Jejunal Interposition after Failed Esophageal Atresia Repair

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BACKGROUND: The early outcomes of using jejunal interpositions to establish esophageal continuity in patients who have had a failed repair of esophageal atresia (EA) were determined.

STUDY DESIGN: This was a retrospective review of all patients treated at our institution with a jejunal interposition after a failed EA repair from 2010 to 2015. Demographics, anatomy encountered, operative techniques, requirement for microvascular support, and length of stay were analyzed. Outcomes measures included conduit survival, as well as feeding status at last follow-up.

RESULTS: Ten patients were reviewed. Median age at time of interposition operation was 48 months (range 8 to 276 months) and median weight was 14.2 kg (range 7.2 to 49.7 kg). Preoperative anatomy, operative techniques, and outcomes are presented. Four patients had microvascular "supercharging" for a long jejunal graft. Median follow-up was 1.5 years (range 0.5 to 5 years) with no long-term loss of graft or deaths. Six patients are eating by mouth completely, 1 by mouth primarily with supplemental night-time feeds, 1 is transitioning from tube to oral feeds, and 2 with functional grafts are fed mostly enterally due to severe oral aversion in 1 and aspiration in 1.

CONCLUSIONS: Jejunal interpositions have been used for the past 5 years to establish esophageal continuity after a failed EA repair. All jejunal conduits survived and were joined to the upper esophageal segment. For shorter gaps with a longer upper esophageal pouch, a thoracic esophageal anastomosis was possible without additional vascular support. For longer interpositions into the neck, upper conduit survival might benefit from additional vascular anastomoses (ie, supercharging). To provide adequate space in the mediastinum, the first rib can be removed, as well as a portion of the manubrium to enlarge the pathway into the neck. (J Am Coll Surg 2016;222:1001−1008. © 2016 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Esophageal substitution is occasionally required in infancy and young children. Most commonly, a graft is chosen because of esophageal atresia (EA) due to a gap that is too long for a primary anastomosis or after an unsatisfactory repair. The consequences of an earlier unsatisfactory EA repair can also complicate and jeopardize the choice of esophageal reconstruction. Among the various choices for an interposition, the jejunum offers several important long-term advantages, although it is acknowledged to be the most technically difficult to create. Nevertheless, because of the utmost importance of good long-term function for the very young child, we have used jejunal interpositions as an esophageal substitute in these complex situations since 2010.

The types of esophageal substitutes that have been used historically have included gastric pull-up and transposition procedures, the creation of gastric tubes, colon interpositions, ileal-colic grafts, and segmental jejunums.[1-7] Each of these substitutes has its own advantages and disadvantages and, consequently, its advocates and detractors. The choice of esophageal interposition graft is influenced strongly by

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the experience of the surgeon and surgical team, and all interpositions require surgical skill and expert management. For young patients, the long-term outcomes become a very important consideration, and the goal for pediatric patients should be for 70 or more good years, which is a very stringent requirement.

We believe that the jejunum has substantial long-term advantages over other esophageal substitutes.[7] It maintains peristaltic activity once in place; consequently, it typically continues to function well and does not dilate over the years. The peristaltic function also seems to inhibit the development of detrimental and difficult to treat problems that are common in other interpositions, such as aspiration or damaging reflux. The jejunum has very few intrinsic diseases that can surface in later years. These advantages have been borne out in favorable medium-term results without signs of deterioration when a jejunal interposition was used as the initial solution to EA/tracheoesophageal fistula (TEF) with a long gap.[7]

Despite these important benefits, however, the jejunum has not been commonly used as an esophageal substitute. When used, most, but not all, series have reported on jejunal interpositions in adult patients.[3,5-13] The principal reason for this appears to be the greater technical difficulties in creating a successful jejunal graft; for our patients, these difficulties would predictably be increased by an earlier failed EA repair. The potential long-term advantages, however, seemed to outweigh these obstacles and have led us to use the jejunum in these difficult situations. To provide information on its suitability, this study reviewed our first 10 cases of jejunal interposition used to establish esophageal continuity after an unsuccessful EA repair.

METHODS

The first 10 cases of a jejunal segment being used to establish esophageal continuity after a failed EA repair from 2010 to 2015 were reviewed with IRB approval (IRB-P00014882). The data collected for this retrospective study included the initial type of EA and the presence of significant associated anomalies, the history of the EA repair and complications, and the status of the patient at the time of the operative creation of the jejunal interposition.

The surgical details recorded included the technique used to mobilize the jejunal segment, the route taken to join the jejunal graft to the upper esophagus, the method of jejunal anastomosis, and the methods for microvascular anastomoses. The initial evaluation of these procedures, the length of hospital stay after the first operative procedure for creating the jejunal interposition, as well as the additional procedures required, such as anastomotic dilations, were also determined.

The follow-up included aspects of learning to eat, and whether the current oral intake was sufficient for adequate hydration and nutrition, and whether feeding supplementation was required. These data were analyzed to provide information on the suitability as well as the difficulties of using a jejunal interposition to establish continuity after a failed EA repair. All patients were evaluated preoperatively and followed up with our multidisciplinary esophageal and airway treatment team, which included pediatric surgeons, pediatric nurse practitioners, pediatric cardiothoracic surgeons, pediatric gastroenterologists, pediatric pulmonologists, pediatric intensivists, pediatric anesthesiologists and pain specialists, pediatric plastic and microvascular surgeons, as well as nutritionists, feeding specialists, and social workers. All pertinent patient issues were reviewed by the esophageal and airway treatment team members at each visit.

Surgical techniques

The creation of a jejunal interposition graft after a failed EA repair began with an understanding of the remaining esophageal segments. If a good-quality upper esophagus extended well below the apex of the pleural spaces (preferably to the carina of the trachea), the upper extent of the interposition could be within the thorax and not need microvascular support. If a cervical esophagostomy was present, or if the upper esophagus was short, the anastomosis would be planned to be in the neck. A longer jejunal interposition graft can benefit from, or even require, microvascular support, often termed *supercharging*, to ensure adequate arterial supply and the important venous drainage.[13-15]

Creating the jejunal graft began through a laparotomy incision; the jejunum was freed up and the vasculature was inspected by transillumination and dissection of the superior mesenteric artery and vein and its branches. At least one substantial artery was left behind proximally to ensure an adequate blood supply to the proximal jejunum. The preparation of the length of jejunum required an assessment of its blood supply via the vascular arcades, which are quite variable and, although the division of some arcades to take out the redundancy and straighten the graft has been described,[16] efforts were made to avoid arcade injury and division to maximize blood flow to the graft. The length needed was determined mainly by the location of a satisfactory upper esophagus and by the route taken to reach it.

There were several possible routes for the jejunal limb to reach the upper esophagus. The posterior mediastinal

Table 1. Patient Data and Surgical Techniques

Variable	Data
Patient data	
Patients, n	10
Age, y, median (range)	4 (0.7–23)
Weight, kg, median (range)	14.2 (7.2–49.7)
Original EA defect, n	
Type C with long stricture, TEF	7
Long gap, previous conduit	3
Colon interposition(s)	2
Gastric tube	1
Surgical techniques, n	
Pathway of jejunal interposition	
Right pleural space	5
Anterior mediastinum	3
Left pleural space	1
Posterior mediastinum	1
Site of upper anastomosis	
Neck	6
Chest	4
Additional vascular anastomosis, n	
Internal mammary artery and vein	3
Carotid artery/internal jugular vein	1
Colon marginal vessels	2
Gastroepiploic vessels	1

EA, esophageal atresia; TEF, tracheoesophageal fistula.

route following the original esophageal route is the shortest, the left chest slightly longer, the right chest a little longer still, and the longest route is the anterior mediastinal (substernal) route. In all cases, however, the jejunal limb was first brought through the mesentery of the transverse colon (retro-colic). The jejunal segment was then brought up through the anterior or posterior mediastinum or across either pleural space to the proximal esophagus. All of these routes were used successfully in this series (Table 1). The longer jejunal graft that was needed, the more necessary it became to supplement the arterial inflow and ensure adequate venous drainage by microvascular anastomoses along the upper end (Fig. 1A, B). Microsurgical vascular techniques were used to join the vessels of the upper end of the transplanted jejunal segment to the internal mammary or neck vessels to augment arterial inflow and venous drainage.[13-15] This is best done by a sternotomy and anterior mediastinal placement of the jejunal graft. Although we were successful in doing a graft along the spine in the left chest with 2 microsurgical vascular pedicles (1 from the gastroepiploic vessels after gastric tube takedown, the other to the carotid and internal jugular vein), technical challenges resulted in the distal 2 cm of the jejunal graft suffering temporary ischemia and stricturing. Consequently, we do not recommend this route for the microvascular supercharge-dependent grafts.

The anterior mediastinal route was prepared by median sternotomy and by taking down the ligaments of the left lobe of the liver and dividing the round ligament. The left lobe was then moved to the right using the round ligament, which opened the pathway to the anterior mediastinum or pleural space. To provide room for grafts to pass into the neck, the anterior portion of the first rib was usually removed, along with a portion of the manubrium.

A posterior mediastinal route into the right chest tracing the normal location of the esophagus offered some advantages. If the lower esophagus reached the airway (EA/TEF) or, at least, above the diaphragm, the esophageal hiatus was well formed and able to serve as the entrance into the chest. A pathway for the jejunal limb could then be developed through the esophageal hiatus and into the posterior mediastinum, which was the shortest and straightest route to the upper esophagus. This route has the potential disadvantage of constricting the blood supply of the jejunal conduit, so the constructed path must be generous.

A right chest route was chosen when the anastomosis was intended to be in the chest, but the posterior mediastinal route was believed to be too difficult or risky due to scarring from previous surgery.

The esophageal anastomoses to the jejunal limb were constructed using a single layer, full-thickness technique with nonabsorbable, monofilament sutures (Prolene; Ethicon) to minimize local inflammation. Seven grafts were joined end-to-side and in 3, the upper esophagus was joined end-to-end to the jejunal limb. In 7 patients, the lower end of the jejunal graft was anastomosed to the stomach and 3 are currently in a Roux-en-Y configuration.

Conduit function and learning to eat

Conduit function was evaluated in this series by contrast studies to determine the presence of strictures and peristaltic activity (Fig. 2A, B). Jejunal graft function in this study was also assessed indirectly by determining the ease of swallowing, the ability to eat a variety of foods appropriate for age, the lack of evidence for chronic aspiration, and the absence of signs and symptoms of gastroesophageal reflux.

RESULTS

In all 10 patients an earlier EA repair had failed; in 6 patients, the attempted repair was still in place with a long, recalcitrant stricture; and in 2 patients, large residual leaks were also present. One patient had a failed

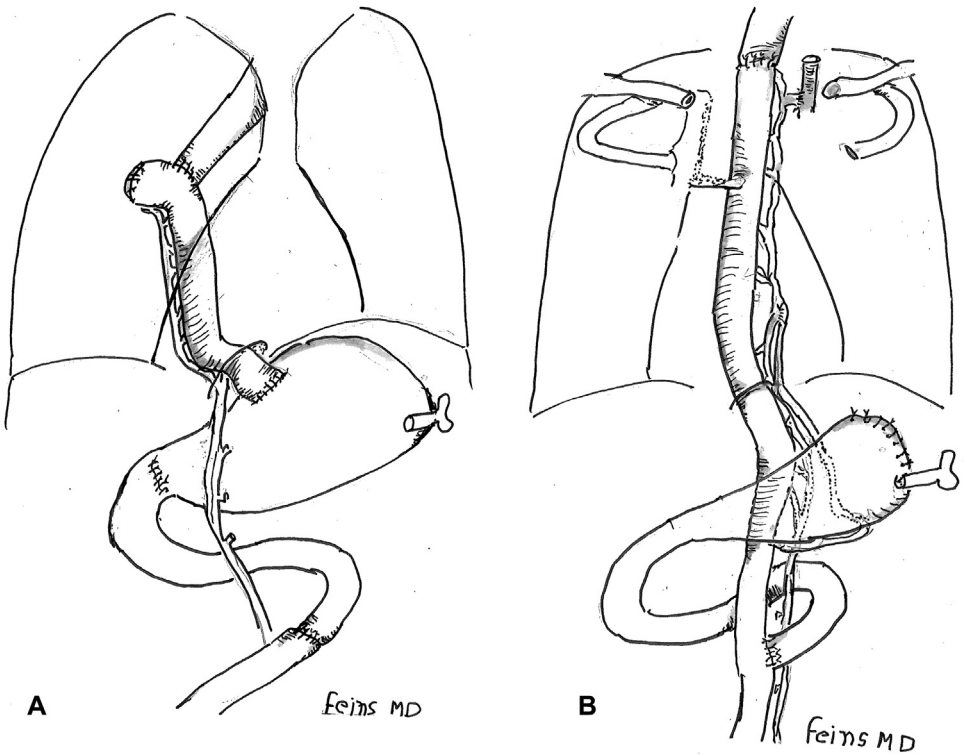

Figure 1. (A) Jejunal interposition from thoracic esophagus to stomach without microvascular supercharge. (B) Jejunal interposition to cervical esophagus and Roux-en-Y reconstruction with supercharging using internal mammary and gastroepiploic vascular anastomoses. (Drawings reprinted courtesy of Dr Neil Feins.)

growth procedure without an anastomosis. Three patients had failed conduits—2 colon interpositions and 1 gastric tube. Mean age of the patients at the time of jejunal substitution was 4 years (range 0.7 to 23 years) with a mean weight of 14.2 kg (range 7.2 to 49.7 kg) (Table 1).

The pathways created for the jejunal limb included 5 through the right pleural space, 1 through the posterior

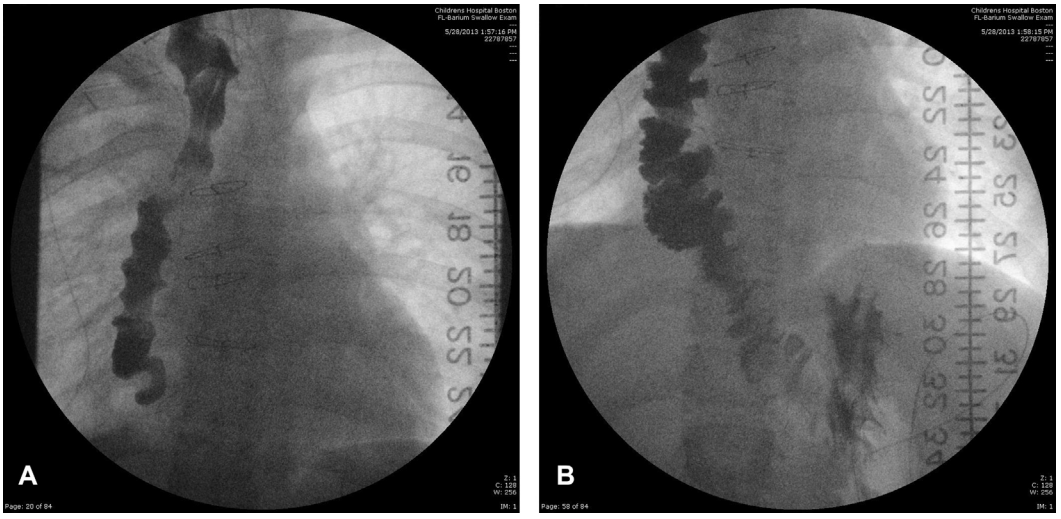

Figure 2. Contrast of study of jejunal interposition. (A) Uniform caliber of graft with normal-appearing mucosa. (B) Study 30 seconds later showing peristaltic contraction in the graft.

mediastinum, 3 anterior mediastinum, and 1 through the left pleural space along the spine (the route of the previous gastric tube) (Table 1). To increase the space for the anterior mediastinum jejunal graft at the upper end, the first rib was resected in 5 patients, and in 3 patients a portion of the manubrium was also removed.

The jejunal limbs were mobilized as described and all were brought through the mesentery of the transverse colon (retrocolic), then antegastric in 9 and retrogastric in 1 patient. In 4 patients, microvascular anastomoses were added to increase the distal blood supply and drainage (supercharged). The most frequent method used was the internal mammary vessels mobilized together after a sternotomy. Both of the failed colon grafts provided colonic marginal mesentery vessels for central jejunal graft augmentation, as did the gastroepiploic vessels from the failed gastric tube. In these cases, the earlier interposition grafts were resected and maintained their vascular supply in situ. These afforded additional and useful options for further mid-jejunal microvascular graft support.

Six upper anastomoses were carried out in the neck and 4 in the thorax. In 7 patients, the lower end of the jejunal limb was joined to the stomach and 3 were left in a Roux-en-Y configuration. Contrast studies were done in all and the conduit sizes were of normal diameter and revealed peristaltic activity (Fig. 2A, B). One patient had a contained anastomotic leak that sealed spontaneously. Five patients have required balloon dilations (3 of those with stent use) in the postoperative period. One of these patients required a stricture resection procedure twice before eventual satisfactory jejunal interposition function.

Aspiration has been significant in only 1 of the 10 patients due to pre-existing bilateral vocal-cord paralysis. Substantial reflux into the graft, however, occurred in 3 patients who had been on jejunal feeding through a gastrojejunostomy tube for many months. A pyloroplasty was done in 4 patients to increase gastric emptying.

With a median follow-up of 1.5 years (range 0.5 to 5 years), 6 of the 10 patients are eating completely by mouth, 1 primarily by mouth with supplemental night-time feeds, 1 with severe oral aversion is slowly transitioning from enteral to oral feeds, and 2 with functional jejunal grafts are fed mostly enterally due to severe oral aversion in 1 and aspiration in 1. There were 8 patients younger than 5 years old at the time of their jejunal interposition. Four of these patients are eating by mouth completely, 1 by mouth primarily with supplemental night-time feeds, 1 with severe oral aversion is slowly transitioning from enteral to oral feeds, and 2 with functional grafts are fed mostly enterally due to severe oral aversion in 1 and aspiration in 1. For the 3 patients who had a jejunal interposition in the last 12 months, 2 are fully orally fed (1 Roux-en-Y and 1 gastric configuration), and 1 is transitioning from enteral to oral feeds (Roux-en-Y configuration).

There is a significant learning curve for this procedure. The overall postoperative course was very satisfactory in the last 7 patients, with a length of stay between 30 and 49 days and one of 95 days. Only the first 3 cases were prolonged or required a staged approach over more than one hospitalization, which increased the overall mean length of stay to 90 days.

Major complications have occurred in several patients that deserve specific mention, although all eventually had satisfactory jejunal conduit function. Our first patient in the series used a jejunal conduit in the right chest brought to the neck for cervical anastomosis. In this patient, a recalcitrant stricture developed that required many dilations, a stent, and 2 upper anastomotic stricture resections before success. The graft was not supercharged in this patient.

The second patient in the series came with not only failed EA repair, but 3 failed esophageal replacement attempts using stomach, ileocolic segment, and colon. The jejunal replacement required staging over 17 months; this patient again had a cervical anastomosis with conduit pathway in the right chest, without supercharged vascular support. Similar to the first patient, this patient required multiple dilations for an upper anastomotic stricture.

The third patient in our series had immediate partial jejunal graft loss due to vascular arcade injury and occlusion at the diaphragm. This was ameliorated by returning the jejunal graft to the abdomen and allowing a period of time for recovery before performing the interposition procedure. This case was also complicated by an acquired TEF from the upper esophageal pouch (initial anatomy as newborn was pure EA type A). The final procedure went very well using the substernal pathway to create a cervical anastomosis with microvascular support of the interposition based on the internal mammary vascular pedicle. Lastly, an anastomotic stricture developed in 1 patient after a delayed cervical microvascular anastomosis due to technical challenges; however, this has now resolved.

The first 3 patients we completed with high thoracic and cervical jejunoesophageal anastomoses without microvascular supercharging had strictures that required considerable effort to overcome, including 1 patient that required 2 stricture resections. We have not had problems with strictures—except in the patient with a considerable delay in re-establishing blood supply due to technical

issues—since we started using the microvascular support for the longer jejunal grafts to the neck.

DISCUSSION

Repair of serious congenital defects in infants and young children should have the goal of providing 70 or more good years. Although the majority of primary EA/TEF repairs are successful, perhaps 5% fail for one reason or another, and the patients are left without a functioning esophagus. In addition, the uncommon pure atresia without a TEF (type A EA), or the even rarer type B defect with only an upper fistula and a blind lower esophageal segment, usually have a long gap between esophageal ends. Until recently, with the advent of the esophageal growth procedure, these patients often required an esophageal substitute.

Normal eating is very important to the physical and psychological development of children. Solving the problem of a failed EA repair might require an interposition graft to avoid life-long enteral feeding. The choices of esophageal graft are several and most commonly have been fashioned from other portions of the gastrointestinal tract (ie, stomach, small bowel, and colon). Once transplanted to a new location, these grafts might not function well, although some can have adverse consequences or develop intrinsic diseases, such as colon cancer. Normal growth and development of a young child and a satisfactory quality of life in adulthood will depend on the ability of the interposition graft to serve as a functional esophagus for decades.

The 2 most commonly used substitutes are a section of colon or a portion (or all) of the stomach. Although these are the most frequent choices for an esophageal substitute, there are significant issues. For both, the principal advantages appear to be the ease of creation, robust vascular supply that can reach the neck, and widespread experience with them. For the longer term, however, significant problems can develop. The aperistaltic colon graft might begin to dilate, leading to chronic aspiration and difficulty in emptying, which developed in 2 patients in this series who had colon grafts, and even changing the first colon graft to an ileocolic graft in 1 patient failed to solve them. The lack of peristalsis in these thin-walled colon grafts predisposes them to dilation, leading to pulmonary and other problems.[4,17,18]

The grafts constructed from the stomach can also produce unsatisfactory consequences. A stomach graft can show rapid emptying initially, but will be without peristaltic function, and these grafts will characteristically slow the passage of food and allow detrimental reflux into the cervical esophagus, leading to chronic aspiration and poor growth.[19,20] Denervation of the stomach, usual in the pull-up procedure, also commonly leads to atrophic gastritis with detrimental long-term consequences.[21] Acid reflux can produce considerable cervical esophagitis, a problem commonly produced by gastric tubes and pull-up procedures.[4,19,22]

The long-term consequences reported for colon- and stomach-based grafts stand in contrast to the lack of late problems reported for jejunal interposition. The jejunum continues to function well and showed no sign of deterioration after 30 or more years in the longest reported follow-up.[7] It should also be noted that the jejunum was used for 1 of the very first 2 successful EA/TEF repairs reported (the other used a skin tube).[1,7] Despite its advantages, however, it has not been a popular esophageal substitute. The principal reason has been the greater technical difficulty in creating a jejunal interposition.

Although the technical requirements are greater for jejunal grafts, they have been achieved by many, and a number of reports detail how to accomplish these interpositions.[7-16] One of the potential difficulties associated with a long jejunal graft has been solved by adding distal microvascular anastomoses (supercharging) to ensure adequate distal blood flow.[13-15] The only long-term issue has been that the jejunum might continue to grow actively and become redundant. Due to retention of jejunal motility, we believe this might not become a significant problem.

The jejunum can typically reach well into the chest (around the carina level) without need for additional microvascular support, and occasionally can reach higher. With microvascular supercharging, the jejunum can typically reach into the neck. These estimates can be compromised in patients who have severe mesenteric fibrosis or mesenteric shortening from earlier surgical, infectious, or other injury. Despite these potential difficulties, the considerable long-term advantages of a jejunal interposition certainly deserve greater consideration.

In this series, a jejunal interposition was constructed in all 10 patients and successfully joined to the upper esophagus. The earlier EA repairs and attempted interpositions predictably resulted in adhesions of varying density within the abdomen, chest, and neck, which needed to be taken down. Other obstacles included the presence of long, recalcitrant strictures, leaking esophageal remnants, failed colon interpositions or, in one patient, an unsatisfactory gastric tube that required removal. Despite these additional difficulties, in all patients a satisfactory esophageal substitute using jejunum was eventually created.

Several points have emerged from this study and review of our patients. First, the use of microvascular graft support can improve the perfusion, healing, structuring,

and function of the conduit. Some of our initial complicated patients illustrate this pointedly and this is especially true for conduits that must reach the neck for cervical anastomosis. Additionally, the use of gastrojejunal feeding might have resulted in a relatively small, noncompliant stomach in 3 patients who had reflux develop with lower jejunum gastric anastomosis. In these patients, the small-volume stomachs filled quickly and reflux became a problem. This resolved over several months of slowly increasing gastric feeding volumes. With a normally compliant stomach, however, reflux was not significant with jejunal interposition grafts, perhaps because they maintain active peristalsis. When a jejunal interposition is contemplated for a patient on jejunostomy feedings, a period of preoperative feeding via the gastrostomy site might be beneficial to enlarge the gastric volume and increase the compliance of the stomach.

The limitations to this study are several. Primarily, it is a retrospective review that includes only a small number of patients who were quite varied in their clinical situation. As a result, the surgical approaches and details were customized for each patient from their initial surgical evaluation and throughout their postoperative visits to clinic. There has been a steep learning curve and our care has evolved with our continued experience. The follow-up is relatively short for what are long-term problems and solutions; it is our hope to continue to report on these outcomes, as we have one of the largest lifelong follow-up multidisciplinary clinics. These outcomes demonstrate that the jejunum can be used as an esophageal graft even in very difficult cases with failed multiple earlier operations for correction of EA/TEF. These results contribute important information to the choice of interposition graft and the early treatment of these complex patients.

CONCLUSIONS

A jejunal interposition was created successfully in all 10 patients in this series with long-term graft function and without irreversible complications. A previous failed EA/TEF repair made these procedures more challenging, but did not prevent successful results. Consequently, even though a jejunal interposition is more difficult to create than a colon or stomach graft, in addition to the complexity added by a previous failed EA/TEF repair, the long-term benefits still make it a good choice in experienced programs for infants and children in this situation.

Author Contributions

Study conception and design: Bairdain, Foker, Smithers, Hamilton, Labow, Baird, Taghinia, Feins, Manfredi, Jennings

Acquisition of data: Bairdain, Foker, Smithers, Labow, Feins, Manfredi, Jennings

Analysis and interpretation of data: Bairdain, Foker, Smithers, Labow, Feins, Manfredi, Jennings

Drafting of manuscript: Bairdain, Foker, Smithers, Labow, Feins, Manfredi, Jennings

Critical revision: Bairdain, Foker, Smithers, Hamilton, Labow, Baird, Taghinia, Feins, Manfredi, Jennings

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