Esophageal Replacements in Children

12

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12.1 Introduction

For historical reasons, Lausanne University Hospital (Lausanne, Switzerland) has always been involved in esophageal replacements. In 1907, Cesar Roux successfully carried out the first total esophageal replacement on a 12-year-old child in Lausanne. The child suffered from caustic stenosis. It was a presternal jejunoplasty (also called "esophago-jejuno-gastrostomosy"), a new procedure for untreatable esophageal stenosis. That patient died at age 53 years. Since then, many surgical procedures have been used to replace the injured or abnormal esophagus [1–4].

12.2 Epidemiology and Indications for Esophageal Replacement

The indications for esophageal replacements differ according to the native country of the child. However, in high-income countries, despite laws stating that containers must have child-resistant lids, ingestion of corrosive substances (e.g., alkalis or acids) is the most common indication for esophageal replacement.

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The true prevalence of these injuries is not known. According to one report on pediatric trauma by the World Health Organization and UNICEF in 2008, >120,000 children under 6 years of age suffered caustic injuries in the USA in 2004 [5]. Chemicals around the house to which children may have access contribute significantly to unintentional poisonings in childhood in high- and low-income countries, only the substances differ. In high-income countries, bleach, dishwasher detergents and ammonia are common. Dishwasher tablets are the household products most frequently involved in esophageal injuries. Dishwasher detergents are highly corrosive, causing potentially life-threatening injuries and ongoing morbidity. In most countries, dishwasher tablets are not included in the regulations for child-resistant closures. In low-income countries, sodium hypochlorite or sodium hydroxide (lye, caustic soda) is used to make soap and textiles. It is also used: as a bleaching agent; for the washing or chemical peeling of fruits and vegetables; for cocoa processings for the softening or blackening of olives; or to prepare "medicines". All of these items can be accessed by children. Most exposures to cleaning agents result in mild poisoning, but strong alkalis and acids can lead to severe tissue damage. In the pediatric group, 90% of burns are caused by alkaline substances and 10% by acidic substances [6].

Other indications for esophageal replacements are uncommon. Our team (which I will

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now refer to as 'we') has been involved in the treatment of isolated cases of: post-infectious strictures; fungal (candida) or viral (herpes) causes; malformations (long congenital strictures or long duplications of the esophagus); tumors (giant leiomyoma); stenosis post-radiotherapy or related to epidermolysis bullosa.

Since 1987, we have never carried out an esophageal replacement, either for a peptic stricture or for esophageal atresia. Peptic strictures are released with dilatations after anti-reflux procedures. Most anastomoses of "long-gap esophageal atresia" can be done as delayed procedures, waiting sometimes for several months with a gastrostomy, as long as cervicostomy has not been done. The native esophagus is the best, and everything must be done to preserve it. There is a strong correlation between precipitated procedures and complications including graft necrosis, anastomotic leaks and sepsis [7,8].

12.3 Etiology and Pathogenesis

Acids and bases can be defined as "caustics", which cause significant tissue damage upon contact with the esophagus. Caustic ingestions in children are in general accidental, but some may result from neglect and/or abuse.

Most acids produce coagulation necrosis by denaturing proteins, inducing a coating coagulum that protects the underlayers from deeper penetration. Bases induce more severe injuries known as "liquefaction necrosis", i.e., protein denaturation together with fat saponification, which penetrate deep through the esophageal wall (and can perforate).

The severity of damage is related to the pH, concentration and volume of the agent ingested. The contact time is of little relevance because a lesion occurs within a few seconds. The physical form of the agent plays a significant part. Ingestion of solid pellets results in prolonged local contact time with the esophagus, resulting in deep, localized burns; liquids generate superficial but more extensive lesions. Hence, it is of major importance to refrain from drinking after pellet ingestion because it may induce both types of lesion.

Like skin, the long-term effect of caustic esophageal burns is a hypertrophic scarring process which can result in stricture formation. Mucosal re-epithelialization is a slow process that is usually not complete before 4–6 weeks. Inflammation continues and granulation tissue matures until complete re-epithelialization occurs. Thus, stricture formation is detectable as of the second week, and is definite by the fourth week. This is the best time to start dilatations.

The caustic burn induces a shortening of the esophagus and motility disorder. These actions result in poor esophageal clearance and reflux, which adds a peptic stenosis to a caustic one. Hence, all of our patients undergoing conservative treatment with dilatations receive proton pump inhibitors [Reinberg, unpublished observation].

12.4 Diagnosis and Initial Treatment

About 1 month after ingestion of a caustic material, the diagnosis of stenosis can be assessed by esophagography and endoscopy once the edema has resolved. Then, according to the severity of the stenosis, a dilatation program can be started which is continued every 3 weeks for 6–12 months. The rate of stricture formation reported in the literature varies from to 2% to 63%. Subsequently, indications for esophageal replacements and their timing vary widely. As a result, children are often subjected to prolonged courses of dilatations before esophageal replacement or, conversely, may be exposed to unnecessary surgery [7]. A strong predictor of poor outcome is the delay from ingestion to the beginning of dilatations [7, 8].

Isolated short stenosis of the esophagus (i.e. 1–2 cm) can be treated by dilatations with good results. Long ones (>3 cm), multiple stenosis (>2), or those with a tracheo-esophageal fistulae cannot be solved by dilatations and require esophageal replace-

ment [7]. However the decision should not be precipitated.

The scarring process of the esophagus is long, and the persistence of a stenosis must be confirmed by repeated esophagography. An apparent severe stenosis related to the inflammatory process can last for months before its disappearance. Conversely, a dilatation program without significant improvement after 1 year can be considered to be a failure. For these reasons, a stenosis is considered persistent after 6 months without improvement and we do not continue a dilatation program after more than 1 year [9].

Benign esophageal strictures usually produce dysphagia for solids, liquids or both, with slow and insidious progression of weight loss and malnutrition. If the stenosis is important with subsequent dysphagia lasting for >1 month, a gastrostomy should be done (see below for gastrostomy placement). Most patients, even those with a gastrostomy, are referred to us in poor condition, and must be placed under a refeeding program before surgery.

A preoperative evaluation of the oropharynx and larynx (including vocal-cord movements) must be done. The aim is to document possible scarring processes and the status of the recurrent laryngeal nerves before surgery in the neck. The level of a pre-existing tracheoesophageal fistula must be defined by tracheoscopy. The length of the intact proximal esophagus above the first stenosis should be measured carefully to anticipate swallowing problems. The day before surgery, we recommend bowel preparation because we do not know which transplant will be used.

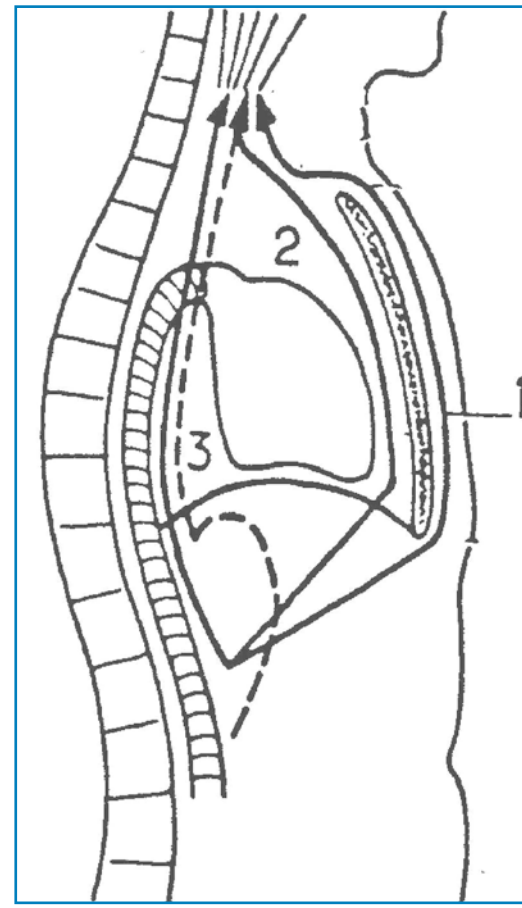

Fig. 12.1 Routes for substitute placement: presternal (historic) (*1*); retrosternal (*2*); and orthotopic mediastinal posterior (*3*)

12.5 Therapeutic Management

12.5.1 Where Should the Esophageal Substitute Be Placed?

Choosing the appropriate route for esophageal replacement is an important decision. Historically, the route was presternal (Fig. 12.1) because, at that time, the thorax could not be open. Then, the transplant was placed in the retrosternal position in a first step and the native esophagus was removed in a second step (Fig. 12.1). We introduced the one-stage procedure in 1989, placing the transplant in the orthotopic position (i.e., in the posterior mediastinum) after a closed-chest esophagectomy (Fig. 12.1) [10]. The path for an orthotopic plasty is straighter and shorter than that of the retrosternal route, but requires removal of the native esophagus. It avoids the two kinks at the upper cervical opening and at reentry into the abdomen. It is our favorite procedure because it seems that peri-esophagitis limits dilatation or the redundancy of the transplant [2, 10–12].

However, in some circumstances, the retrosternal route must be used. It is easy to create a path behind the sternum in a space with very few adhesions. However, with time, any transplant placed in this space will widen, especially if there is a narrowing at the distal end where it reintegrates the abdomen. This is more common in colonic transplants than in gastric tubes. Colonic transplants placed retrosternally have a strong tendency to become redundant, and we have had to tailor some of them. A gastric tube is more appropriate if the transplant is placed in the retrosternum.

12.5.2 Should we Remove the Native Esophagus and, if so, how?

There are two reasons to remove the native esophagus before an esophageal replacement: (i) to place the transplant in the orthotopic position (as mentioned above) and (ii) the oncologic risk induced by the burned esophagus. The prevalence of malignancies (mostly carcinoma) is not known, but has been shown in several reports to range from 1.8% to 16%, and the malignancies are known to take decades to develop. No one knows the fate of a disconnected, burned esophagus. However, some cases of carcinoma in a native esophagus after replacement have been reported [9, 13]. We believe that a demucosed, short segment of an abandoned disconnected esophagus is an acceptable risk.

In 1978, Orringer and Sloan were the first to describe a blind esophagectomy without thoracotomy [14]. In 1989, we introduced the one-stage orthotopic esophageal replacement after a closed-chest esophagectomy [10, 15]. The esophagus is removed through a left cervical incision after its transhiatal dissection by laparotomy without thoracotomy. A blind dissection by digitoclasy is undertaken in the middle part of the esophagus. At this site, scarring adhesions to the major vascular structures and bronchi are the most severe, and can lead to serious, life-threatening injuries [15]. Some anatomical considerations on the vascularization of the esophagus are particularly useful if carrying out the hemostasis from the cervical opening and hiatus [16]. A greater danger remains at the level of the aortic arch and left bronchus, where the more important adhesions are, and which is the farthest point from the skin incisions during blind dissection. When total esophagectomy becomes too dangerous, we abandon certain esophageal remnants at the level of the aortic arch after removal of the mucosa without subsequent narrowing of the esophageal substitute. Even after >200 cases we consider this step to be the most dangerous part of the procedure, showing a prevalence of 16% for various complications. It allows the esophagus to be completely removed in 71% of cases and to be partially removed in 16% of cases [17].

During this step of the procedure, two complications related to anesthesia can occur: (i) displacement of the endotracheal tube during blind dissection of the esophagus (which requires tractions on it and through it) and (ii) obstruction of the endotracheal tube or of the bronchi (mainly the left bronchus) because of mobilization of mucous plugs from the lungs during esophagectomy.

For these reasons, we have tried to achieve esophagectomy under visual control without opening the thorax. Since 2006, we have used a standardized procedure through a laparoscopic transhiatal approach [18, 19]. Some cases of esophageal dissection in children using thoracoscopy [20], or a combination of thoracoscopy and laparoscopy, have also been reported [21–23].

During the laparoscopic procedure, the child lays supine at the foot end of the operating table. The legs are wrapped in the “frog position” (as for an anti-reflux procedure). The operating table is tilted to a 30° anti-Trendelenburg position. To allow good access to the esophagus, the right-hand port is placed in relation to the position of the gastrostomy (i.e., slightly inward and inferior to it). This will not only help dissection of the esophagus (especially during dissection in the mediastinum) but also allow easier insertion of

instruments by giving the appropriate direction to the mediastinum through the open hiatus. The esophageal diaphragmatic hiatus is enlarged by a 2–3-cm incision at 10 o'clock. Two large (0 or 2) transparietal monofilament threads are passed through the two crura from both sides of the patient, and taken out through the skin. They allow a wide opening of the crura (similar to the raising of a stage curtain). Transhiatal dissection of the esophagus is pursued under direct vision in close contact with the esophageal wall using a sealing device (LigaSure™ Dolphin Tip Laparoscopic Instrument (LS1500) made by Covidien). Once the distal third of the esophagus has been freed, the liver retractor can be introduced into the mediastinum below the heart to allow a wider view of its major anatomical structures. A 30° rotation of the camera provides with a better view of both sides of the esophagus. This approach provides a clear view of the vagus nerves and facilitates their preservation. Should a pleural tear occur, a drainage tube is inserted under direct vision. The anatomical structures which run the greatest danger of being damaged during dissection are the left bronchus (whose soft posterior membrane usually adheres firmly to the esophagus) and the left brachiocephalic vein (innominate vein). The esophagus can be freed as far up as possible (usually 2 cm below the clavicle). Using this technique, no vascular or bronchial wound occurred, and the prevalence of total removal of the esophagus increased up to 89% without producing complications [18, 19].

Cervical dissection of the esophagus requires the greatest care in both techniques to avoid a tracheal tear or a lesion to the left recurrent laryngeal nerve. Preserving the most proximal centimeters of the native esophagus is crucial to avoid swallowing disorders.

A pre-existent or preoperative tracheoesophageal fistula must be identified and occluded. The healing of such a suture requires good vascular coverage because of the firm and poorly vascularized scarring processes in the mediastinum. For this purpose, a pericardial flap can be used (or a muscular flap taken from the intercostal muscles or from the latissimus dorsi in the most severe cases). However, in some cases, we have left part of the native esophagus after removal of its mucosa and used it as tracheal or bronchial coverage with success.

12.5.3 Which Transplant?

The esophagus may be replaced by a segment of colon, the entire stomach, a gastric tube or a part of the small bowel. However, none is perfect or can operate as a normal esophagus.

12.5.3.1 Colonic Transplant

The colon is the most frequently used conduit to replace the esophagus; the transverse, ascending or descending colon has been used in an antiperistaltic or isoperistaltic fashion. It offers the advantage of a segment of bowel with several possible vascular supplies that is long enough to be mobilized. Its width is approximately the same as that of the esophagus. Its length can be adjusted to the specific requirement [8, 9, 12]. This procedure requires meticulous attention to technical details for a successful outcome.

The procedure is carried out through a midline incision from the xyphoid process to the umbilicus. The best transplant is taken on the transverse colon, vascularized by the left colonic artery and placed isoperistaltically (Fig. 12.2). Before ligating the unused vascular bundles, it is wise to generously mobilize the colon from the right to the left, severing the gastrocolonic ligament and to explore carefully its arteries. An efficient left colonic artery is missing in about 10% of patients, and the anastomotic transverse colonic arcade can be absent. We check the quality of the chosen arterial supply by clamping the unused arteries during 10–15 min with atraumatic vascular bulldog artery clamps. The superficial arteries must be pulsating (especially those at the farthest end from the vascular supply) and peristaltism must be present. Once an appropriate

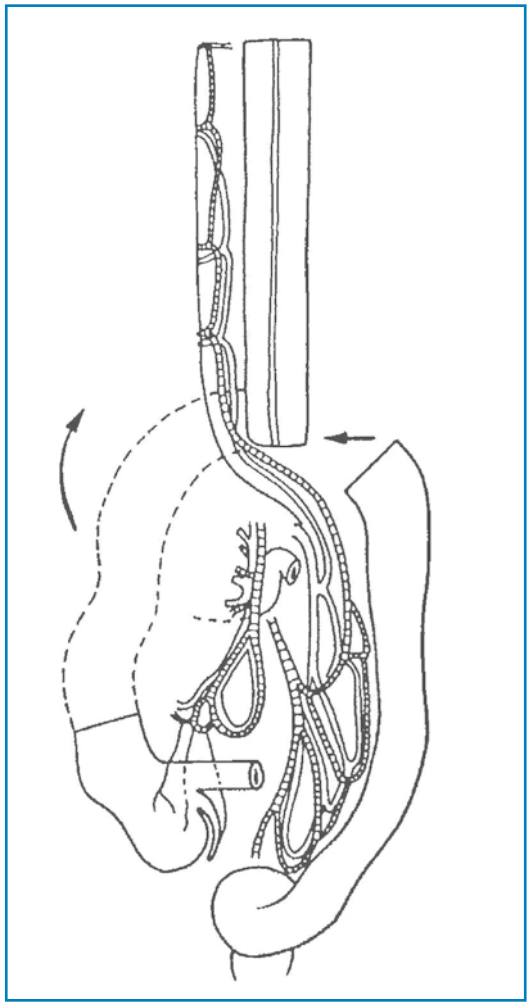

Fig. 12.2 Isoperistaltic transverse colon vascularized by the left colonic artery

length is chosen, the transplant is prepared by severing the unused vessels while preserving long arcades. We use conventional ligatures and never coagulate them to prevent vascular spasms. Once freed, the transplant is cleaned and preserved in warm cloths, avoiding tension on its vascular supply.

The colonic transplant has no efficient propulsive contraction and empties by gravity. However, it was demonstrated by Jones et al. in 1971 on animals [24] and since then in humans [25] that acid reflux in the transplant can induce a contraction which protects the colonic mucosa against acid aggression. If reflux occurs, this intrinsic contraction (which can be reproduced with the amplitude of 15–20 mmHg for 45–50 s) can rapidly clear the colon. For this reason, we believe that colonic transplants should be placed (if possible) in an isoperistaltic position to benefit from this self-protection.

If the right colon is used, it can be placed in an isoperistaltic fashion using a vascular supply from the middle colonic artery or antiperistaltically on the ileocolic artery. The right colon is shorter than the transverse colon, so the distal ileum is used with sacrifice of the valve to gain some extra length.

In some cases, we use an interesting artifice suggested in 1974 by Papahagi and Popovici. When carrying out the gastrostomy, these authors ligated the middle colonic artery and sometimes the right one to stimulate development of the left one, anticipating transverse isoperistaltic colonic replacement [26].

To bring the transplant to the neck, we use a large (40 mm) Penrose drain, the proximal end of the transplant being placed inside and sutured to it. This avoids any friction to its proximal edge when pulling it up. We check the arterial pulse with Doppler ultrasonography, but also the venous return.

We always perform the proximal end-to-end anastomosis using single-layer, full-thickness interrupted resorbable sutures with a V-shape incision of the proximal esophagus to make the colon width fit to its diameter (if needed). In some cases, if a short stenosis is present in the upper part of the native esophagus, we widen it using the Mikulicz procedure to avoid the anastomosis being too close from the upper esophageal sphincter.

The distal cologastric anastomosis is undertaken on the anterior wall of the stomach by the upper third of the small curvature. The suture is done using two layers of resorbable stitches, with disrupted stitches on the seromuscular suture and a running stitch on the mucosa.

As we placed the colons in an orthotopic position, we experienced frequent reflux and/or stasis in the transplants. Thus, we felt

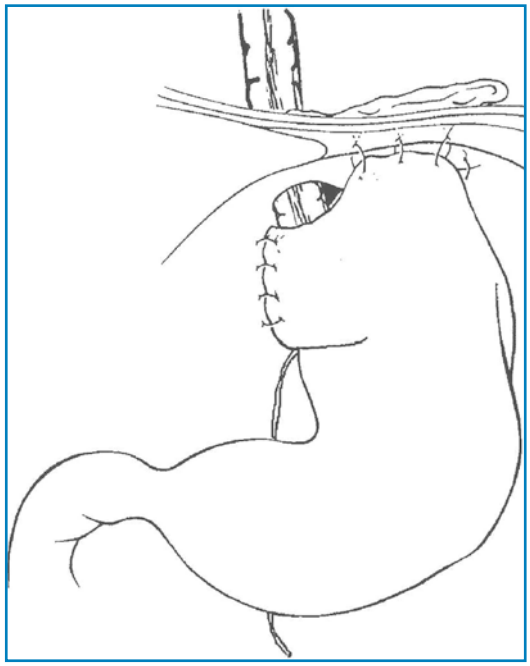

Fig. 12.3 Anti-reflux wrap for colonic transplants

the need of a new anti-reflux procedure because the standard procedure (Nissen, Toupet) was too efficient on the weak wall of the colon. We described in 1993 a new anti-reflux procedure for colonic transplants using an anterior wrap similar to the one described by Dor that was made out of the fundus but fixed to the right crus [27] (Fig. 12.3). It covers 3 cm of the distal transplant. The wrap must be loose enough not to compress the vascular pedicle located behind the transplant. The opening of the hiatus behind the transplant is never closed. This loose anterior wrap is efficient enough on a colonic transplant to prevent reflux (as shown by esophagography on day 10). It reduces the reflux from 48% to 7.5% using the anti-reflux wrap and from 40% to 21% on later esophagograms. A long-term prevalence of stasis of 25% in the transplant is not increased with this valve [27].

We have never carried out gastric drainage or a Mikulicz pyloroplasty even if damage to the vagus nerves was suspected. We have observed some stasis in the stomach and in the transplant, but they have all resolved spontaneously within a few days or weeks. Some children have delayed gastric emptying before surgery, so we believe that the vagus nerves have suffered transparietal burns because it is in the scar of the peri-esophagitis.

12.5.3.2 Gastric Tube

The concept of a gastric tube comes from experiments on gastrostomies undertaken during the second half of the nineteenth century. The first use of a gastric tube as an eseophageal substitute was by Daniel Gavriliu from Romania in 1951. Heimlich claimed he did it first but, in 1957 after visiting him, he paid tribute to Gavriliu. The first gastric tube procedure in the USA was by the Canadian James Fallis. Dan Gavriliu built two tubes using the greater curvature vascularized by the gastroepiploic artery. The first one was a reversed gastric tube, the pre-pyloric antrum being brought to the neck and vascularized by the left gastroepiploic artery; the second tube was isoperistaltic and supplied by the right gastroepiploic artery. At that time, both required a splenectomy [2,3]. Today, most gastric tubes are reversed, built from the greater curvature of the stomach and with blood supply from the left gastroepiploic artery without splenectomy (Fig. 12.4). It brings the antrum to the neck, this part of the stomach producing less acid than the fundus.

The procedure involves first the division of the gastrocolic ligament, preserving the gastroepiploic artery from the pyloroduodenal artery to the splenic one. Usually, the short gastric vessels can be preserved. The free edge of the tube should be taken at about 3 cm from the pylorus. The gastric curvature is molded around a 24-F tube using 2–3 shots of a 75 mm-long GIA™ stapler or is hand-sewn. It is brought to the neck in the same manner as for a colonic transplant. Care must be taken to the hinge between the tube and the stomach, and some reinforcement stitches can be useful. The upper anastomosis is done in the same way as for the colon. A gastrostomy is carried out on the anterior wall of the stomach. A

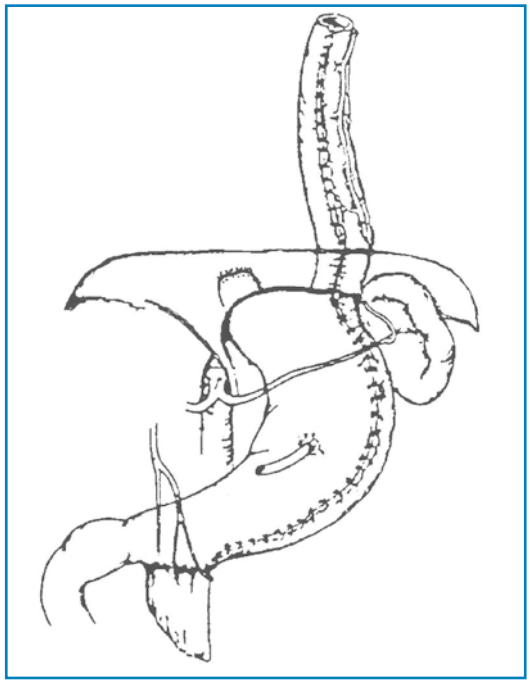

Fig. 12.4 Reversed gastric tube vascularized by the left gastroepiploic artery

decompression tube into the transplant, a gastrostomy tube and a jejunal feeding tube are placed through it [8].

The gastric tube is an excellent substitute to the esophagus with a reliable blood supply, better than the colon. However, a major problem is related to the position of a previous gastrostomy along the great curvature, which interrupts the gastroepiploic artery. We had to deal with several redo esophageal replacements for severe stenosis of the upper part of gastric tubes because the surgeons had closed gastrostomies along the curvature to build their tubes. When carrying out a gastrostomy for caustic stenosis, it is wise to place it far away from the great curvature, just in case a tube should need to be created. Even with an apparently intact gastroepiploic artery, defects in its continuity have been shown in cadaver studies by Koskas et al. and Ndoye et al. [28, 29].

Because a part of the stomach has been used, an anti-reflux wrap is not possible. Thus, the gastric tube has the disadvantage of an associated gastroesophageal reflux with the possibility of an ulcer later on. The long suture carries the risk of a leak and progressive dysfunctional propulsion. It appears to act purely as a passive conduit. The volume of the stomach reduced at the beginning grows with time. The gastric tube keeps its tubular shape without developing dilatations.

12.5.3.3 Gastric Pull-up

In the last two decades, the gastric pull-up became predominant. This has been due to the works of Sweet in adult patients with esophageal cancer [30] and Spitz in children [31]. Discouraged by the long-term results of colonic transplants at his institution, Spitz reintroduced it for esophageal atresia at first [9].

The gastric pull-up involves mobilization of the entire stomach, creating a space in the mediastinum and achieving only one anastomosis in the neck with the cervical esophagus. The patient is positioned supine with the neck, chest and abdomen prepared and draped. A midline laparotomy is done and the gastrostomy is taken down and closed. The stomach should be totally freed from adhesions: the gastrocolic ligament with the short gastric vessels should be carefully divided as well as the gastro-hepatic omentum. The right gastroepiploic artery is preserved and the left one divided. This may imply removal of the spleen. The gastroesophageal junction is closed with two layers of sutures. The stomach must be completely freed, preserving the blood supply *via* the right gastric artery and right gastroepiploic vessels. The stomach is brought to the neck through the mediastinum. Extra length can be obtained by addition of a Kocher maneuver or by other improvements of the technique (e.g., additional Collis procedure) [32]. The esophagus is sutured to the fundus of the stomach using a single layer of full-thickness interrupted sutures. This gives the longest possible conduit [33].

The vagus nerves are divided bilaterally during gastric pull-up, so most authors recommend a Mikulicz pyloroplasty. However, Cowles and Coran advocate an extramucosal pyloromyotomy considering that a formal

Mikulicz pyloroplasty is placed under tension when the conduit is pulled into the neck and a pyloromyotomy is suitably efficient. A feeding jejunostomy should be done for the postoperative period [33].

The gastric pull-up requires a single cervical anastomosis and the conduit has an excellent blood supply. However, the closures of the gastrostomy, esogastric junction and the pyloric procedure are at risk of leakage in case of gastric distension [8].

Hirschl et al. found no deaths in 41 patients who underwent surgery between 1985 and 2002, but a high prevalence of leaks (36%) and strictures (49%) was noted [34]. In a large, single-center updated series of 192 gastric pull-up procedures over a 25-year period, Spitz reported no instances of transplant failure but deaths in 5.2% of cases. Morbidity is not unusual, and can include cervical fistulae (12%), anastomotic strictures (19.6%), swallowing dysfunctions (30.6%), and delayed gastric emptying (8.7%) [35].

For the sake of comparison, from 1989 to 2012 we undertook 280 esophageal replacements using the colon or a gastric tube (but no gastric pull-up): no deaths were observed and no transplant lost. The complications were cervical leaks in 12% (all of which resolved spontaneously within a few days), proximal stenosis requiring 1–12 dilatations (and two enlargement surgeries, see below) in 35%, and <20% refluxes in the transplants.

In 2009, Tovar et al. reviewed a series of 33-year median follow-ups of 65 patients with colonic interpositions, and reported deaths in 9% of cases. Patients experienced mild symptoms of reflux (43%), scoliosis, (22%) and other complications [9].

Gastroesophageal reflux is a major problem encountered by 25–30% of patients with gastric transplants with acid and/or biliary reflux even if pyloroplasty is not carried out. The prevalence of reflux esophagitis in the upper native esophagus if the stomach is used as a substitute is 30–78%. The gastric conduit is aperistaltic and surgically denervated even if studies have shown mass contractions of the body of the stomach without obvious rhythmic peristaltic contractions [36].

Another major problem is related to the volume of the stomach in the chest of small children, which compromises lung function and the venous return. We were involved in undoing gastric pull-ups for life-threatening events and possibly some of the reported deaths were related to that. According to Newman and Anderson, reports suggest that several patients undergoing gastric pull-up in the 1960s required colon transposition in the 1980s because of lung problems associated with chronic acid reflux, aspiration pneumonia and compression by a dilated intrathoracic stomach [37].

12.5.3.4 Small Bowel Interposition

Several techniques of small bowel interposition have been tried using the jejunum or ileum on their pedicles [38, 39] or as free grafts [40].

Jejunal interposition is seldom used because the blood vessels of the jejunum are thin and frequently compromised after anastomosis. According to its vascular disposition, the jejunal transplant requires withdrawal or a greater length than needed to divide the vascular arcades and to allow curves in the jejunum to be straightened [2, 38]. Furthermore, the jejunum is fragile to the erosion of acid, so the jejunum should not be the first choice. However, we have used the jejunum as a rescue transplant for referred patients after failure of a colonic and/or gastric transplant. Nevertheless, the jejunum can be used in the neck as a free graft with microvascular anastomosis on the facial or superior thyroid arteries. We used it successfully in short stenosis of the cervical esophagus or in 2 cases after recurrent stenosis of the proximal anastomosis in transplants.

12.5.4 Pharyngeal-associated Burns

Burns from the ingestion of caustic agents may also include the oral, pharynx and larynx. Combined lesions of the esophagus and phar-

ynx are unusual but represent a challenging problem. Among 281 esophagoplasties undertaken for caustic burns since 1989, 20 children had associated pharyngeal burns with partial or total destruction of the epiglottis, pharyngolaryngeal stenosis, and/or obstruction of one or both pyrifom sinuses with variable severity (including total closure of the airways in 4 cases). In spite of severe narrowing of the airways related to subglottic diaphragm with respiratory impairment, only 3 cases had tracheostomies when referred. However, they all had intact vocal cords. The closure reflex of the laryngeal vestibule during accidental ingestion of caustic materials acts as protective measure at the level of the larynx [41]. With the help of ENT surgeons, we totally resected the pharyngo-epiglottic stenosis with a CO_2 laser under suspension micropharyngoscopy at the beginning of the procedure. This allowed resection of the two pyriform sinuses with excellent homeostasis and located exactly the place where the transplant should be brought.

Then a one-stage esophagoplasty is done using isoperistaltic colonic interposition or a gastric tube associated with an endocopic pharyngoplasty, the proximal anastomosis being done at the level of the arythenoids on the larynx and higher in the oro-pharynx posteriorly. Thus, the proximal end of the transplant is 3–5 mm from the vocal cords. A long stay in the Intensive Care Unit (ICU) is needed after surgery because of possible pharyngeal and pulmonary complications, in spite of tracheostomies.

In all but one child we were able to recover normal swallowing within 2–6 months. After this time they did not present with broncho-aspiration during the day once the tracheostomy was closed. It took 3–12 months until they stopped coughing at night. During this period, pulmonary aspirations were frequent and a high prevalence of pneumonia episodes (1–5 per child) noted. With a follow-up of 1–10.6 years all children are healthily eating and breathing normally.

We believe that very proximal pharyngeal anastomosis of esophageal replacements can be attempted as long as children do not have impairment of mobility of the vocal cords by glottic scars or lesions in the recurrent laryngeal nerve. However, the rehabilitation takes time, during which aspirations and subsequent pneumonia occur. Regardless of the transplant used, there is an important difference in those in which the proximal anastomosis is done a few centimeters below the upper esophageal sphincter or if it has been destroyed.

12.6 Outcome, Complications and Follow-up

12.6.1 Immediate Follow-up

Patients leave the operating theater with several pieces of equipment. We place a low-pressure suction tube into the transplants to avoid postoperative distension. We believe that most vascular problems are not related to the arterial supply but due to venous stasis. Deflating the transplants improves venous return.

The children cannot eat postoperatively (sometimes for an extended period), so we avoid total parenteral nutrition, placing a gastrostomy in all cases. It is used to deflate the stomach while the gastric sutures heal, and a jejunal tube is placed through it to feed the child promptly.

Intraoperatively, we always place a non-resorbable, never-ending thread through the nose, throat and transplant, and it is exteriorized through the gastrostomy. This never-ending thread is left *in situ* for months. It can be used to replace a probe in the transplant without the risk of perforation related to blind introduction in a tortuous conduit. Furthermore, it has the advantage of safe dilatations, and Rehbein bougies are used for the same reasons.

12.6.2 Postoperative Period

Postoperative care demands a stay in the ICU because of potential pharyngeal and pul-

monary respiratory complications. Hence, we intubate patients for 2–5 days. We ask intensivists to administer adequate fluids and sometimes amines during the first 24 h to maintain as high a mean arterial pressure as possible, thereby avoiding poor perfusion in the transplant.

12.6.3 Stenosis and Leaks

The most frequent short- and long-term complications of esophageal replacements are leaks and stenosis of the proximal anastomosis. Leaks at the proximal anastomosis occur even if the transplant is well vascularized and the suture line free of tension on an intact proximal esophagus. We believe they are related to ischemia of the farthest end of the transplant. Slight ischemia seems to be related to venous stasis rather than poor arterial supply, as evidenced by the fact that a straighter transplant gives better results with less leakage and stenosis than a tortuous one.

The same explanation can be ascribed to stenosis of the proximal anastomosis but may follow persistent ischemia. We noticed that all patients with a leak of the proximal anastomosis require dilatations. Two children developed cervical stenosis 3 months after the replacements, and 2 others developed cervical stenosis 3 years and 5 years after surgery even though the radiological, endoscopic and surgical aspects were normal and they were already eating. These findings were probably related to a recurrent hypertrophic healing process induced by the surgical procedure and/or by subsequent oral feeding. These recurrences raise the question of how long these children should be kept under observation.

12.6.4 Long-term Follow-up

Patients in our series had a mean long-term follow-up of 8.6 years. All patients are eating normally, with no failure to thrive and no growth retardation. Most children or parents have no complaints. Those who are now adults lead a normal life. Nevertheless, many children experience noisy breathing, coughing refluxes, and have acquired strange eating habits (e.g., drinking between each bite).

12.7 Conclusions

According to Cowles and Coran, 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 [33]. With experience of >280 esophageal replacements during 24 years, we still do not know the best procedure.

When intending to replace an esophagus the surgeon does not know which transplant can be used: if the gastrostomy has been placed too close from the great curvature he/she may face an interruption of the gastroepiploic artery, and a gastric tube cannot be achieved. If the surgeon plans a colonic transplant, a missing artery could make it impossible. Therefore, the surgeon must be able to adapt his/her technique to the patient's condition, and so must be aware of several techniques.

Our belief is that a successful esophageal replacement does not behave as a normal one. The best esophagus for a child is his/her own one. Everything must be done to preserve it, and esophageal replacement should be the last resort.

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