Double Supercharged Jejunal Interposition for Late Salvage of Long-gap Esophageal Atresia

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Background: A variety of surgical techniques exist to manage long-gap esophageal atresia (LGEA), including gastric pull-up (GPU), colonic interposition (CI), jejunal interposition (JI), and distraction lengthening. Salvage reconstruction for late failure of any conduit type is a complex surgical problem fraught with technical difficulty and significant risk. Jejunal interposition can be used as a salvage procedure in the management of LGEA. However, the opposing requirements of conduit length and adequate perfusion make the procedure technically challenging. Chronic comorbidities and abdominal and thoracic adhesions may further complicate these cases.

Methods: We report a technique for the management of 3 late treatment failures of LGEA using pedicled JI in conjunction with 2 additional arterial and venous anastomoses, or *double supercharging*. For 2 patients who presented with failed CI, pedicled JI was performed and supercharged to internal mammary vessels as well as vasculature preserved from the prior colonic flap mesentery. The third patient presented with failed GPU and underwent pedicled JI that was supercharged caudally to the gastroepiploic vessels and cranially to the left common carotid artery.

Results: No flaps were lost in any patients. Median operation time was 16.5 hours. Patients were monitored postoperatively in the intensive care unit for a median of 23 days, extubated after 14 days, and discharged at 41 days. Postoperatively, all patients tolerated an oral diet by discharge and continue to enjoy oral intake of all food consistencies without dysphagia or aspiration. Follow-up time spanned 2 to 4 years (average, 3.3 years). One patient required dilatations and temporary stent for stricture, and another required removal of prominent sternal wires; otherwise, no additional procedures were performed.

Conclusions: Although technically difficult, double supercharged JI should be considered as a salvage operation to restore esophageal continuity after CI or GPU failure for LGEA, when there are otherwise limited reconstructive options.

Key Words: esophageal atresia, jejunum, jejunal flap, microsurgery, supercharge

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A variety of surgical techniques exists to manage long-gap esophageal atresia (LGEA), including gastric pull-up (GPU), colonic interposition (CI), jejunal interposition (JI), and distraction lengthening. Although no consensus exists as to the optimal reconstructive approach, a recent large meta-analysis of 470 patients spanning 15 studies reported that CI remains the most common primary form of reconstruction (73%), with GPU and JI performed in 21% and 6% of patients, respectively.[1]

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Short-term morbidity and mortality results are similar for both CI and GPU and include anastamotic leak and graft loss.[1,2] Long-term complications differ between these 2 approaches, with pulmonary complications predominating in GPU, and gastrointestinal (GI) complications more common after CI.[1–4] Although minimal data are available regarding the frequency of conduit failure necessitating late secondary esophageal reconstruction, a need exists for long-term salvage procedures for LGEA patients with late conduit dysfunction.

Salvage reconstruction for late failure in LGEA is a complex surgical problem fraught with technical difficulty and significant risk. When prior colonic or gastric conduits degenerate, JI can be used as a salvage procedure. Although the success rate of JI in the management of LGEA is high, the opposing requirements of adequate conduit length and sufficient perfusion make the procedure technically challenging. In the presence of intraabdominal and intrathoracic adhesions and chronic comorbidities, standard approaches may be insufficient in salvage situations. We report a technique in the management of 3 late treatment failures of LGEA, 2 from CI, and 1 from GPU. In our series, JI was performed in a pedicled manner in conjunction with 2 additional arterial and venous anastomoses, known as *double supercharging*. Supercharging has been previously reported for both pedicled[5–12] and free[13,14] JI reconstruction of esophageal and pharyngoesophageal reconstruction. This article presents a unique technique in using vessels preserved from the previous conduits, as well as mediastinal vessels, as recipient vessels for the microvascular anastomoses.

METHODS

Institutional review board approval was obtained to review the medical records of patients who underwent salvage double supercharged JI for reconstruction of LGEA at our institution between 2013 and 2016. We collected information pertaining to patient demographics and clinical characteristics, including sex, age, height, weight, body mass index (BMI), and past surgical history. For patients less than 20 years old, BMI-for-age percentiles were calculated using the Centers for Disease Control and Prevention Child and Teen BMI Calculator.[15] Body mass index category for these younger patients was derived using the following criteria: underweight (BMI-for-age percentile <5), healthy weighted (BMI-for-age percentile between 5 and 84), and overweight/obese (BMI-for-age percentile ≥85).

Procedural details, including operative duration and technical characteristics of the JI, were also obtained. Outcomes assessed included duration of postoperative intubation, intensive care unit (ICU) stay, length of postoperative hospitalization, and feeding and swallowing performance. Because of our small sample size, numerical data are presented as ranges, and median durations of intubation, ICU stay, hospitalization, and clinical follow-up are reported.

Operative Technique

Salvage double supercharged JI is typically accomplished as a 2-stage operation (Fig. 1), because extensive scarring and the resulting lysis of adhesions that has been necessary in the course of removing the failed conduit warrants a short interval of patient resuscitation before

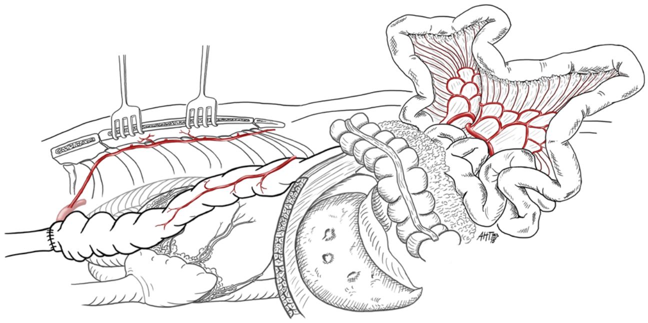

FIGURE 1. Sagittal cross section, showing previous CI still in place, left internal mammary artery isolated, and jejunal arcades exposed.

proceeding with the reconstructive portions of the procedure. The first stage creates a cervical esophagostomy and mobilizes the existing conduit, either a CI or GPU. A midline sternotomy is performed, taking care to protect underlying structures, including any previous retrosternal CI. The conduit is mobilized; this entails meticulous dissection of extensive thoracic and abdominal adhesions while taking care to protect and maintain important structures, including the phrenic nerve and the vascular pedicle supplying the conduit (Fig. 2). Arteries supplying failed conduits are identified by means of palpation and pencil Doppler (Fig. 3). Once dissected, the conduit is mobilized and delivered into the abdomen for later retrieval and removal in the second stage. A new gastrostomy may be created. Because of the long nature of these procedures, at this point, the patient is kept intubated and sedated and is transported to the ICU for 48 hours of resuscitation in preparation for the second operative stage.

The primary aim of the second operative stage is the creation of a new esophageal conduit with a pedicled and double supercharged jejunal flap. Because of the risk of thrombosis, patients receive an intraoperative heparin infusion (10 units/kg/h) that continues for 3 to 7 days postoperatively. In addition, a heparin bolus (20 units/kg) is administered before division of the vessels and microvascular anastomosis. The operation begins with a hockey-stick excision of the neck, extending from the cervical esophagostomy to a midline sternal and abdominal incision. The sternocleidomastoid muscle is elevated, and partial resection of the manubrium and clavicular head is performed to optimally position the proximal esophageal stump and to minimize compression of the jejunal flap during closure of the chest. The recipient vessels are carefully dissected; the most commonly used vessels are

FIGURE 2. Patient 3. Former GPU conduit has been dissected. Eye spears point to the vascular pedicles that will be preserved before division and removal of the conduit.

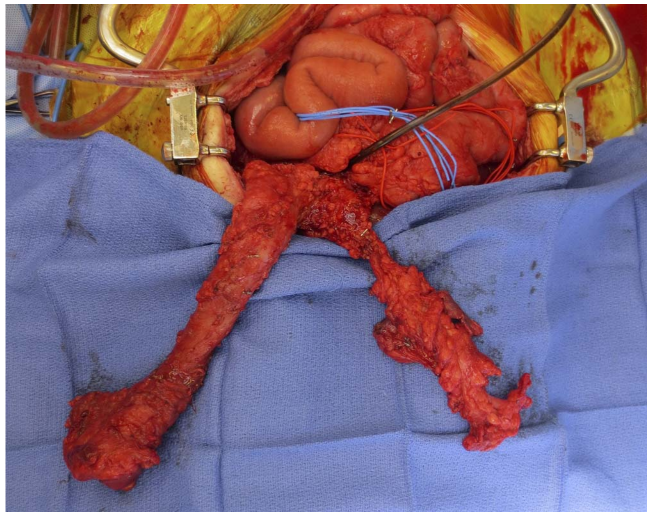

FIGURE 3. Patient 3. The pedicle (right) has been dissected off the failed gastric pull up (left).

an internal mammary artery and vein. At this point, a window is created in the transverse mesocolon to allow for cephalic transport of the jejunal flap in a retrocolic position. A suitable loop of jejunum is identified distal to the ligament of Treitz. Transillumination is used to visualize the jejunal vasculature. The jejunal arteries and veins are dissected down to their origins at the superior mesenteric artery and vein, respectively. Once all the vessels have been identified and fully dissected, an area is chosen in the bowel to be divided. This area is a vascular watershed between 2 jejunal branches, usually but not always the first and second jejunal branches. The bowel is then divided, and jejunal branches are divided as necessary to provide sufficient mobilization of the flap to reach the remnant cervical esophagus (Fig. 4). In the case of primary JI for LGEA, this can usually be accomplished by the division and subsequent revascularization of a single jejunal branch. In salvage situations where a prior conduit has been used, abdominal adhesions and mesenteric scarring limit mobilization of the jejunum and may necessitate the division of multiple jejunal branches to allow adequate transposition to the neck. This creates a greater area of ischemia along the jejunal flap length.

The jejunal mesentery is responsible for the inherent curvature of the jejunum and limits flap reach. The flap mesentery is divided to unfurl and adequately straighten/lengthen the new conduit. When possible, only avascular territories of the mesentery are divided, aiming to preserve any marginal vessels that may be present. The jejunum is fed through the window created in the transverse mesocolon and transposed overlying the mediastinum in a substernal position. The flap's most cephalad portion is secured with temporary sutures to the esophagostomy to prevent shearing and movement during the microsurgical portion.

An operating microscope is brought into the surgical field. Interrupted 8-0 and 9-0 nylon sutures are used to perform 2 sets of end-to-end vascular anastomoses between: (1) jejunal and mediastinal vessels, and (2) jejunal vessels and the preserved pedicles of failed conduits (Table 1). Subsequently, the jejunal flap is assessed for color, pulsatility, and peristalsis (Fig. 5). The GI anastomoses are then performed. Incisions are closed, and the patient is transferred to the ICU for monitoring.

In the ICU, patients initially receive total parenteral nutrition and are gradually weaned as they are transitioned to enteral caloric intake. Typically, the patients remain intubated for several days. Aspirin is administered for thirty days postoperatively to prevent thrombosis.

RESULTS

A total of 3 patients have undergone double supercharged JI for late salvage of LGEA at our institution, after failure of CI (n = 2) and

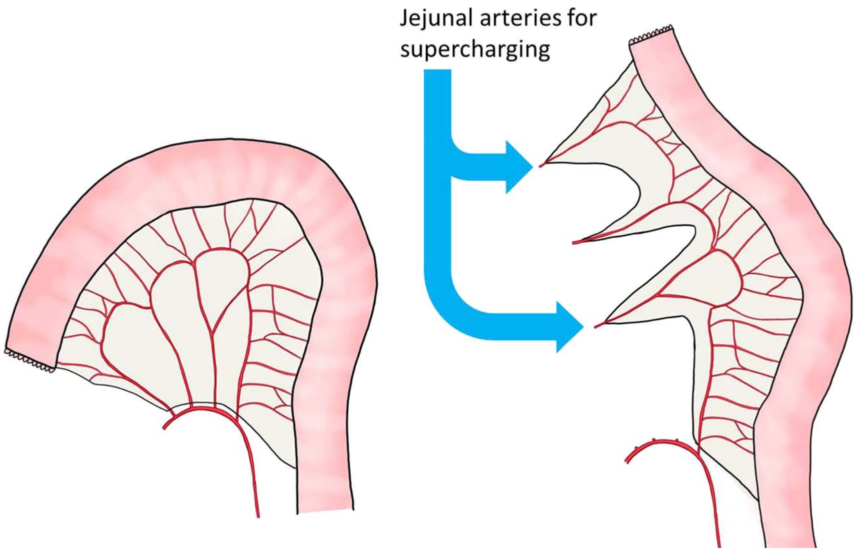

FIGURE 4. On the left, jejunum before division of the vascular arcades. On the right, the jejunum is unfurled after division of the first, second, and third jejunal branches.

GPU (n = 1). Two patients were male, and 1 is female. Ages ranged from 10.8 to 23.8 years at the time of operation (Table 2). One patient (patient 1) had already previously undergone removal of the conduit before attempted distraction lengthening (Table 1). Operative time for double supercharged JI ranged from 15.7 to 21.5 hours. No flaps were lost, and there were no mortalities. Postoperatively, patients remained intubated for a median of 14 days; they spent a median of 23 days in the ICU and 41 days in hospital (Table 3). By postoperative day 40, all patients tolerated some form of oral intake, and by postoperative day 50, all met their caloric needs enterally (includes oral intake and gastrostomy tube supplementation). The patients have been followed for at minimum 2 years (average, 3.3 years). Postoperative evaluation has included routine endoscopy and upper GI fluoroscopy, which all show patent, functional jejunal segments (Fig. 6). Currently, 2 patients (patients 1 and 3) meet their caloric needs exclusively via the oral route, whereas 1 patient (patient 2) still requires supplemental gastrostomy tube feeds. All 3 patients enjoy foods of all consistencies, without dysphagia or aspiration.

Patient 1

Patient 1 is an 18-year-old female who was born with LGEA. She underwent CI at an outside hospital in infancy, with an ileocolonic segment based on the middle colic artery. She developed strictures at the upper and lower anastomoses and presented with dysphagia and early satiety; she could eat only milk and butter and had labored breathing when eating. At age 18, she underwent the Foker process, a technique in which the upper and lower esophageal segments are mobilized and gradually increasing tension is applied to the esophageal ends using traction sutures.[16] The primary goal of the Foker process is to induce esophageal lengthening in preparation for a tension-free primary esophageal repair. However, the procedure was complicated by 2 episodes of both distal and proximal traction suture breakage, as well

TABLE 1. Operative Technique

	Operation Duration, h		Jejunal Arterial and Venous Branches Divided at Their Origins From the SMA and SMV	Cephalad Arterial Anastomosis		Cephalad Venous Anastomosis		Caudad Arterial Anastomosis		Caudad Venous Anastomosis	
	Stage 1	Stage 2		Recipient	Donor	Recipient	Donor	Recipient	Donor	Recipient	Donor
Patient 1	21.5*	N/A	2, 3, and 4	Right internal mammary artery	2nd jejunal arterial branch	Right cephalic vein	2nd jejunal venous branch	Right colic artery	4th jejunal arterial branch	Right colic vein	4th jejunal venous branch
Patient 2	11.0	15.7*	1, 2, and 3	Left internal mammary artery	1st jejunal arterial branch	Left internal mammary vein	1st jejunal venous branch	Middle colic artery	3rd jejunal arterial branch	Middle colic vein	3rd jejunal venous branch
Patient 3	12.0	16.5*	1, 2, and 3	Left common carotid artery	1st jejunal arterial branch	Branch of subclavian vein	1st jejunal venous branch	Gastroepiploic artery	3rd jejunal arterial branch	Gastroepiploic vein	3rd jejunal venous branch

*Double supercharged JI performed.

SMA, superior mesenteric artery; SMV, superior mesenteric vein.

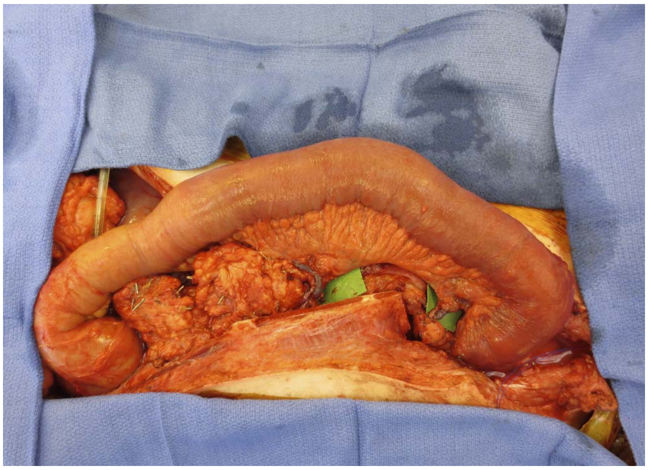

FIGURE 5. Patient 3. Intraoperative photo showing cranial (left) supercharging of the second jejunal artery and vein from the internal mammary vessels and caudal (right) supercharging of the third jejunal artery and vein from the gastroepiploic vessels of the failed conduit.

as by esophageal-ileal leak at the proximal anastomosis. Ultimately, attempts to bridge the gap were unsuccessful. In preparation for JI, the edges of both the proximal and distal esophagus were resected—the distal stump was closed and tacked to the prevertebral fascia, and the proximal end was brought out through the skin as a cervical esophagostomy.

Salvage esophageal reconstruction was performed with a single-stage, pedicled, and double supercharged jejunal flap. The operation was performed as described above. When the remaining portion of the previous conduit was removed, its vascular pedicle was preserved. The right internal mammary artery was of excellent quality. Its adjacent vein, however, was heavily scarred and unsuitable; instead the right cephalic vein was identified in the deltopectoral groove and tunneled up into the upper chest for venous anastomosis (Fig. 7). The right colic artery and vein provided a second supercharge to the jejunal conduit through the fourth vascular arcade (Fig. 8).

Two weeks postoperatively, a barium swallow study showed no evidence of stricture, anastomotic narrowing, or leaks. By discharge on day 43, the patient was meeting her caloric needs exclusively by oral intake of foods of varying consistencies. She has been followed postoperatively for over 4 years. Because of a sensation of pressure in her chest while eating, endoscopy was performed 3 years postoperatively and identified a small jejunal pouch near the proximal anastomosis; otherwise, the jejunum was healthy and patent. She has not required dilatation or any further procedures.

Patient 2

Patient 2 is a 10-year-old boy with vertebral defects, anal atresia, cardiac defects, tracheo-esophageal fistula, esophageal atresia, renal anomalies, and limb anomalies and associated LGEA and imperforate anus. In infancy, he underwent esophagostomy and gastrostomy, as well as colostomy for the imperforate anus. At 3 years of age, he underwent CI to establish esophageal continuity. The colonic conduit dilated and required tapering when the patient was 9 years old. Subsequently, the patient was unable to tolerate any liquids or solids; he required gastrostomy tube feeds as well as monthly endoscopic dilatations.

For salvage reconstruction, he underwent a 2-stage pedicled and double supercharged JI reconstruction. A very long jejunal conduit was needed to reach the cervical esophagostomy. This patient's postoperative course was complicated by edema such that the sternum could not safely be closed at the end of the case without causing hemodynamic compromise and excessive pressure on the jejunal conduit. The patient was taken to the ICU with an open chest, which was closed 5 days later without complication. One week postoperatively, he experienced small bowel obstruction and returned to the operating room for extensive lysis of adhesions. In the subsequent days, he developed aspiration pneumonitis from emesis related to the bowel obstruction; peripherally inserted central catheter infection with gram-negative sepsis; and absence-type seizure activity in the setting of the above respiratory insufficiency and sepsis. He was medically stabilized and transferred from the ICU to the floor 20 days postoperatively.

He began tolerating oral feeds on postoperative day 40, and he was discharged from the hospital on postoperative day 51 in improved condition. He required removal of prominent sternal wires 1 year later and has been followed for over 3 years without other complication. Routine annual postoperative endoscopies have shown healthy jejunal conduit without stenosis. He eats a normal diet by mouth, albeit at a slow pace, with caloric supplementation by gastrostomy tube.

Patient 3

Patient 3 is a 23-year-old male with Down syndrome, who was born with LGEA as well as duodenal atresia, initially treated as an infant at an outside institution. There, upon exploration for CI, an interruption in the mesentery in the midtransverse colon was noted, making rotation of the right colon impossible. Instead, he underwent GPU as well as duodenoduodenostomy. The repair functioned well until he was in his late teens when he began to experience obstruction and required dilatations. He presented to our institution with refractory obstruction of the esophageal conduit and several episodes of aspiration pneumonia. After these late complications, a gastrostomy tube was placed, and he became entirely dependent on gastrostomy tube feeds. Barium swallow study showed an extremely tight stricture at the thoracic inlet. Because of the multiple previous reconstructive attempts, he had right posterolateral thoracotomy, left thoracoabdominal, midline abdominal, and transverse upper abdominal scars. He underwent a 2-stage procedure to mobilize and resect the gastric conduit and perform JI for total esophageal reconstruction, with jejunal anastomosis in the neck. During the case, the thoracic tunnel was initially too tight for passage of the jejunum, and it had to be enlarged, prolonging ischemia of the flap. Postoperatively, the patient developed a small stricture at the proximal enteral anastomosis that required dilatation and temporary

TABLE 2. Preoperative Patient Characteristics

	Age	Sex	Height, cm	Weight, kg	BMI, kg/m^2	BMI-for-Age Percentile*	BMI Category	Type of Original Reconstruction
Patient 1	18.6	F	158.0	44.7	17.9	6.0	Healthy	CI
Patient 2	10.8	M	140.0	25.4	13.0	3.0	Underweight	CI
Patient 3	23.8	M	161.0	49.7	19.2	NA	Healthy	GPU

*BMI-for-age percentile calculated for patients less than 20 years old.

TABLE 3. Postoperative Outcomes

	Postoperative Duration of Intubation, d	Postoperative Length of Stay in ICU, d	Postoperative Length of Stay in Hospital, d	Time Until Tolerating Oral Intake, d	Time Until Meeting all Caloric Needs Orally, d	Complications	Duration of Follow-up, y
Patient 1	14	27	37	14	43	Sedation withdrawal	4.2
Patient 2	15	23	41	22	377	Stenosis of esophageal-jejunal anastomosis requiring dilatations and temporary stenting	2.2
Patient 3	8	21	51	40	Most caloric needs met orally; still requires supplemental gastrostomy tube feeds	Small bowel obstruction, PICC infection/sepsis, seizure	3.4

PICC, peripherally inserted central catheter.

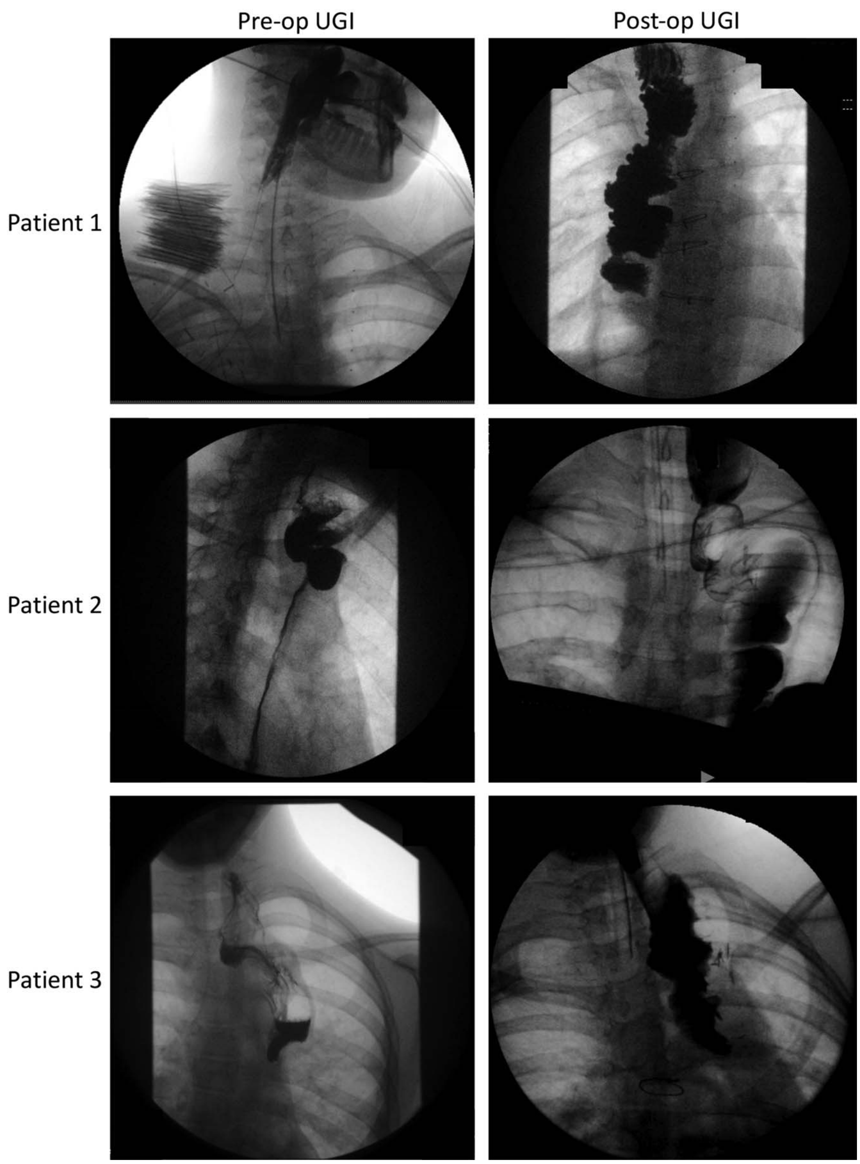

FIGURE 6. Upper GI fluoroscopy. Patient 1 preoperatively and 3 months postoperatively (top). Patient 2 preoperatively and 1 year postoperatively (middle). Patient 3 preoperatively and 1 year postoperatively (bottom).

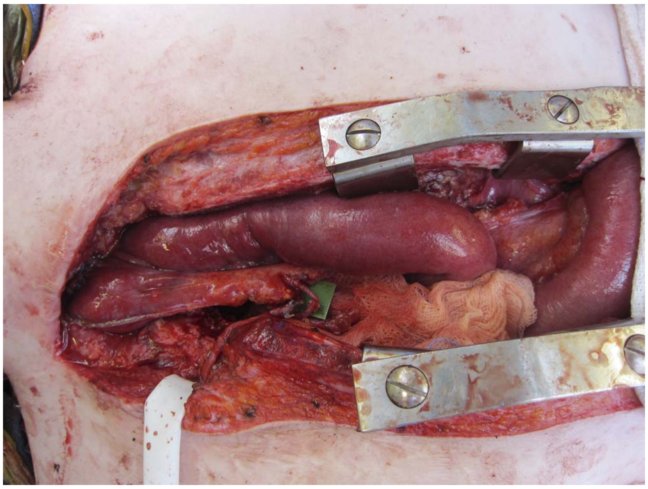

FIGURE 7. Patient 1. Intraoperative photo showing cranial arterial anastomosis of second jejunal artery and vein to the internal mammary artery and right cephalic vein, respectively.

stenting. He thereafter has been eating foods of all consistencies without dysphagia or aspiration; he meets all his caloric needs orally. He has been followed for 3 years postoperatively. He later had removal and closure of the prior gastrostomy site and has required no other procedures.

DISCUSSION

Late failure of CI and GPU for esophageal reconstruction can occur among children with LGEA. Currently, children and young adults with failed conduits face a paucity of reconstructive options, with many patients simply accepting long-term gastrostomy tube feeds. In the present study, we report a technical variation of JI that takes advantage of previous esophageal reconstruction efforts. Through preservation of the vasculature of prior conduits, microvascular anastomoses can be performed to augment the blood supply to pedicled jejunal flaps, a technique known as *supercharging*. In addition, mediastinal vessels are harvested for a second set of more proximal microvascular anastomoses, thereby achieving double supercharged JI.

Although others have successfully transposed pedicled jejunal flaps to establish esophageal continuity, the need for supercharging sometimes arises in primary reconstruction when esophageal defects are particularly large. Chana et al[12] have estimated that supercharging is necessary when defects are greater than 30 cm, whereas others have suggested that supercharging becomes beneficial any time the jejunal conduit is required to reach all the way to the neck.[5–12] Without adequate blood supply, ischemic complications such as cervical leaks and strictures may occur.[17,18]

Secondary reconstruction and late salvage patients are inherently heavily scarred, and the jejunum is typically more fixed than in primary reconstruction situation. This necessitates the division of multiple jejunal arterial branches to achieve adequate mobilization. In turn, this creates a sizeable ischemic territory that may exceed the ability of a single arterial revascularization to perfuse. The addition of a viable second arterial inflow allows for increased mobilization without the risk of ischemia.

The energy requirement of the conduit is elastic.[19] During the procedure, the conduit has low metabolic demand and may appear pink and healthy after a single anastomosis. However, it can be difficult to assess if the newly established blood flow from a single anastomosis is enough to nourish it during periods of digestion and peristalsis. Additional anastomoses may be beneficial to provide the blood supply needed for these dynamic requirements.

Based on our group's experience, one set of microvascular anastomoses (ie, single supercharging) is typically acceptable to maintain sufficient jejunal flap perfusion, provided that only 1 or 2 jejunal arterial branches have been divided. However, children who have experienced failure of a CI or GPU are more likely to require longer jejunal flaps for reconstruction; these patients are likely to have had at least 2 instances of partial resection of their native esophagus (ie, at the time of initial reconstruction and again during conduit takedown) and foreshortening of the mesentery due to prior interventions. All 3 of the cases in this series required the division of three jejunal vessels (Table 1), prompting a desire for additional inflow and drainage to limit the risk of ischemic complications.

In addition, although the jejunum receives its blood supply on a segmental basis, marginal arteries (of which the anatomy is highly variable) may provide a collateral blood supply to devascularized segments. In our experience, the marginal arcades support venous drainage much better than arterial inflow. When dividing the jejunal mesentery to unfurl and lengthen the flap, every effort is made to preserve any marginal vessels that may exist; only avascular portions of mesentery are purposely divided. However, in instances where a long esophageal defect must be repaired, theoretically, the mesentery could be divided down to the level of the serosa including any marginal vessels that may exist, thus essentially creating a free flap that is dependent on the blood supply from the microvascular anastomosis.[11] In our experience, this has not been necessary.

Not only is JI a valuable salvage operation after failed CI/GPU, but the jejunum itself has several advantages over alternative conduits. The jejunum closely approximates the diameter of the esophagus, maintains its peristaltic activity when transposed, typically remains free of intrinsic disease throughout life, and is less likely to dilate over time compared to the colon. Disadvantages of JI include the technical difficulties, need for long segments of jejunum, and its naturally furled course.

There are several important considerations when planning this operation. This form of reconstruction requires meticulous perioperative multidisciplinary collaboration. As cardiothoracic anomalies and history of related procedures (eg, aortopexy) are common in patients with LGEA, the cardiothoracic surgeon may be an essential component of the surgical team. A consensus must also be reached among microsurgeons and general surgeons regarding the degree of jejunal mobilization/positioning and selection of recipient vessels specific to the patient's surgical history and anatomy. Perioperative planning with the anesthesia and ICU teams helps optimize fluid

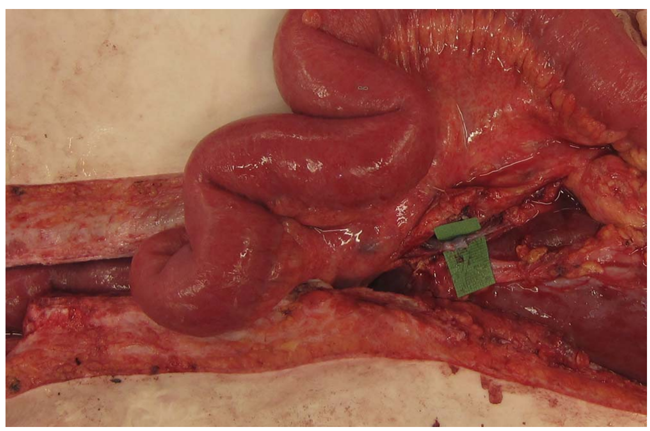

FIGURE 8. Patient 1. Intraoperative photo showing partial manubriectomy, jejunum in retrosternal position, and double vascular supercharge of the right colic artery and vein to the fourth vascular arcade of the JI (green background).

balance, ensuring adequate perfusion to the flap, and preventing constriction from generalized edema. A gastroenterologist plays a key role in the postoperative assessment of the flap through routine endoscopy and any necessary dilatations. The nursing team is critical in managing these complex patients at every step of their care.

The present study is limited by its small sample size and tertiary center referral bias. Furthermore, although each patient in the series demonstrated improved esophageal function for a minimum of 2 years, a longer follow-up time is required to assess the longevity of repair. The goal is to achieve lasting ability to meet caloric needs through an exclusively oral route. Ultimately, this form of reconstruction will require decades of follow-up with respect to feeding, patient reported quality of life, endoscopy, swallow studies, and potential late flap complications.

CONCLUSIONS

Double supercharged JI may be performed as a salvage operation to restore esophageal continuity after CI or GPU failure for LGEA. Although technically difficult, this operation takes advantage of the anatomy of previous reconstruction attempts to provide jejunal flaps with a robust blood supply. This technique should be considered in children with failed CI or GPU, particularly when esophageal defects are large and alternative reconstructive options are otherwise limited. In cases where JI is planned after CI/GPU failure, it may be advantageous to preserve the vascular pedicles of the former conduits to retain the option of a double supercharged flap as a potential reconstructive option.

REFERENCES

1. Gallo G, Zwaveling S, Groen H, et al. Long-gap esophageal atresia: a meta-analysis of jejunal interposition, colon interposition, and gastric pull-up. *Eur J Pediatr Surg*. 2012;22:420–425.
2. Ahmad SA, Sylvester KG, Hebra A, et al. Esophageal replacement using the colon: is it a good choice? *J Pediatr Surg*. 1996;31:1026–1030.
3. Coopman S, Michaud L, Halna-Tamine M, et al. Long-term outcome of colon interposition after esophagectomy in children. *J Pediatr Gastroenterol Nutr*. 2008;47:458–462.
4. Spitz L, Kiely E, Pierro A. Gastric transposition in children—a 21-year experience. *J Pediatr Surg*. 2004;39:276–281.
5. Saeki M, Tsuchida Y, Ogata T, et al. Long-term results of jejunal replacement of the esophagus. *J Pediatr Surg*. 1988;23:483–489.
6. Ascioti A, Hofstetter W, Miller M, et al. Long-segment, supercharged, pedicled jejunal flap for total esophageal reconstruction. *J Thorac Cardiovasc Surg*. 2005;130:1391–1398.
7. Bairdain S, Foker JE, Smithers CJ, et al. Jejunal interposition after failed esophageal atresia repair. *J Am Coll Surg*. 2016;222:1001–1008.
8. Blackmon SH, Correa AM, Skoracki R, et al. Supercharged pedicled jejunal interposition for esophageal replacement: a 10-year experience. *Ann Thorac Surg*. 2012;94:1104–1111.
9. Cusick E, Batchelor A, Spicer R. Development of a technique for jejunal interposition in long-gap esophageal atresia. *J Pediatr Surg*. 1993;28:990–994.
10. Poh M, Selber JC, Skoracki R, et al. Technical challenges of total esophageal reconstruction using a supercharged jejunal flap. *Ann Surg*. 2011;253:1122–1129.
11. Barzin A, Norton JA, Whyte R, et al. Supercharged jejunum flap for total esophageal reconstruction: single-surgeon 3-year experience and outcomes analysis. *Plast Reconstr Surg*. 2011;127:173–180.
12. Chana JS, Chen HC, Sharma R, et al. Microsurgical reconstruction of the esophagus using supercharged pedicled jejunum flaps: special indications and pitfalls. *Plast Reconstr Surg*. 2002;110:742–748.
13. Numajiru T, Sowa Y, Nishino K, et al. Double arterialized free jejunal flap. *J Reconstr Microsurg*. 2010;26:165–170.
14. Takushima A, Momosawa A, Asato H, et al. Double vascular pedicled free jejunum transfer for total esophageal reconstruction. *J Reconstr Microsurg*. 2005;21:5–10.
15. Centers for Disease Control and Prevention. BMI Percentile Calculator for Child and Teen. Available at: https://nccd.cdc.gov/dnpabmi/Calculator.aspx. Accessed August 26, 2017.
16. Foker J, Linden BC, Boyle EM Jr, et al. Development of a true primary repair for the full spectrum of esophageal atresia. *Ann Surg*. 1997;226:533–541.
17. Bax KM. Jejunum for bridging long-gap esophageal atresia. *Semin Pediatr Surg*. 2009;18:34–39.
18. Cauchi JA, Buick RG, Gornall P, et al. Oesophageal substitution with free and pedicled jejunum: short- and long-term outcomes. *Pediatr Surg Int*. 2007;23:11–19.
19. Jeays AD, Lawford PV, Gillott R, et al. A framework for the modeling of gut blood flow regulation and postprandial hyperaemia. *World J Gastroenterol*. 2007;13:1393–1398.