchi procedure can be performed [24].

Rothenberg [31] recently reported his experience with redo fundoplication for this disease. Of the 118 children undergoing redo surgery, 30 were from his own series, suggesting a 3% need for redo surgery in very experienced hands. In this group of redo patients, the complication rate was 3.8%. The complications included delayed perforations requiring reoperation and development of an incarcerated paraesophageal hernia requiring repair in the early postoperative period. The postoperative dysphagia rate was 3.8%, and the wrap failure rate was 6% during an average follow-up period of 48 months.

Endoluminal therapy

Endoluminal gastroplication has been tried in a group of children who failed medical management [37]. All of the patients showed symptomatic improvement after treatment, but the symptoms in 3 of the 17 children recurred, prompting a repeat procedure. At a mean of 33 weeks, 14 of the 17 patients were off medication and had remained asymptomatic, suggesting that endoluminal plication may be an effective alternative approach for selected patients. The group in Ann Arbor has had a similarly successful experience using the Stretta procedure for pediatric patients [26]. Whether these types of therapeutic maneuvers will prove effective in the long term, ultimately replacing fundoplication in infants or children, or whether they simply will be used as a salvage maneuver when the initial wrap fails remains to be seen.

Discussion

As the findings show, GERD in infants and children is a complex disease that is not easy to remedy. We tend to focus our management strategies in two main areas. First, we have effective agents to reduce acid secretion and thus the likely damage to the esophagus and lungs from their long-term or repeated exposure to low pH. Second, we can correct some of the anatomic abnormalities. Using artificial means, we can increase tonicity and restore some degree of function to the lower esophageal sphincter.

In the normal individual without GERD, both acid clearance and a competent lower esophageal sphincter coexist. The GERD patient undergoing medical management alone is left with nonacid reflux, and still may be subject to chronic subclinical pulmonary disease. Similarly, after being subjected to an antireflux procedure, some patients are left with a loosely constructed wrap. Although most of the reflux is under control in these patients, they remain at risk and can benefit from continued PPI therapy. Some of the newer endoluminal procedures designed to restore lower esophageal sphincter pressure without significantly disturbing the patient's anatomy also may benefit from the concomitant use of PPI therapy.

When presented with a patient who has GERD, we first must clarify whether the etiology is primary or secondary. In cases of secondary GERD, it is essential to make certain that any existing anatomic or neurophysiologic defects are remedied first or as a part of the GERD management. When the GERD is primary, the patient should be studied thoroughly. Surgery should be considered only for patients who have failed maximal medical therapy and those who for some special reason are not candidates to undergo medical therapy.

Because the mechanisms for primary GERD appear to be so complex, each patient should be studied sufficiently well for a clear understanding of his or her special problem. It is only with this sort of understanding that the proper plan of management can be designed.

The relatively high failure and complication rates that we see after fundoplication probably is partly because this surgery has been applied to inappropriate patients. For example, we know that many of these children have a high degree of esophagus dysmotility and perhaps some delay in their gastric emptying time. The problem in these children may be GERD, with a defect in their ability to clear the acid once it refluxes into the esophagus. Nonetheless, many of these children are inadequately evaluated. Consequently, they are referred for surgery and end up with a fundoplication early. This can result in a tightening of the diaphragmatic crura and transmission of increased (abdominal) pressures to the lower esophagus, which may already have sufficiently high pressure much of the time. Such a patient may be "cured" of any possible reflux, at least in the short term. The patient may, however, be plagued with severe dysphasia and gas bloat for some time after the operation, and it is highly likely that this patient will require additional intervention to deal with the complications of the surgery. This same patient may have benefited more by appropriate use of high-dose PPI therapy with or without the addition of a prokinetic agent.

It is clear that there are certain groups of patients who will require fundoplication or some other procedure to protect them from GERD that is refractory to the most intensive medical management. When there are anatomic considerations, such as a large hiatal hernia contributing to the reflux, then surgery is clearly indicated. The same can be said for the patient who fails to thrive or the neurologically impaired patient with a gastrostomy tube in place who cannot be nourished sufficiently because of GERD. Nearly all other patients deserve a thoughtful evaluation, such as that proposed by Mattioli et al. [27] , and a trial of maximum medical therapy before surgery should be considered.

An extensive review of the literature does not leave the surgeon with a clear understanding as to which specific technique is best. This is complicated by the fact that each technique has about as many different variations as there are surgeons performing it. Most pediatric surgeons currently seem to prefer a 360° wrap or some variation of a Nissen fundoplication. Whether the short gastric vessels are divided routinely, whether the crura are always sutured, whether pledgets are used, and many other variations seem to be less consistently described, and their inclusion does not necessarily alter the results or the complication rate. Data from Georgeson et al. [15] do, however, suggest that a partial wrap is associated with a higher recurrence rate in children and that there is little to gain from this approach. Because there are so many variations of technique, and because there is some evidence that the manner in which the operation is performed may relate to the development of complications, it becomes extraordinarily difficult to compare one experience with another in a meaningful way. Nonetheless, we must carefully assess what we do from here on if we are to improve our results.

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