11 Gastric Pull Up: Open Approach

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Introduction

Native esophagus is always the best, and all efforts should be made to preserve the native esophagus. In circumstances where the esophagus is not available, a suitable substitute is needed to perform the function of the esophagus. All the substitutes available have their advantages and disadvantages. The best substitute would be the one which allows close to normal swallowing with minimum reflux and reduced number of complications like strictures, leaks, and dilatation.

Stomach with excellent blood supply and easy availability is a good alternative. The use of the stomach was first demonstrated by the adult surgeons in patients with esophageal cancer. The first use of stomach as an esophageal substitute was reported from the Great Ormand Street Hospital for children by Prof Lewis Spitz in 1981 [5]. In 2014, he reported results of 236 children undergoing GPU at this hospital from 1980. There have been few other series from all over the world with good results [2].

Indications

1. Long gap esophageal atresia
2. Lye/alkali stricture

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3. Multiple strictures due to repeated surgery
4. Long peptic strictures
5. Other rare causes

Routes for Esophageal Replacement

1. Trans-hiatal route (orthotopic)
2. Substernal/retrosternal
3. Retrohilar (behind the lung hilum thoracic)
4. Subcutaneous/presternal

Trans-hiatal is the most commonly used route. Substernal is the next choice when trans-hiatal route is not available. Retrohilar and subcutaneous routes are rarely used. Discussed in detail separately.

Surgical Anatomy of the Stomach

Stomach is a completely intra-abdominal organ extending from the lower end of the abdominal esophagus to the pyloroduodenal junction. The stomach has a cardia, fundus, body, antrum, pylorus, greater curvature, and lesser curvature as its parts. The fundus of the stomach is in proximity with lower surface of the diaphragm and the anterior surface of the spleen. The short gastric vessels arising from the splenic artery and also directly from the splenic surface tether the spleen to the anterior and superior aspect of the spleen (Fig. 11.1). Pulling on the fundus extensively can cause these blood vessels to disrupt and cause extensive bleeding during surgery.

The visceral peritoneum from the under surface of the diaphragm continues over the intra-abdominal esophagus as the phreno-esophageal ligaments. These ligaments are in contact with the endothoracic fascia through the diaphragmatic hiatus which in turn is in close proximity with the pleura. These ligaments have to be taken down during mobilization of the lower end of the esophagus for esophagectomy. During this dissection there is a risk to the esophageal musculature as well as risk of damaging the pleura due to close proximity to each other.

The lesser curvature has the lesser omentum attached to it. It has two parts the hepatico-duodenal ligament and the hepatico-gastric ligament. It houses the right and left gastric artery. The greater omentum or the gastrocolic omentum is attached to the greater curvature and houses the gastroepiploic vessels. Mobilization of the stomach for esophageal substitution starts with dividing the gastrocolic omentum. It is important to stay away from the greater curvature to prevent damage to the gastroepiploic arcade. Also, during the placement of the gastrostomy, it is important to place it away from the greater curvature to prevent damage to the epiploic arcade.

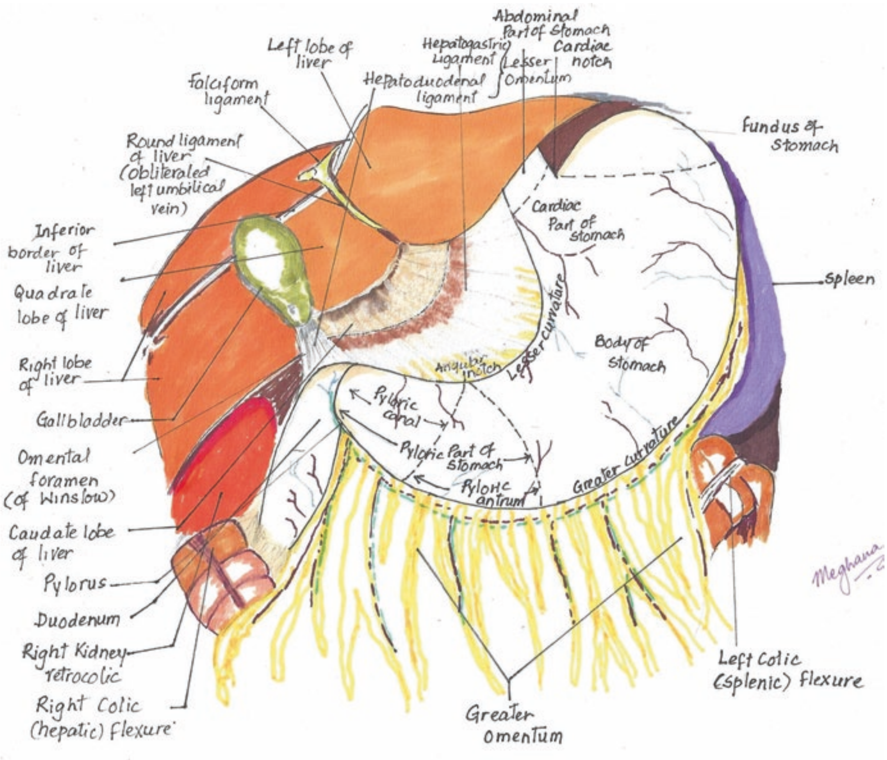

Fig. 11.1 Anatomy of stomach

Blood Supply of the Stomach

The stomach has a very robust blood supply and is at a very small risk of devascularization even if majority of its blood supply is sacrificed (Fig. 11.2).

1. Left gastric artery: Arises from the celiac trunk. It is a short artery, and it supplies blood to the lower end of the esophagus and the right upper or proximal stomach. It first goes up and after giving branches to lower esophagus it turns downward to lie along the upper part of the lesser curvature. At almost the center of the lesser curvature, it anastomoses with the right gastric artery.
2. Right gastric artery: Is a branch of the hepatic artery which is a branch of the common hepatic artery arising from the celiac trunk. The right gastric artery runs along the lower or distal part of the lesser curvature of the stomach and supplies blood to the lower right part of the stomach. It anastomoses with the left gastric artery in the center of the lesser curvature. This artery is preserved during the mobilization of the stomach for esophageal substitution.

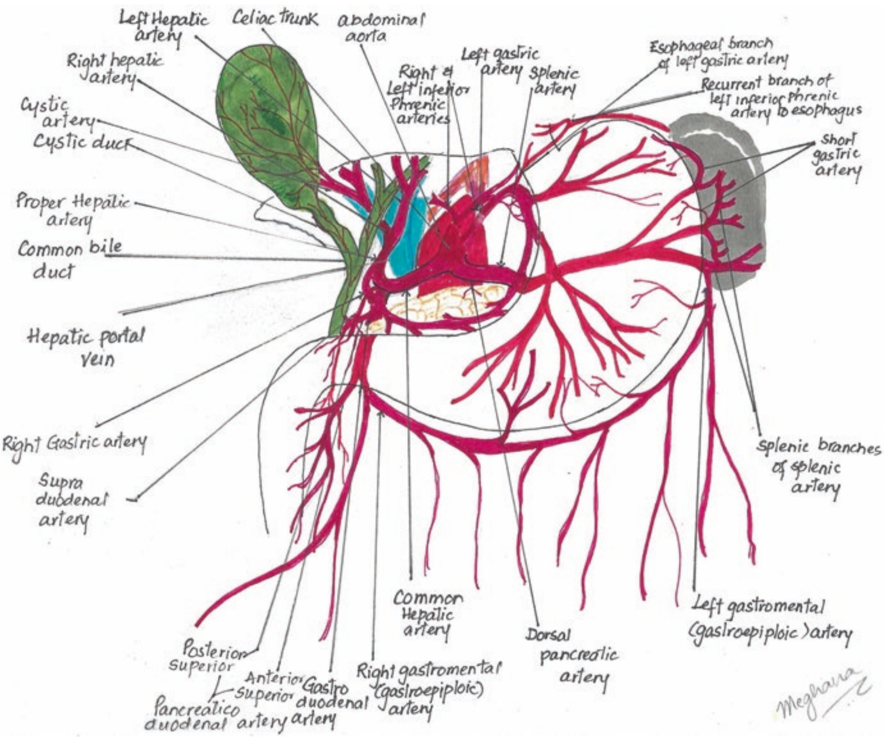

Fig. 11.2 Blood supply of the stomach

3. Left gastroepiploic artery: This artery is a branch of the splenic artery and runs along the upper or proximal part of the greater curvature. It anastomoses with the right gastroepiploic artery forming the gastroepiploic arcade along the greater curvature.
4. Right gastroepiploic artery: This artery is a branch of the gastroduodenal artery which is a branch of the common hepatic artery. It runs along the lower/distal part of the greater curvature and anastomoses with the left gastroepiploic artery to form the gastroepiploic arcade along the greater curvature. This artery along with the gastroepiploic arcade is preserved during gastric mobilization.
5. Short gastric arteries: These are several small arteries arising from the splenic artery and supply the fundus of the stomach. They need to be divided during gastric mobilization for esophageal substitution. These are very short and fragile vessels, and they bleed easily if the stomach is pulled away from the spleen during mobilization.
6. Other small arteries: Several other blood vessels that are in the vicinity also supply the stomach. These are branches of the pancreatic and gastroduodenal arteries.

Surgical Technique

A. *Abdominal Portion:*

(a) *Incision:* Midline incision is made from the xiphisternum to the umbilicus, and the abdomen is opened.

(b) *Taking down the gastrostomy:* The procedure is started by taking down multiple adhesions between the abdominal wall and the omentum. The stomach is usually adherent to the liver and sometimes the colon. Adhesions are more in number if the procedure was done as an open gastrostomy as compared to a laparoscopic procedure. The adhesions are carefully separated using blunt and sharp dissection using the monopolar and bipolar diathermy. Once the adhesions are completely separated the gastrostomy is then taken down from the abdominal wall using diathermy. Gastrostomy site is closed with 3′0′ vicryl or PDS using interrupted sutures.

(c) *Mobilization of the stomach:* The process is started by making a small opening in the gastrocolic ligament slightly away for the gastrocolic arcade. Diathermy or harmonic scalpel is then used to mobilize the greater curvature cephalad till the short gastric vessels are encountered. During this process of mobilization of the greater curvature, the left gastroepiploic artery is divided. The short gastric vessels are very short and fragile and can easily bleed if the stomach is extensively retracted. They can be gently divided using bipolar diathermy or harmonic scalpel. Care should be taken to prevent injury to the spleen during this process. The fundus of the stomach should now be free to gently retract caudally. The next step is to divide the phreno-esophageal ligaments to mobilize the lower end of the esophagus. If the child has a pure esophageal atresia or EA without TEF, then there is usually a 3–4 cm stump of the lower esophagus that can now be delivered through the hiatal opening. At this point the anterior and posterior vagus nerve will be seen and need to be divided. If the child had a lower end fistula and a long gap between the esophageal pouches and had several previous surgeries, then the lower end of the esophagus is much longer and is badly adherent. The mobilization of this scarred esophageal stump is far more difficult and requires a lot of meticulous dissection. The left gastric artery is best approached from the posterior aspect of the stomach, that is, from the lesser sac (Fig. 11.3). The left gastric artery is usually very short and is better divided close to the lesser curvature still preserving the arcade. The dissection is continued further along the lesser curvature to reach the pyloric antrum. The right gastric artery is identified and preserved.

(d) *Pyloromyotomy/pyloroplasty:* A 2 cm longitudinal full thickness incision is placed on the anterior wall of the pylorus. This incision is then closed transversely using 3′0′ PDS interrupted sutures thus completing a Heineke-Mikulicz pyloroplasty. Some surgeons perform a pyloromyotomy instead.

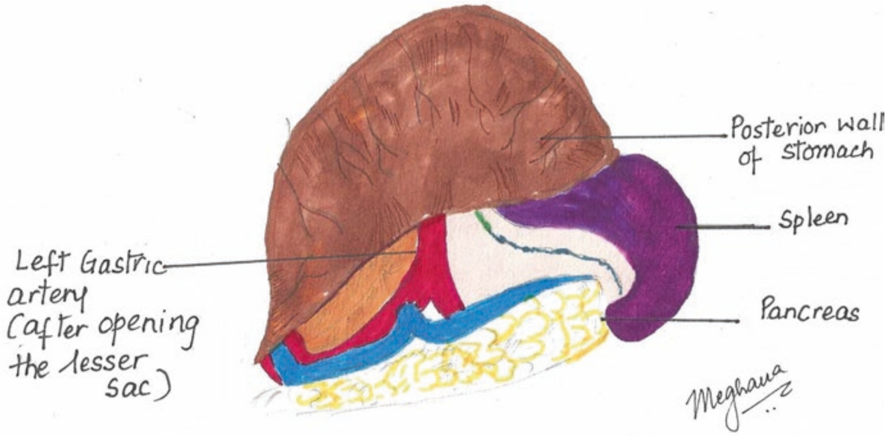

Fig. 11.3 Exposure of the left gastric artery from the lesser sac

(e) *Trans-hiatal esophagectomy:* In children with corrosive injury to the esophagus, this would be the time for esophageal dissection. After division of the esophago-phrenic ligaments, the lower esophagus is retracted downward, and using blunt and sharp dissection very close to the body of the esophagus, the esophagus is mobilized. The hiatus may need to be widened for this dissection. Retractors may be placed on both sides of the hiatus for better exposure. Gentle finger dissection is useful to release the scarred esophagus. At this point the finger meets finger of the other hand dissecting from the neck. Sometimes the esophagus is badly stuck to the mediastinal structures, and there is high-risk complication and massive mediastinal bleeding. In these circumstances it is ok to leave some portion of the esophagus that cannot be removed safely. The remnant should be demucosalized as far as possible to prevent future malignant transformation.

B. *Neck Portion*

(a) Without previous esophagostomy

(i) Incision: Left side of the neck 2 cm lateral to the midline and 2 cm above the clavicle in the skin crease.

(ii) Deep cervical fascia is opened, and the sternomastoid muscle and the carotid sheath with the vessels are retracted laterally. Dissection is then carried out on the medial aspect of the carotid sheath. Upper pouch of the esophagus is identified just behind the trachea. A size 10–12 red rubber catheter through the oral cavity helps with identification of the upper pouch. The upper pouch is then mobilized and to get maximum length to get a good anastomosis in the neck. The recurrent laryngeal nerve runs along the lateral aspect of the tracheoesophageal groove and must be protected during this procedure.

(b) With previous left esophagostomy
  (i) Stay sutures with 4′0′ vicryl are placed circumferentially on the esophagostomy. Esophagostomy is then mobilized using monopolar diathermy. Avoid damaging the muscle wall of the esophagus. Mobilize a good length of the esophagus to perform a nice double layer esophagogastric anstomosis in the neck. The recurrent laryngeal nerve runs along the lateral aspect of the tracheoesophageal groove and must be protected during this procedure.
(c) With previous right esophagostomy
  (i) Mobilization is done similar to the left side, but the esophageal pouch is brought from right to the left side behind the trachea to do the esophagogastric anastomosis on the left side of neck. This avoids a kinking of the esophagogastric anastomosis in the neck.

C. *Mediastinal Tunnel*
(a) A trans-hiatal mediastinal tunnel is now created using blunt finger dissection from the abdominal and neck incision. The abdominal tunneling is done through the esophageal hiatus. Finger is used for blunt dissection. It is important to stay on the vertebral column all the time during dissection. This will keep the dissection within the mediastinum and prevent damage to the pleura. If pleural damage happens, a chest tube should be placed on the side of damage before concluding the procedure. The neck tunnel is created lateral to the trachea, medial to the carotid sheath and behind the clavicle. Dissection in the mediastinum behind the heart could lead to sudden cardiac arrest or severe bradycardia. Withdrawing the dissecting finger and stopping the dissection reverses the process immediately. The anesthetist should be made aware of this situation to prevent panic during surgery. It is good to have two teams working together. One on the abdominal side and the other on the neck side. Both teams working simultaneously reduces the time of surgery. However, the entire procedure can be done by one surgical team if another team is not available. Once the dissecting fingers from the top and bottom touch each other, the dissection is complete. The next step is to dilate the tunnel enough to accommodate the stomach. Tunnel should be dilated to two to three finger size. The hiatus may need to be widened to accommodate the stomach (Fig. 11.4)
(b) Gastric pull up: A long Kelly clamp is now passed from the neck incision and gently passed through the newly created mediastinal tunnel very carefully and slowly. The clamp is passed all the way to the esophageal hiatus guided by a finger from the hiatal side. The blunt lower esophageal stump/end is now grasped and pulled gently through the tunnel into the neck wound. Some surgeons divide the stump with the stapler in the abdomen and use stay sutures on the fundus to pull the stomach. Using the stump to pull the stomach is an advantage as it reduces trauma to the fundus (site of anastomosis). With an adequate size tunnel, the stomach should pull up eas-

Fig. 11.4 Creation of mediastinal tunnel

ily. If too much force is needed to pull the stomach, then the tunnel is not adequate, and it should be dilated again before the stomach is pulled back up. Once the stomach is pulled up and it moves up and down easily, the tunnel is considered to be adequate. At this point the vascularity of the stomach should be checked by looking at the color. If all looks good, then the blunt lower esophageal stump should be divided with the endoGIA stapler (Fig. 11.5).

D. *Esophagogastric Anastomosis*

(a) The upper esophageal stump is now anastomosed to the fundus of the stomach with wide anastomosis in two layers with 2′0′ vicryl or PDS. This anastomosis should be such that the esophagus should be buried into the stomach for about 2 cm. A size 10–12 F trans-anastomotic tube should be used, and the stomach is completely decompressed and suctioned before the anastomosis is completed. In our experience this reduces the anastomosis leaks and stricture. The fundus of the stomach may be pexied to the prevertebral fascia to reduce the tension on the anastomosis. Placement of a penrose drain near the neck anastomosis depends on surgeon's choice (Fig. 11.6).

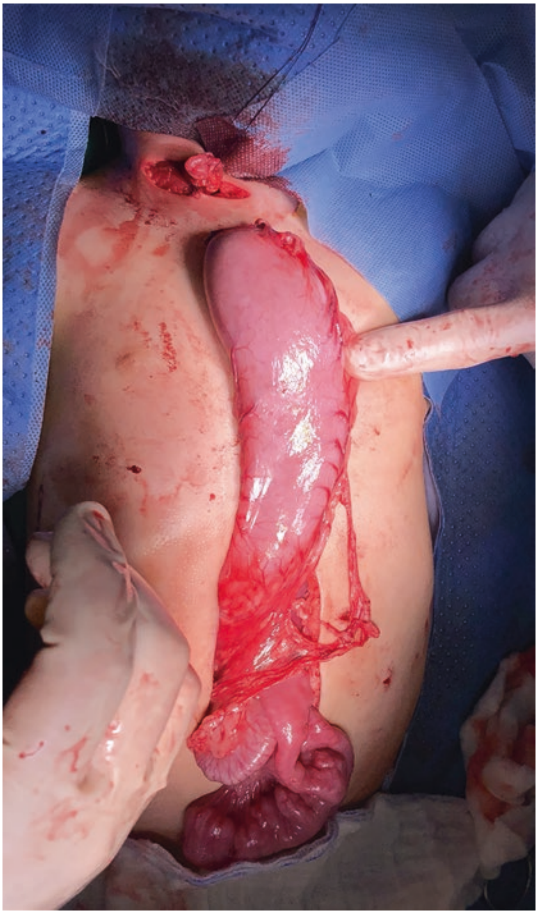

Fig. 11.5 Mobilized stomach easily reaching the neck with no tension

E. *Feeding Jejunostomy*
  (a) It is useful to have a feeding jejunostomy till everything has healed, and it is safe to feed orally. A Witzel or Roux-en-Y feeding jejunostomy can be made. Neck wound and abdominal wound are closed in layers.

Postoperative Care

1. Complete decompression of stomach using NG tube with suction.
2. Chest X-ray in recovery.
3. Postoperative ventilation and extubation based on individual patient.
4. Prevent fluid overload in the PICU(pediatric intensive care unit)/Floor.
5. Contrast study to rule out anastomotic leak on day 5–7 post surgery.

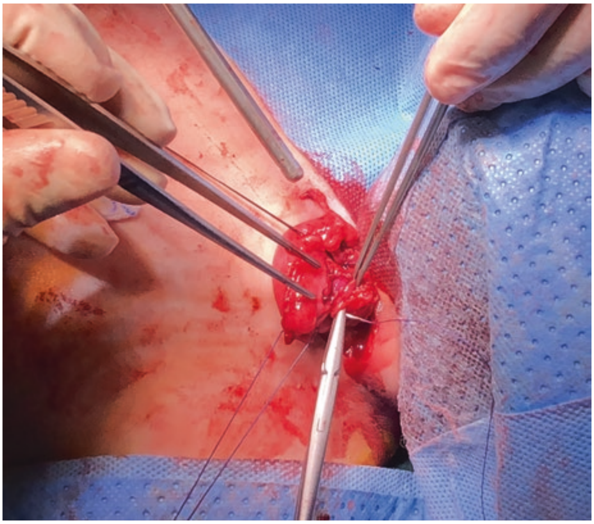

Fig. 11.6 Esophagogastric anastomosis in the neck

Why Choose Gastric Pull Up?

Benefits

- Stomach has excellent blood supply.
- Procedure involves single anastomosis in the neck.
- Double-layered buried anastomosis in the neck reduces the leak rate significantly.
- Stomach is easily available in the vicinity.
- Gastric pull up is relatively easy to perform and teach.
- Long-term outcomes are excellent.

Drawbacks

- Stomach in the chest causes respiratory compromise.
- Pressure on mediastinal vessels reduces the venous return.
- Can cause dumping in the short term.

Outcomes

Respiratory Compromise

Most of the mortality for gastric pull up happens due to compression of the mediastinal structures and the lung. The mediastinal compression due to the large stomach also reduces the venous return and complicates matters further. Therefore, it is imperative to keep the stomach completely decompressed for the first 1–2 weeks.

Death/Mortality

Mortality is slightly higher with this procedure mostly due to respiratory compromise and reduced venous return due to mediastinal compression. Some deaths may also be due to aspiration and sepsis. Hirschl et al. reported 41 patient series with zero mortality [1]. On the contrary, Spitz et al. reported a series of 236 patients with a mortality rate of 2.5% [2]. In their initial reports, this mortality was higher (5.2%) [3]. Some of this improvement could be because of the learning curve related to the procedure, and some may be due to improvement in postoperative care.

Anastomotic Leaks

Anastomotic leaks are relatively few if a double-layered (buried esophagus) anastomosis is performed as compared to the conventional single-layered anastomosis. The leak rates with the conventional single layer anastomosis are close to 12–15% in different series [1–8]. In the largest series by Spitz et al. of 236 patients, the leak rate was 12% [2]. Most of the leaks are self-healing, and most resolve by themselves in few days to weeks. However, they do add a lot of morbidity and hence are best avoided. Major leaks may lead to strictures and hence need close surveillance.

Leaks can also occur from other sites such as the pyloroplasty, the gastrostomy closure site, or the site of closure of the upper esophageal stump. These can cause mediastinitis or peritonitis but are fortunately rare.

Anastomotic Strictures

With a wide double-layered anastomosis, the strictures are rare. Conventional single-layered anastomosis has a stricture rate of up to 49% [1]. Most of the strictures respond to serial dilatation. Some of them however need resection and re-anastomosis. Spitz series of 236 patients reported a stricture rate of 20% [2]. Most of them resolved with dilatation but three required resection and re-anastomosis. Strictures are more common with corrosive injuries as the esophagus at the site of the anastomosis is damaged due to the caustic insult.

Swallowing Difficulties

Swallowing difficulties are mostly due to oral aversion prior to the gastric pull up. Some are due to the corrosive injury to the oropharynx and others are due to gastric motility, drainage, and anastomotic problems. Sham feeding is possible and should be done when a child has an esophagostomy. Most tertiary care centers now practice delayed esophageal repair without an esophagostomy when primary repair is not feasible at birth. Sham feeding is not possible in these kids, and prolonged period of postoperative oral rehabilitation is necessary to get back to normal swallowing. Vagotomy reduces the gastric motility drastically, and hence a drainage procedure like pyloroplasty is needed. This allows the stomach to act like a conduit. In some children, the pyloroplasty may need to be dilated, while in some children the pyloromyotomy may need to be converted to a pyloroplasty, whereas some may even need a Roux-en-Y gastrojejunostomy [2–7]. However, in some children, this motility problem still persists and causes significant swallowing problems. Associated gastroesophageal reflux worsens it further. Anastomotic dysfunction nonmechanical and mechanical also results in swallowing difficulties.

Gastroesophageal Reflux

Gastroesophageal reflux into the native upper esophagus has been reported ranging from 0% to 55% [4, 9]. Gupta et al. [10] reported reduction of the GER over a period by doing serial nuclear scans at 3, 6, and 9 months. All patients with gastric pull up have a vagotomy and drainage procedure, and the stomach just functions as a conduit. Vagotomy reduces the acid production, and the emptying is improved by a pyloroplasty, and reflux even though present is not a big problem in the long term.

Dumping Syndrome

In children with gastric pull up, stomach acts as a conduit. There is no longer a reservoir for the food that is consumed orally. Sudden input of food leads to dumping syndrome like symptoms. Dumping is a problem in the initial years, but it resolves in few months. Patients learn to avoid heavy meals at one time, and the body physiology adjusts to this new environment.

Delayed Gastric Emptying

Most patients with gastric pull up have a pyloromyotomy or pyloroplasty. This prevents delayed gastric emptying in most patients. Ravelli et al. [11] in their series of 12 patients showed that gastric emptying was delayed in 7 patients and accelerated in 4. One child had normal emptying. His study did not find any co-relation of emptying to performance of a pyloroplasty. Since the valve mechanism is no longer working, the bizarre emptying patterns may be related to GER and or duodenogastric reflux.

Redo Surgery

Several patients who are in need of a gastric pull up have had multiple surgeries in the past. Several patients that get referred for this procedure have had multiple attempts to save the native esophagus which leads to extensive mediastinal scarring. Also, corrosive injures to the esophagus can cause excessive mediastinal scarring. This scarring makes the gastric pull up procedure difficult and leads to bad outcomes [12]. Decision to substitute the esophagus must be made early and not after endless attempts at esophageal salvage.

Jejunostomy-Related Complications

If support with TPN is not available, then a jejunostomy may be needed for nutritional supplementation. A Roux-en-Y or a Witzel jejunostomy is usually performed. Jejunostomy may be associated with complications like obstructions, adhesions, internal herniation, and anastomotic leakages.

Growth (Height and Weight)

Growth is affected in all children with gastric pull up, and they are behind their peers in weight and height. Kids who underwent gastric pull up as a primary operation for long gap esophageal atresia fared well compared to ones who had multiple surgeries to save the native esophagus [14].

Quality of Life Assessment

Though the overall outcomes are very good, kids with gastric pull up continue to have some fullness in the chest after meals. They have minor to moderate dysphagia and breathlessness. Some evidence symptoms of GER and delayed gastric emptying. There are very few studies with long-term follow-up, but most report a low complication rate and better quality of life compared to other techniques of substitution [2, 13, 14].

Neonatal Gastric Pull Up

In neonates with LGEA, GPU has been used as a primary procedure. The LGEA with attempts to preserve the native esophagus can be fraught with several complications and may be associated with multiple surgical procedures and prolonged hospital stay. Primary neonatal gastric pull up can be used as a single surgical option to minimize the morbidity of the esophagus preserving techniques and prevent multiple hospital visits and admissions to the hospital according to the surgeons who advocate its use [10].

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