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REVIEW ARTICLE

Gastric transposition in infants and children

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Abstract The loss of esophageal length in long-gap esophageal atresia or obliteration of the esophageal lumen due to stricture may require major operative reconstruction. A number of procedures have been developed to allow anatomic replacement of the esophagus. The gastric transposition requires a single cervical anastomosis and uses a gastric conduit with excellent blood supply. This review illustrates the procedure and discusses its indications, planning, and outcome.

Keywords Atresia · Replacement · Esophagus · Transposition · Stricture · Long gap

Introduction

The importance of an intact and functional esophagus cannot be overemphasized. Congenital and acquired diseases of the esophagus have significant adverse effects on growth and development. Conditions such as esophageal atresia with tracheoesophageal fistula can usually be adequately treated with a direct surgical correction and result in excellent long-term outcomes. In other children, however, such as those with complex long-gap esophageal atresia, and those with severe corrosive esophageal injury due to caustic ingestion, an excellent outcome cannot be guaranteed via the standard surgical approach. In these cases, replacement of the esophagus with a conduit may be the only viable alternative in order to restore anatomic and functional continuity between the mouth and the gastrointestinal tract. The ideal esophageal replacement conduit for children should (a) be long-lasting, (b) be associated with minimal reflux, (c) be technically feasible, (d) not affect cardiac or pulmonary function, and (e) allow oral consumption of nutrition. While the colon interposition and gastric transposition are the most commonly applied esophageal replacement procedures, other techniques have been described (Table 1) and can be considered under certain circumstances. This report will review the experience with gastric transposition procedures for esophageal replacement in children.

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History

The concept of gastric transposition for esophageal replacement was developed while treating adult patients with esophageal cancer. These procedures involved a combined abdominal and cervical approach with eventual cervical esophagogastrostomy. The use of this procedure in children is limited mostly to treatment of benign processes and has gained increasing support.

Indications

Indications for esophageal replacement are varied (Table 2). In infants and children, the majority of cases

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Table 1 Types of esophageal replacement procedures

Colon interposition
Gastric tube - Graviliu (antiperistaltic and isoperistaltic)
Jejunal interposition
Gastric transposition

Table 2 Indications for gastric transposition

Isolated esophageal atresia with long gap
Failure of alternate esophageal conduit
Failure of standard repair of esophageal atresia
Caustic ingestion with persistent stricture
Persistent peptic stricture
Tumors (diffuse leiomyomatosis, inflammatory pseudotumor)
Foreign body injury (e.g. battery)
Achalasia

involve esophageal atresia with long gap or patients who failed primary repair. When a primary anastomosis is impossible due to the distance between the two esophageal ends, a replacement procedure should be considered. Whether a cervical esophagostomy is performed or not is a matter of surgeon preference. Children can be managed with nasoesophageal suction temporarily while awaiting a definitive procedure. If the delay prior to definitive repair is predicted to be lengthy, a cervical esophagostomy may allow for sham feeding and care at home without fear of aspiration. Caustic ingestion injuries to the esophagus remain an important indication for esophageal replacement. This indication is more commonly seen in developing countries, where caustic agents are an ongoing cause of injury. While some caustic injuries are treated with dilation and supportive measures, severe injuries may not respond and replacement can be considered. Severe, unresponsive peptic strictures, tumors, and inflammatory conditions are uncommon indications for esophageal replacement [1].

Timing of surgery

Esophageal replacement is an elective operation and should not normally be considered in an urgent or emergent setting. The timing of esophageal replacement depends primarily upon the underlying condition leading to surgery. In cases of caustic ingestion with persistent stricture, surgery is often considered once standard therapy consisting of serial dilations has failed, usually after 6–12 months. The timing of surgery in infants with esophageal atresia, however, is more variable. Traditionally, a feeding gastrostomy is placed once the diagnosis of long-gap esophageal atresia is made. Some advocate a cervical esophagostomy to allow sham feedings and safe discharge home without suction or before eventual transfer to a facility for definitive care. Alternatively, a sump suction tube can be left in the pouch for drainage of oral secretions until a definitive repair can be performed. Often the final decision to perform a definitive esophageal replacement is made once other options have failed or if the gap between the ends of the esophagus is deemed far too long to attempt primary repair. This determination can be made after about 3 months of age. When considering gastric transposition in the setting of long-gap esophageal atresia, enough time must be allowed for adequate growth of the stomach.

Preoperative preparation

Preoperative evaluation of children who are being prepared for gastric transposition should be geared toward the underlying condition. In cases of esophageal atresia, a cardiac evaluation, pulmonary functional assessment, and a reliable measurement of gap length should be performed. In children with caustic ingestion, pulmonary function and the quality of the stomach should be assessed. An endoscopy, if possible, will delineate the stomach and an assessment can be made of its usefulness as a conduit. We recommend a formal bowel preparation in case the stomach is not usable and an alternative conduit is contemplated. If possible, an evaluation of vocal cord movement is advisable preoperatively in all cases to document the status of the recurrent laryngeal nerves before surgical manipulation of the neck.

Technical details of gastric transposition

The patient is positioned supine generally with the left chest elevated and the left arm prepped and mobile in the field. This allows for exposure of the left neck. The IV lines should be placed in the lower extremities. In this manner, the neck, chest, abdomen and left upper extremity are prepped and draped. The abdominal incision is made first. A gastrostomy is often present and should be taken down from the abdominal wall. The stomach should be freed from adhesions and, if present, a fundoplication should be unwrapped. The gastrocolic omentum with the short gastric vessels should be carefully divided as should the gastrohepatic omentum. The right gastric vascular arcade is preserved and the left gastric vessels are divided.

The distal esophageal remnant is then dissected from the mediastinum (Fig. 1a). In isolated esophageal atresia, this is often a short diverticulum, which is easily dissected (Fig. 1a), but in cases of corrosive injury, the scarred esophagus is often difficult to dissect from the mediastinum. The gastroesophageal junction can be divided with a

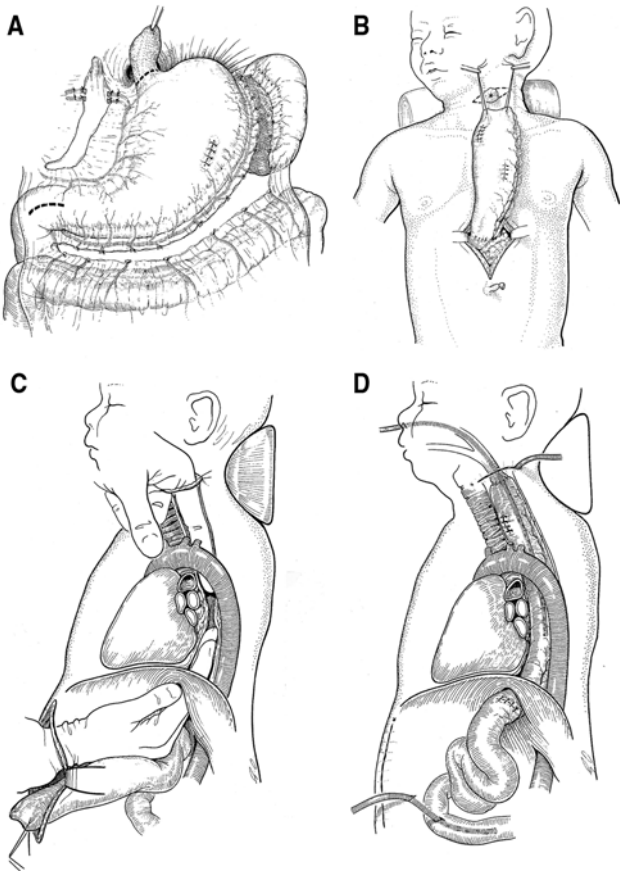

Fig. 1 Technique of gastric transposition: **a** The stomach is dissected with care to preserve the right gastric and right gastroepiploic vessels. The distal esophagus is dissected from the mediastinum. In long-gap, isolated esophageal atresia, the distal esophagus is often a short diverticulum that comes off the stomach (shown). **b** The stomach is completely freed. The gastrostomy site and gastroesophageal junction are closed. Note the length that can be expected from the gastric conduit. **c** A posterior mediastinal tunnel can be created with blunt dissection. **d** The conduit is carefully passed via this tunnel and into the neck, where a cervical esophagogastrostomy is performed (Reproduced with permission of Hodder education from Spitz L (2006) Gastric replacement of the esophagus. In: Spitz L, Coran AG (eds) Operative pediatric surgery. Hodder Arnold, London, UK, pp 147–150)

stapler or amputated and closed with sutures. The gastrostomy site can be removed similarly. These maneuvers free the stomach completely, preserving the blood supply via the right gastric artery and right gastroepiploic vessels (Fig. 1b).

By definition, the vagus nerves are divided bilaterally during the gastric transposition procedure and most authors recommend either a pyloroplasty or a pyloromyotomy. Our group has used the pyloromyotomy with excellent success and we feel that a formal Heineke-Mickulicz pyloroplasty is placed under tension when the conduit is pulled into the neck. It should be noted that performance of a pyloromyotomy on an essentially normal pylorus requires significant care in order to avoid violating the mucosa. If needed, a Kocher maneuver may be performed in order to allow the conduit to reach the neck.

The esophageal hiatus is opened from the abdominal approach. With retraction of the left arm, a left cervical incision is made and the cervical esophagus, or the esophagostomy, is isolated. Care should be taken in this area to avoid injury to the recurrent laryngeal nerves. In isolated esophageal atresia, when no esophagus lies in the posterior mediastinum, a path can be created for the gastric conduit using blunt dissection from the abdominal and cervical approaches (Fig. 1c). When the native esophagus has been present, it can be dissected bluntly and the resulting path can be used for the conduit. A large chest tube (28–32 french) can be passed from the cervical incision into the abdomen via the posterior mediastinal path. On the abdominal side, the tube is sutured to the fundus of the gastric conduit, which is the highest point on the stomach, with care taken to avoid twisting of the conduit as it is pulled through the posterior mediastinum. Once the conduit is comfortably pulled to the level of the left cervical incision, we recommend anchoring the conduit to the sternocleidomastoid muscle's medial boarder laterally and the strap muscles medially. A gastrotomy is performed and the upper esophageal pouch is opened. The most distal part of the upper esophagus and the apex of the gastric conduit are connected with a single layer anastomosis using interrupted sutures (Fig. 1d). A transanastomotic nasogastric or orogastric tube is left in place for decompression of the gastric conduit and to be used for a postoperative contrast study. The cervical incision is closed over a Penrose drain. We obtain a contrast study of the conduit during the postoperative period to assess the anastomosis, to evaluate for leak, and to document gastric emptying (Fig. 2).

Postoperative feeding is achieved using a variety of methods. It should be stressed that the gastric conduit is aperistaltic and surgically denervated. For this reason, it must drain by gravity, making it imperative that these children feed orally in the upright position. Despite these maneuvers, however, many children have delayed oromotor function and it is often difficult to fully nourish them orally immediately following gastric transposition. Nasogastric tube feedings can be employed but rely upon the security of a nasal tube. Alternatively, a feeding jejunostomy may be placed and used during the postoperative period. This latter approach must be considered in patients who have been fully reliant on their gastrostomy prior to esophageal replacement. Our preferred method is a "button-loop" jejunostomy rather than the standard Witzel tube jejunostomy. Briefly, the jejunum just distal to the Ligament of Treitz is isolated, folded on itself and anchored in a side-to-side configuration. The apex of the jejunum is opened and an endoscopic stapler is used to create a side-to-side common opening between the two limbs. Two

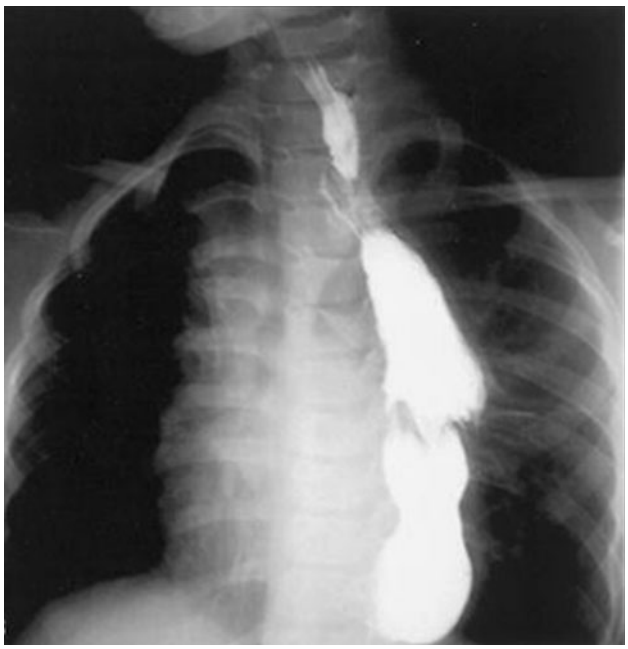

Fig. 2 A postoperative contrast study of the gastric conduit shows the stomach as a tubular structure in the posterior mediastinum (Reprinted with permission from reference [8])

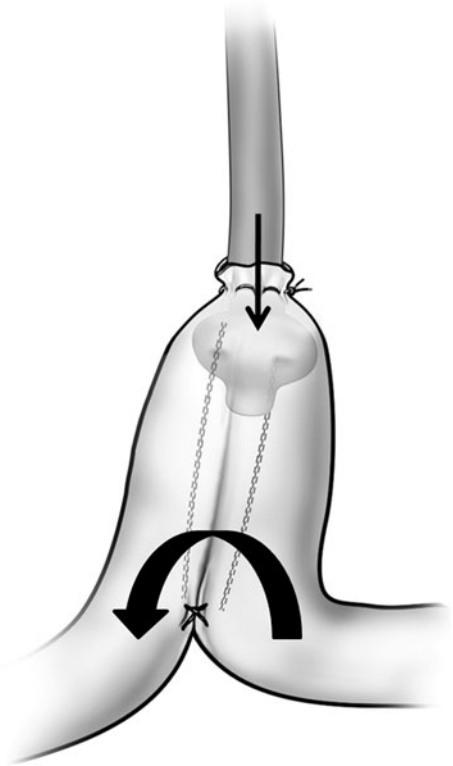

Fig. 3 Jejunostomy technique that creates a jejunal "loop" diverticulum. A replaceable balloon device can be used. Feedings are infused via the jejunostomy tube (*straight arrow*) and intestinal contents pass distally (*curved arrow*)

purse-string sutures are placed and the tube is anchored once these sutures are tied and the tube is then brought through the skin (Fig. 3). The details of this technique have been previously published [2]. The technique allows for insertion of a replaceable button device that is secure and the jejunostomy is not prone to obstruction. Another advantage is that when the jejunostomy is no longer needed, the button can be removed. Thus, this type of jejunostomy functions like a Roux-en-Y jejunostomy, but is simple to perform and requires no operation to close.

Outcomes

Few large studies exist that document outcomes of gastric transposition in infants and children. In 1948, Sweet [3] published his description of gastric transposition which brought the stomach behind the hilum of the left lung and into the neck. In 1984, Spitz [4] reported his initial experience with four children with long-gap esophageal atresia where the gastric conduit was brought into the neck via the posterior mediastinum without thoracotomy in order to achieve a cervical esophagogastric anastomosis, an approach similar to what is often used in the treatment of esophageal cancer in adults. Spitz [5–7] published updates of his growing experience with gastric transposition in 1992, 2004, and again in 2009. In the latest report, 192 cases were reviewed. Mortality rates were low (<5%), but morbidity such as anastomotic leak (12%), anastomotic stricture (19.6%), swallowing dysfunction (30.6%), and delayed gastric emptying (8.7%) was not uncommon over the 25-year period [7]. Hirschl, Coran et al. [8] reported a multi-institutional experience with gastric transposition in 2002. Of the 41 patients described, 26 had esophageal atresia. The mortality rate was zero and no conduits were lost. Interestingly, the reported rates for anastomotic leak (36%) and stricture (49%) were higher than those reported by Spitz. These differences are likely related to each group's definition of leak and stricture.

Davenport et al. [9] reported long-term outcomes after gastric transposition in 17 patients who had undergone surgery more than 5 years previously. In this study, gastric transposition was associated with diminished lung capacity, efficient gastric emptying, low iron stores, and overall excellent parental satisfaction. On average, children were also smaller than normal, but it is unclear whether this result is associated with the underlying condition or with the gastric transposition itself. In 2003, Ludman and Spitz [10] reported on the quality of life in their gastric transposition patients. Overall, nearly all patients reported high satisfaction and led a "normal" life after gastric transposition. There was a tendency toward social and emotional delays and there appeared to be quality of life benefits for those who underwent primary gastric transposition versus

those who had failed attempts at primary esophageal repair initially.

Since 1987, the senior author (AGC) has been involved in 166 cases of gastric transposition treated at several institutions and, of these, 144 have adequate follow-up for analysis. In 111 (77%), gastric transposition was performed for esophageal atresia, most commonly with long gap, 17 (12%) for caustic stricture, 5 (3%) for diffuse leiomyomatosis, and the remaining 11 (8%) for failure of previous esophageal, tracheal, or upper gastrointestinal procedures. Currently, our approach is to perform the mediastinal esophageal dissection via a combined abdominal and cervical incision. No significant bleeding has been encountered as a complication. In this series, there was no mortality and no loss of conduit, emphasizing the safety and efficacy of the operation.

Treatment algorithm

Since most gastric transposition procedures are performed for long-gap or isolated esophageal atresia, the following algorithm has been adopted over the past 2 years by the senior author (AGC) when staging the care of these challenging patients.

1. The diagnosis of isolated (or long-gap) esophageal atresia should be confirmed and the presence or absence of a proximal pouch fistula should be assessed via bronchoscopy or during a careful contrast study of the upper pouch. A feeding gastrostomy is indicated early to facilitate feeding and to allow the stomach to grow and dilate.
2. At 6 weeks of age, the esophageal gap can be measured. The authors prefer a technique that uses a soft bougie in the upper pouch and a neonatal endoscope advanced via the mature gastrostomy site and into the lower pouch under direct vision (Fig. 4).
3. If the gap between the upper and lower pouches is three vertebral bodies or less, then a primary repair may be attempted. If the gap is greater than three vertebral bodies, then it is advisable to re-measure the gap after a second 6-week interval (a total of 12 weeks).
4. If the distal pouch resembles a small diverticulum or if primary repair appears impossible, a primary gastric transposition can be performed as described in this chapter at 12 weeks. If gap length suggests that primary end-to-end repair appears feasible, the child should be prepared for a right thoracotomy. The authors recommend patient positioning and an operative approach that would allow for conversion to a gastric transposition if primary repair turns out to be impossible. This requires that the abdomen right chest, right upper extremity and right neck be placed in the sterile operative field.
5. While wide dissection of the lower pouch is traditionally not recommended, taking down the diaphragmatic attachments to the esophagus, performing upper and lower pouch myotomies and even ligating the left gastric vascular pedicle can facilitate a primary esophageal anastomosis. This approach has been used in five patients during this past year, with success in accomplishing a primary anastomosis in four. Only one of these five patients underwent a gastric transposition.

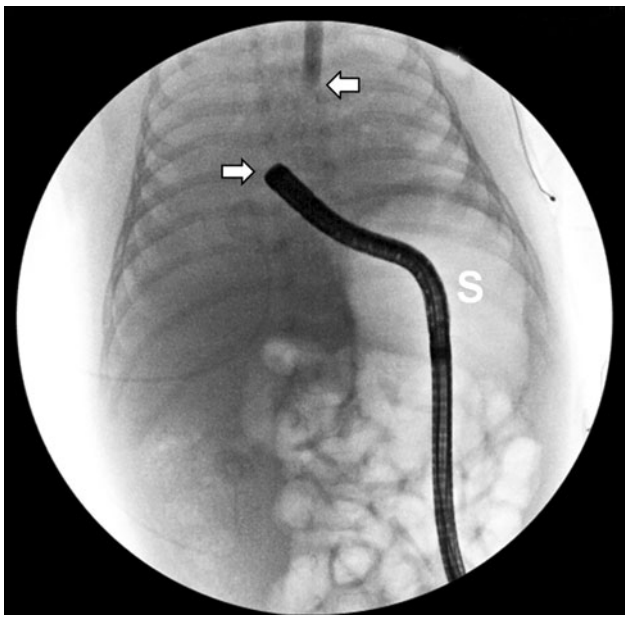

Fig. 4 Endoscopic technique to measure the gap between esophageal pouches in long-gap esophageal atresia. Placement of the endoscope into the stomach (*S*) via the gastrostomy ensures that the distal pouch is being clearly marked (*lower arrow*). A bougie dilator is placed from above to delineate the upper pouch (*upper arrow*). Fluoroscopic images are used to estimate gap length

Conclusions

In children, esophageal replacement when needed can be accomplished with a variety of intestinal conduits. Gastric transposition, while popularized for the treatment of esophageal cancer in adults, is an effective esophageal replacement procedure. Gastric transposition obviates the need for a thoracotomy, places the conduit in the natural esophageal bed, preventing redundancy and lung compromise, requires only a single cervical anastomosis, and appears to be associated with excellent long-term outcome and patient satisfaction.

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