The Benefits of the Supercharged Ileocolic Flap in Patients Who Underwent Total Esophagectomy and Gastrectomy

Filippo Marchi, MD[1,2,3] Shih Ching Kang, MD[4] David Chon Fok Cheong, MD[2] Shao Yu Hung, MD[2] Szu Han Wang, MD[2] Ting Han Chiu, MD[2] Yu Ting Chen, MD[2] Chung Kan Tsao, MD[2,5]

[1] Department of Plastic and Reconstructive Surgery, Chang Gung Memorial Hospital, Chang Gung Medical College, Chang Gung University, Taipei, Taiwan
[2] Department of Plastic and Reconstructive Surgery, Chang Gung University, Chang Gung Memorial Hospital, Chang Gung Medical College, Taipei, Taiwan
[3] Department of Otorhinolaryngology, IRCCS Ospedale Policlinico San Martino, University of Genoa, Genoa, Italy
[4] Department of Trauma and Emergency Surgery, Chang Gung University, Chang Gung Memorial Hospital, Chang Gung Medical College, Taipei, Taiwan
[5] Center for Tissue Engineering, Chang Gung Memorial Hospital, Taoyuan, Taiwan

Address for correspondence Chung Kan Tsao, MD, Department of Plastic Surgery, Chang Gung Memorial Hospital, 5 Fu-Hsing Street, Kuei-Shan, Gueishan, Taoyuan 333, Taiwan (e-mail: nightman251@hotmail.com).

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Abstract

Background Patients who undergo total esophagectomy and gastrectomy present a challenging scenario for reconstructive surgeons. Several techniques have been described. However, the best choice is still a matter of debate. We aim to report our experience with the supercharged ileocolic flap, then to compare the long-term functional outcomes in cancer and caustic injury patients. We investigate the safest route of transposition and demonstrate the importance of supercharging the flap. Last, we perform a literature review to compare our results with the ones reported in the literature.

Methods A total of 36 patients underwent the supercharged ileocolic flap procedure. The details reviewed included the type of defect, flap characteristic, route of transposition, complications, patient survival, and swallowing evaluation. Survival and long-term function preservation were considered as the main outcomes. A secondary end-point was the identification of the safest route of transposition. We extracted the pertinent literature on supercharged bowel flaps from 1995 to July 2020

Keywords
- ileocolic flap
- esophageal reconstruction
- corrosive caustic injury

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Results All flaps survived; only two flaps were partially lost. Thirty-three percent of the cohort experienced postoperative complications; the most common was leakage of the cervical anastomosis (17%), followed by neck wound infection (8%). The 5-year dysphagia-free survival rate was 87% in corrosive injury patients and 78% in cancer patients. The mean time to be free from dysphagia after surgery was 25.12 ± 4.55 months for corrosive patients and 39.56 ± 9.45 months for cancer patients ($p = 0.118$). The safest route of transposition was retrosternal extra-mediastinal. From the literature review, the data from 11 studies were extracted.

Conclusion The supercharged ileocolic flap is a robust option for total esophageal replacement when the stomach is not available and the retrosternal route is the safest for transposition. The functional outcomes are excellent, with acceptable morbidity and a good life expectancy, either in cancer and noncancer patients. Supercharging the flap is recommended.

In patients with an intact stomach who are diagnosed with esophageal cancer, gastric pull-up is always the preferred technique for reconstruction after esophagectomy. However, in cases of extensive gastroesophageal junction cancer with aboral spread and after previous gastric surgery, alternative methods for reconstruction are required.[1]

Over the last three decades, several techniques and flap design variations have been described. However, the best choice is still a matter of debate.[2] The supercharged jejunal flap gained popularity approximately 20 years ago; this procedure can be successfully performed as an alternative reconstruction when the stomach is unavailable and is associated with good long-term functionality and acceptable morbidity.[3]

Most of the available English literature report nonhomogeneous series in terms of the type of flap harvested, the vascular supply, and the transposition route. Each technique has its advantages and drawbacks.[1,4,5]

For total esophageal reconstruction, the right colon seems to be more favorable for several reasons, including the possibility to harvest a longer part of the ileum, which can increase the length and improve the size match. The problem of the poor and unpredictable blood supply of the ileum-cecum segment can be overcome by creating a hybrid flap and harvesting a supercharged flap 3. Supercharge the flap means to perform a set of microanastomosis of an auxiliary vascular pedicle.

We aim to report our institution's experience with total esophageal reconstruction with a supercharged ileocolic flap (SICF). We investigate the functional outcomes in cancer and noncancer patients and identify the factors affecting the complications rate. Furthermore, we performed a literature review to compare our results with the studies published in the past 25 years.

Methods

A retrospective review was performed from November 2004 to August 2019 at Chang Gung Memorial Hospital, Taipei, Taiwan, at the Department of Plastic and Reconstructive Microsurgery. The inclusion criteria were complete esophageal defect, concomitant or previous gastrectomy or previous gastric pull-up, and at least 6 months of follow-up. The exclusion criterion was any different flap used apart from the right SICF. A total of 36 patients were enrolled in the present study.

All patients underwent preoperative chest and abdominal computed tomography (CT) or magnetic resonance (MR), and an upper gastrointestinal (GI) endoscopic biopsy was performed in case of suspected malignancy. In cancer patients, the indications for neoadjuvant and adjuvant therapies were discussed by the multidisciplinary board and proposed following the NCCN Guidelines.[6]

Information on conduit function was collected at least 6 months after reconstruction with a dynamic esophageal video fluoroscopy to allow patients to recover from the procedure and adjust to their new anatomy. Patients were interviewed, clinically evaluated every 3 months during the first and the second year, every 4 months during the third and fourth year, every 6 months from the fifth year; they underwent total-body CT as cancer follow-up and to assess the status of the reconstructed tract and every 6 months.

Patients were categorized as "no evidence of disease" (NED) if they were alive at the last follow-up and did not have signs of the disease for which they had been treated, "dead from disease" (DOD) in the case of disease-related death, and "dead from other causes" (DOC) when a patient died for any other reason. Follow-up time was calculated from the patient's discharge until the last consultation.

No ethical committee's approval was deemed necessary at our institution after a formal request to the appropriate parties. Every patient signed informed consent for the treatment of personal data for scientific purposes.

Surgical Technique

The surgical team was composed of GI surgeons and plastic surgeons. In the case of concomitant esophagectomy, the thoracic surgeons were involved. The cervical approach

along the esophagostomy scar is of crucial importance to evaluate the caliber of the residual cervical esophagus and to rule out possible stricture or scar. The sizable esophageal stump was prepared, and the length of the defect was measured. The recipient vessels were dissected. The abdominal approach along the previous laparotomy scar should overcome intraabdominal bowel adhesion. The right colon was freed from the retroperitoneum, and the mesocolon was transilluminated to clear the vascular anatomy. The last branch of the ileum was identified; the ileocolic, right colic, and middle colic vessels were dissected to the level of the superior mesenteric artery and vein. We injected the indocyanine green fluorescent (IGF) five times. First, once all the vessels supplying the bowel were identified. We decided to inject at this time to demonstrate better the contribution that the ileocolic pedicle gives to the ileocecal tract of the bowel and to evaluate more clearly any possible vascular anomalies of the right colic, the middle colic, and the marginal arteries system. In such cases, the baseline IGF injection helps us to understand where to put the vascular clamps.

The goal of this procedure was to investigate the perfusion of the colon with a Spy camera; thus, we clamped the ileocolic vessel and right colic vessel and injected one-fourth of a vial of IGF (second injection), leaving the flap to be perfused by the middle colic vessel; at this moment, the proximal part of the colon and the ileum showed mild perfusion through the marginal vessels (►**Fig. 1**). Then, we released the clamp to mimic the condition after supercharge and injected one-fourth of the vial of IGF (third injection). After a few seconds, the entire colon showed significantly better perfusion (►**Fig. 2**).

If the perfusion was adequate (based on the middle colic artery and the ileocolic artery), the ileocolic pedicle was divided at the root of the mesentery to optimize the length. During this surgical step, we considered the IGF as an adjunctive tool that might help us to confirm our clinical assessment, not a replacement. To address adequate perfusion, we relied on three criteria: peristalsis, vessel pulsation, and flap color. When a tract of the colon is less perfused, the peristalsis becomes absent almost immediately, when the perfusion is reestablished, the peristalsis improves very quickly. The vascular changes of bowel's perfusion are quite sudden; once a tract is ischemic, typical signs are visible almost immediately. According to the length needed, the right colic pedicle or small branch of the middle colic pedicle was ligated and separated (►**Fig. 3**). The mesentery was divided up to the vessels preserved as a pedicle. The terminal ileum was transected; an appendectomy was performed and the ileocecal trunk was divided. Afterward, the isoperistaltic flap was rotated clockwise, then passed through a tunnel in the neck with a substernal route (in some cases

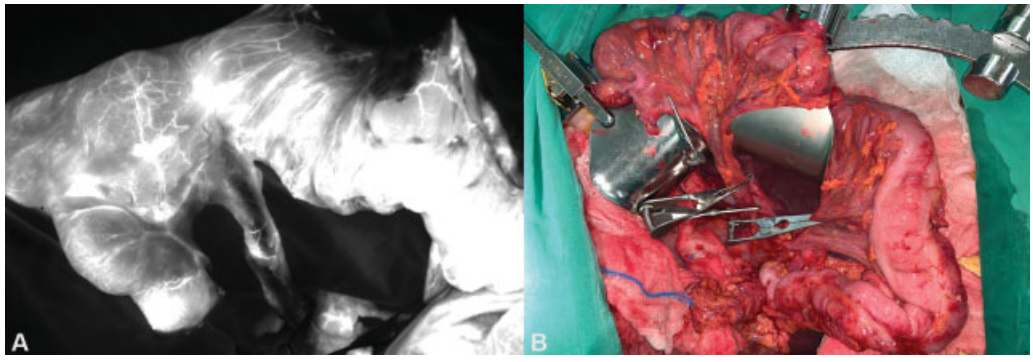

Fig. 1 The right colon and the ileal tract are isolated. Indocyanine green fuorescent injection under spy camera (**A**) and the surgical field (**B**) showing poor perfusion of the proximal right colon while the ileocolic and the right colic vessels are clamped. The ileocolic tract in only perfused by the middle colic vessels.

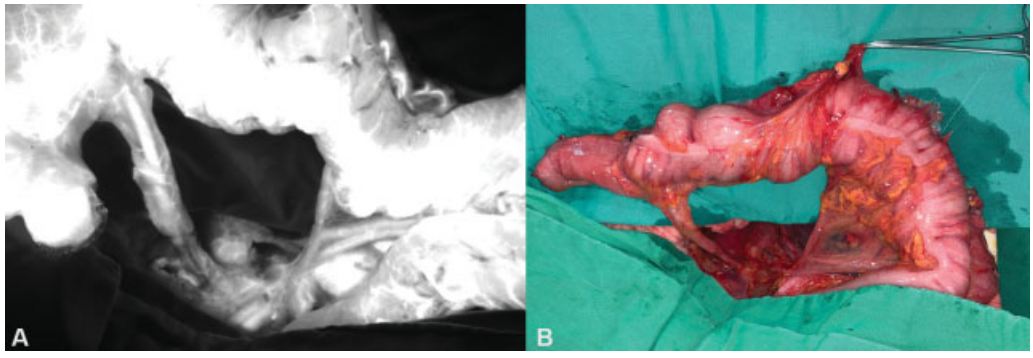

Fig. 2 Indocyanine green fluorescent injection under spy camera (**A**) and the surgical field (**B**) showing better perfusion of proximal right colon through the ileocolic artery once the entire flap is perfused by the ileocolic and right colic vessels.

Fig. 3 Transposition in the neck of the supercharged ileocolic flap, based on the right colic artery and on the ileocolic pedicle (transected).

subcutaneous or transmediastinal). The transverse colon was transected for GI reconstruction. The short segment over the previous jejunostomy site was resected. Roux-en-Y reconstruction, including side-to-side colojejunostomy, end-to-side jejunojejunostomy, and side-to-side ileo-T-colostomy, was performed with a GIA 75–3.5 staplers. A Jackson-Pratt tube was placed in the abdomen, and a new feeding jejunostomy was placed distal to the jejunojejunostomy. When the flap was passed through the substernal route to the neck, one-fourth of the vial of IGF was injected (fourth injection). The sternoclavicular joint was never resected. We injected again after mobilizing the flap to assess if the transposition affected the perfusion. The pedicle might sometimes be accidentally twisted or the flap compressed in the tunnel, two scenarios that are not always easy to detect. The perfusion was assessed, checking the component of the flap that reaches the neck area, out of the sternum. Again, the proximal part of the colon and ileum showed modest perfusion and weak peristalsis (►**Fig. 4A**). Then, the microvascular anastomosis between the ileocolic pedicle and recipient vessels in the neck was accomplished, and a one-fourth of the vial of IGF was injected again (fifth injection). Finally, the flap showed vivid fluorescence, signs of improved perfusion, and vigorous peristalsis (►**Fig. 4B**). The venous backflow through the anastomosis was shown as well (►**Fig. 4C**). Blood flow in the pedicle was documented with a qualitative Doppler signal. Hence, the inset of the flap was done suturing the ileum to the proximal stump of the digestive tract available (hypopharynx or proximal esophagus). One nasogastric tube was placed to reach the distal part of the flap and another one at the level of the anastomotic line between the esophagus and the flap to avoid stricture. Every wound was sutured in a multilayer fashion. A small window ~1 × 1 cm was left open to monitor ileal perfusion.

Literature Review

A review of the studies published from 1995 to August 2020 was performed. Inclusion criteria were patients who underwent esophagectomy ± concomitant or previous gastrectomy; reconstruction performed with right colon/left colon/ileocolon/jejunum supercharge grafts; more than 10 patients enrolled; reported at least two of the following outcomes: graft loss, leakage, dysphagia, reflux, and stricture.

Statistical Analysis

Patient demographics (age, sex, smoking habits, site, comorbidities, length of hospitalization, complications, operative

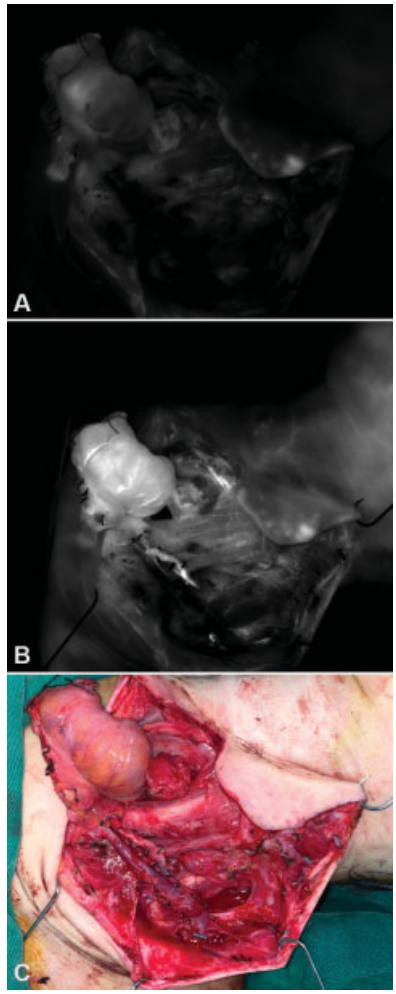

Fig. 4 Indocyanine green fluorescent injection under spy camera before (**A**) and after (**B**) the microanastomosis of the ileocolic vessels; the surgical field (**C**) showing the flap rerouted to the neck when the flap is supercharged by the transverse cervical artery, with robust perfusion of the ileocolic tract and venous backflow.

and ischemia time, survival status, and residual function) were displayed as frequency counts and percentages.

We considered the following survival endpoint: overall survival, which was the date of death from any cause or the date of the last consultation for patients alive at the end of the study (censored observations). Fisher's exact test or one-way analysis of variance test was performed on the descriptive variables (comorbidities, type of previous surgery, exposure to radiation, cause of the defect and conduit location), and the Mann–Whitney *U*-test was performed on the continuous variable (operative time); *p*-value less than 0.05 was defined statistically significant. The variables tested regardless of different outcomes were postoperative complications, stricture, death, and dysphagia. Postoperative complications included leakage, fistula, pneumonia, bleeding, and pneumothorax. Dysphagia was defined according to the type of oral intake that the patient could tolerate.

Five-year dysphagia-free survival (DFS) curves were estimated using the cumulative incidence function IBM SPSS Statistics for Windows, Version 22.0. (IBM Corp., Armonk, NY Released 2013), to estimate the cumulative probability (cum. probability) that a patient is free of tracheostomy, jejunostomy, or nasogastric feeding over the time (months).

Results

From November 2004 to August 2019, 36 patients (22 males and 14 females, mean age 47 years, range 4–74) were reconstructed with 36 right SICFs by the same reconstructive microsurgeon. Twelve patients were free of comorbidities. In the remaining cohort, the most frequent comorbidities were major depression (11 patients), hypertension (5 patients), diabetes mellitus (3 patients), and atrial fibrillation (2 patients).

The reconstructions were performed for esophageal cancer in 9 patients (25%) and for corrosive injuries in 27 (75%) patients. Patients' clinical demographical characteristics are shown in ►**Table 1**.

Table 1 Demographic and preoperative data

Patients characteristics and preoperative data		
Variable		***n* (%)**
All		36 (100)
Age (mean)		46.7
Sex	Male	22 (61)
	Female	14 (39)
Smoking	Yes	11 (30)
	No	25 (70)
Alcohol	Yes	10 (28)
	No	26 (72)
Comorbidities	Yes	25 (69)
	No	11 (31)
Indication	Caustic injury	27 (75)
	Cancer ablation	9 (25)
Timing	Primary	2 (5)
	Delayed	34 (95)
Preoperative CCRT	Yes	5 (14)
	No	31 (86)
Previous gastric procedure	Gastric pull-up	9 (25)
	Gastrectomy	27 (75)

Abbreviation: CCRT, concurrent chemoradiotherapy.

Surgical Outcomes

All 36 flaps survived, and only 2 flaps were partially lost. The entire cohort received the reconstruction as a second stage procedure: 9 patients had an esophageal squamous cell carcinoma (SCC) treated with a total esophagectomy and reconstructed with a gastric pull-up (4 lost the gastric conduit, 4 experienced cancer recurrence). The average time between the ablative surgery and the reconstruction was 13 months (range: 1–40 months).

Five cancer patients underwent preoperative concurrent chemoradiotherapy or radiation alone, and four of them received adjuvant radiation as well.

The remaining 27 patients underwent an esophagectomy combined with a gastrectomy due to corrosive injury. The average length of the flap was 30 cm (range: 22–40 cm). The proximal anastomosis of the conduit was done at the level of the hypopharynx in two patients and at the cervical esophagus in the remaining 34 patients; all the conduit's anastomoses were done in the neck. All the flaps were pedicled on the middle colic artery; to supercharge the flap in the neck, either the ileocolic vessels or the terminal ileal vessels have always been used when a longer pedicle was needed.

The transverse cervical artery was used as the recipient in 29 patients, the superior thyroid artery in four patients, the internal mammary artery in two patients, and the external carotid artery in one patient. The external jugular vein was used in 33 subjects, followed by a branch of the internal jugular vein in two subjects and the internal mammary vein in one subject.

All conduits appeared well vascularized after clamp removal. Furthermore, the prompt return of peristalsis after clamp removal was demonstrated. Of the four recent patients who underwent indocyanine green perfusion evaluation before and after clamp removal, all of them demonstrated significantly improved blood flow in the flap.

The mean operative time was 547 minutes (range: 412–792), the mean ischemia time was 68 minutes (range: 45–93), and the average length of hospitalization was 34 days (range: 18–109).

A total of 33% of the cohort experienced postoperative complications; the most common was leakage of the cervical anastomosis (17%), followed by neck wound infection (8%), leakage from the ileo-T-colostomy (5%), and massive bleeding in one patient. All complications required surgical exploration apart from two leaks that were treated conservatively.

Medical complications related to the procedure, including pleural effusion drained with a pigtail catheter (8%),

Table 2 Operative data

Patient operative data		
Variable		***n* (%)**
Recipient artery	TCA	29 (80)
	STA	4 (11)
	IMA	2 (6)
	ECA	1 (3)
Recipient vein	EJV	33 (91)
	IGV	2 (6)
	IMV	1 (3)
Pathway	Subcutaneous	5 (14)
	Substernal extramediastinal	27 (75)
	Mediastinal	4 (11)
Proximal connection	Hypopharynx	2 (6)
	Esophagus	34 (94)
Length (mean, range)	30 cm (22–40)	
Operative time (mean, range)	547 min (412–792)	
Ischemia time (mean, range)	68 min (45–93)	
Hospitalization (mean, range)	34 d (18–109)	

Abbreviations: ECA, external carotid artery; IJV, internal jugular vein; IMA, internal mammary artery; IMV, internal jugular vein; STA. superior thyroid artery; TCA, transverse cervical artery.

pneumothorax (6%) and aspiration pneumonia (8%), occurred in 22% of the patients. Among the former, one patient treated for esophageal SCC expired, resulting in a 1-month postoperative survival rate of 97%. The operative data are listed in ►**Table 2**.

There were no statistically significant differences regarding the presence of comorbidities (either physical or psychiatric), the causes of treatment, the type of previous surgery, the operative time, and the analyzed outcomes. The different routes of conduit location turned out to be statistically significant when analyzed with different outcomes. The conduit location was the factor most affecting the outcomes. In particular, comparing different routes, the subcutaneous was associated with a higher incidence of stricture ($p = 0.03$), postoperative complications ($p = 0.02$), and dysphagia ($p = 0.01$); while the substernal extramediastinal appeared to be safest. Radiation therapy was statistically significantly associated with increased deaths ($p = 0.01$); this result might be explained because patients received radiation due to esophageal cancer (►**Table 3**).

Follow-Up

There were 35 patients available for the follow-up. The average follow-up time was 30 months (range: 6–98, median 24).

Six months after surgery, 25 (71%) patients tolerated a regular diet, 8 (23%) patients tolerated a soft diet, and 2 (6%) were still under jejunostomy or nasogastric feeding.

Esophageal stricture was the most common late-onset complication in seven patients and was managed with endoscopic procedures and revision surgery in two cases. Esophageal reflux was detected in only one subject. In the remaining cohort, video fluoroscopic swallowing exams showed undisturbed peristalsis.

The overall survival for the entire cohort was 78%. At the last follow-up, 28 patients were NED, 5 were DOD, and 3 were DOC. Applying the cumulative incidence function, the five-year estimated DFS for the entire cohort was 85% (►**Fig. 5**, cum. probability: cumulative probability), 87% in corrosive injury patients, and 78% in cancer patients (►**Fig. 6**). The mean time for the entire cohort, which was free from dysphagia after surgery, was 28.94 ± 4.25 months, 25.12 ± 4.55 months for corrosive patients, and 39.56 ± 9.45 months for cancer patients ($p = 0.118$).

Follow-up data are reported in ►**Table 4**. No statistically significant differences were found analyzing the presence of physical comorbidities, causes of treatment, type of previous surgery, and operative time concerning survival (►**Table 3**).

Literature Review

Eleven studies, published from 1997 to 2014, met the inclusion criteria for a total of 354 patients. A supercharge jejunum graft was utilized in 191 patients, while in the remaining 163 patients a combination of other supercharge grafts (right colon, ileocolon, left colon, and jejunum) was used. In four studies (166 patients), defect was more heterogeneous including isolated esophageal and gastric resections; in the remaining cohort all the patients received esophagectomy and previous/concomitant gastrectomy. The functional outcomes were reported in 10 studies: reflux, stricture, and dysphagia rates ranged from 5 to 19.2%, from 0 to 21%, and from 10 to 38.5%, respectively. The leakage ranged from 7 to 36%, while graft loss ranged from 0 to 7.6%. The results of the review are listed in ►**Table 5**.

Discussion

Our study brings some interesting results. Comparing cancer patients with noncancer patients, we demonstrated that an adequate restoration of function is achieved in both cohorts, regardless of the treatment reason and the need for radiotherapy. After such an extensive procedure that is physically and psychologically challenging for patients, full functional recovery needs to be our primary goal. Several papers addressed this topic, however, often merging different defects extent and flaps design. Few of them stand out for homogeneity regarding the selection of the sample. Fujita et al, more than 20 years ago, compared patients who underwent esophagectomy, reconstructed with a colon flap: 29 of them with a supercharged colon flap, 24 without supercharge. The incidence of leakage after colon interposition without supercharge was calculated to be almost 34 times higher that after colon interposition with supercharge[7] the flap loss rate decreased as well; however, others long-term functional outcomes were barely assessed. The elegant work of Hamai et al reported a homogeneous series using the SICF in patients with the same defect that was reconstructed with the same flap.[8] However, our findings are more specific

Table 3 Analysis between clinical and surgical variables, complications, and deaths

		Outcomes											
		Stricture			Complications			Death			Dysphagia			
		Yes	No	*p*-Value	Yes	No	*p*-Value	Yes	No	*p*-Value	No	Solid	Liquid	*p*-Value
		6	30		16	20		8	28		25	9	2	
Comorbidities														
	Physical	5	20	0.64	11	14	1.00	7	18	0.38	17	7	1	0.71
	Psychiatric	4	12	0.37	5	11	0.19	3	13	0.70	10	5	1	0.72
Radiation therapy		1	8	1.00	6	3	0.14	5	4	0.01	6	3	0	0.81
Previous surgery				0.30			0.47			0.08				0.10
	ES + GS	6	22		11	16		4	24		18	7	2	
	ES + GPU	0	8		5	3		4	4		7	2	0	
Defect cause				0.30			0.10			0.38				0.10
	Corrosive	6	21		12	15		5	22		18	7	2	
	Cancer	0	9		4	5		3	6		7	2	0	
Conduit location				0.03			0.02			0.54				0.01
	Subcutaneous	2	3		3	2		2	3		1	2	2	
	Substernal	2	25		9	18		5	22		21	5	0	
	Mediastinal	2	2		4	0		1	3		3	1	0	
Operative time (mins)		582 ± 143	540 ± 121	0.52[a]	547 ± 124	546 ± 127	0.96[a]	606 ± 114	530 ± 123	0.15[a]	532 + 116	563 ± 136	663 ± 182	0.33[a]
Length of the flap (cm)		–	–	–	29.63 ± 6	30.75 ± 5	0.50	27.88 ± 5	30.93 ± 5	0.09	–	–	–	–

Abbreviations: ES, esophagectomy; GPU, gastric pull-up; GS, gastrectomy.
[a]Mann–Whitney *U*-test was performed.

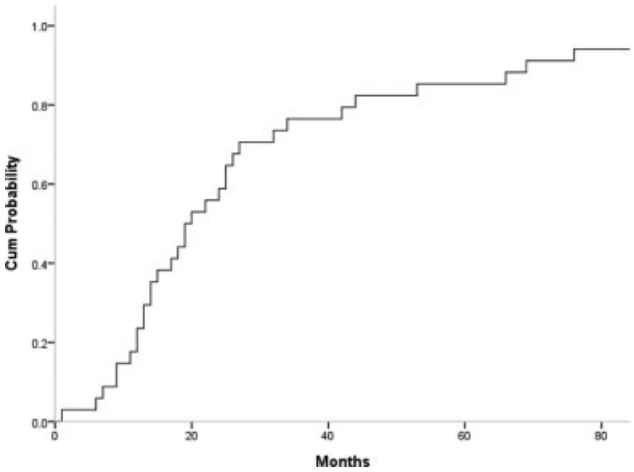

Fig. 5 Cumulative incidence function curve of patients free from dysphagia after surgery (entire cohort).

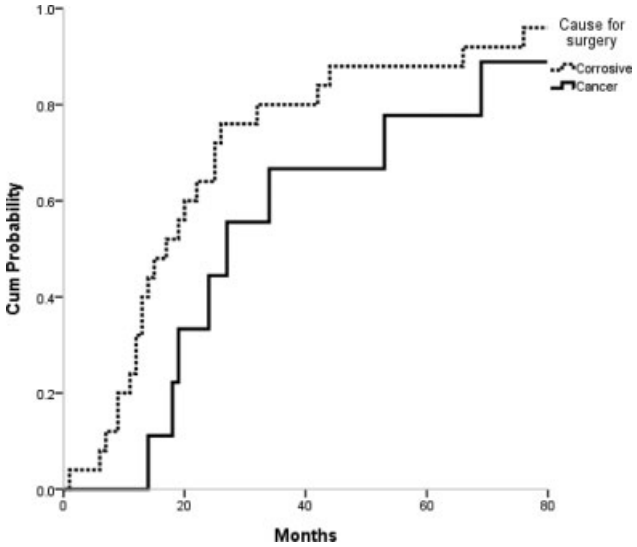

Fig. 6 Cumulative incidence function curve of patients free from dysphagia after surgery (continuous line: esophageal cancer; dotted line: corrosive injury).

and detailed; in particular, we performed an evaluation of the functional outcome in the whole cohort, which demonstrated the benefit of supercharging in terms of flap perfusion.

When the stomach was not available or indicated, the right colon was selected as the first choice due to its advantages, such as orthodromic peristalsis, reservoir capacity of the cecum and when the ileum is included, the presence of the Bauhin valve that prevents regurgitation.

Table 4 Follow-up data

Patient outcomes		
Variable		***n* (%)**
Postoperative complications	Medical	8 (22%)
	Surgical	11 (35%)
Flap loss		2 (5%)
	Partial	2 (5%)
	Total	0 (0%)
Adjuvant treatment	Yes	5 (14%)
	No	31 (86%)
Late stricture	Yes	6 (17%)
	No	0 (0%)
Dysphagia	No	25 (69%)
	Solid	9 (25%)
	Liquid	2 (6%)
Reflux	No	35 (97%)
	Yes	1 (3%)
Status	NED	28 (78%)
	DOD	5 (14%)
	DOC	3 (8%)

Abbreviations: NED, no evidence of disease; DOC, dead from the other causes; DOD, dead from disease.

Furthermore, given that a pedicled flap retains the mesenteric parasympathetic nervous plexus, the peristaltic movements are preserved.[9] However, it has a few drawbacks, such as high variation in blood vessels and larger diameter than the esophagus[2]; moreover, it may encounter a higher rate of anastomotic leakage.[10] Thus, we decided to include different components in the flap that might overcome these issues, preserving its advantages. In our opinion, there are multiple benefits of our flap design. First, the inclusion of an ileal tract provides a better caliber match between the residual conduit and the flap itself, helping to fight reflux and regurgitation. This hypothesis is supported by the lowest rate, ever reported in the literature, of reflux in the present study (3%). Then, using intraoperative IGF, we demonstrated the different patterns of perfusion according to which vessel was selected. Through IGF injection, we aimed to demonstrate the improvement in perfusion, not to quantify it. It has been shown in the literature that the blood supply of the proximal part of the right colon and the distal ileum might not be adequate when the flap is only pedicled on the right or middle colic vessels. We supercharged every flap to demonstrate an improved blood supply in the most critical part of the reconstruction, where the esophageal anastomosis is located.[2] Possibly, for this reason, we encountered a low rate of partial flap failure (5%), without complete flap loss. It was previously demonstrated that supercharging the jejunal flap improves the blood supply and survival; the authors showed that performing an arterial and venous anastomosis had a definite effect on the results of blood gas analysis in most patients.[11] A relevant problem that might be encountered is an anastomotic leakage, which often leads to a cutaneous fistula. Various factors are usually implicated in an anastomotic leakage, including blood supply, physical tension, and radiotherapy. Doki et al showed that the colon has a higher percentage of anastomotic leakage compared with the jejunum (46 vs. 24%).[12] Ascioti et al described a leakage rate of 27%.[4] We encountered a leakage rate of 17%,

Table 5 Review of the past 25 years literature of supercharged bowel grafts for esophageal reconstruction (included only studies with more than 10 patients)

Study	No.	Defect	Reconstruction	Functional outcomes			Surgical outcomes		Comments
				Reflux	Dysphagia	Stricture	Leakage	Graft loss	
Fujita et al 1997[7]	29	H	Left colon Right colon	–	–	7%	7%	0%	Demonstration of the advantages of supercharge Lacking long-term functional results
Ascioti et al 2005[4]	26	H	Jejunum	5%	38%	4.8%	26.9%	7.6%	Not clear inclusion criteria Different defects merged together Short follow-up evaluation
Ueda et al 2007[11]	27	E + G	Jejunum	–	–	11%	11%	0%	Reported improvements in blood gas analysis after supercharging the graft Missing functional outcomes
Doki et al 2008[12]	53	E + G	Jejunum Ileocolon	–	–	–	35.8%	0%	Missing postoperative radiation data Lacking functional outcomes
Poh et al 2011[3]	51	H	Jejunum	–	10%	10%	26%	5.9%	Different defects merged together Detailed post-operative complications
Blackmon et al 2012[14]	60	H	Jejunum	–	17%	–	32%	7%	Different defects merged together Detailed surgical outcomes
Iwata et al 2012[17]	27	E + G	Jejunum	–	–	7%	7.4%	0%	Comprehensive demographics and surgical outcomes No functional outcomes
Hamai et al 2012[8]	40	E + G	Ileocolon	19.2%	38.5%	7.5%	17.5%	5%	Detailed surgical outcomes Detailed functional outcomes Defined inclusion criteria
Chana et al 2002[18]	11	E + G	Ileocolon Jejunum	18%	36.3	18%	36%	–0%	Small cohort Heterogeneous reconstructive methods
Kesler et al 2013[13]	11	E + G	Ileocolon Left colon	–	27%	0%	9%	0%	Small cohort Heterogeneous reconstructive methods
Ninomiya et al 2014[10]	19	E + G	Colon Jejunum	–	–	21%	15.8%	0%	Lacking functional outcomes Heterogeneous cohort
Current study	36	E + G	Ileocolon	3%	6%	17%	17%	0%	

Abbreviations: E, esophagectomy; G, gastrectomy; H, heterogeneous; N, number of patients.

an average result compared with the literature. Our choice to include a piece of the small bowel is even more supported not only by a better size match but also by an acceptable rate of stricture (17%). In fact, from the review emerged that the colon graft tends to increase the risk of stricture, while the jejunum has a lower stricture incidence. Furthermore, we hypothesized that supercharging the flap improves the blood supply in the ileocolic junction and at the level of the upper anastomosis, ensuring adequate healing that otherwise increases the risk of dehiscence and fistula. Moreover, supercharging the graft seems to facilitate spontaneous and more rapid healing.[7]

In different series, the incidence of partial or total colon loss was ~7%,[13,14] reaching up to 17%.[15] We experienced a 3% rate of flap loss. Considering the complexity of the procedure, in our minds, this may be considered a remarkable result, achieved by few authors as well.

Several papers reported a considerably higher complication rate. Those results might be partially explained by the heterogeneity of the patients and flap selection and by missing some important technical aspects, such as supercharging the flap, including a tract of ileum and using an isoperistaltic graft. Our ideas are supported by the results of our analysis. In fact, we did not encounter any differences, regardless of dysphagia rate, meaning that an isoperistaltic flap is appropriate.

Few authors have properly described any functional outcomes. Blackmon et al reported that 17% of their patients were dependent on feeding tubes, while only 6% of our population was not able to have any oral intake.[14] Adequate functional evaluation, done through a combination of clinical and radiological assessments, is not commonly reported in the literature. Only 6% of our patients suffered from dysphagia. To date only Poh et al[3] described a dysphagia rate as low as 10%.

A study from Japan advocated the need to investigate which is the best route of reconstruction.[8] Our study poses an answer to this doubt. As shown in ►**Table 4**, the subcutaneous and mediastinal routes are associated with worse surgical outcomes. The only paper that investigated the outcome of a cohort similar to ours reported a rate of leakage of 17%, which is in line with our results, but the authors experienced a greater rate of digestive complications (38% of dysphagia and 19% of reflux). We reported an overall dysphagia rate of 31% and reflux rate of 3%. We preferred the substernal route instead of the posterior mediastinal route as it's advocated by the Japanese group. An Indian study explored the results of the subcutaneous route, and the authors reported higher rates of fistula (18%) (even if there was a higher percentage of primary cases) and uncompleted follow-up information compared with the current study.[16]

From our analysis, the safest route to transpose the flap was the retrosternal extrathoracic, and if we extrapolate only this subgroup, the results are remarkable: 100% full oral intake, 100% flap survival, and 7% stricture. The retrosternal route, when compared with the subcutaneous route, requires a shorter flap and a pedicle length of ~5 cm; furthermore, less food accumulation occurs above the suprasternal notch. Finally, in the case of infection, it is safer to manage when compared with the mediastinal route. From now on, we will suggest and adopt this route as the first choice in such patients.

We used the IGF not to compare or quantify any improvement. We aimed for a method that can show the contribution in perfusion given by microanastomosis, simultaneously helping us to detect ischemic changes promptly. However, we suggest that the ICG has to be considered as an additional tool, not as a replacement for the intraoperative clinical assessment.

The review sheds light on this complex topic while demonstrating that our results are remarkable. Even if the short/medium-term surgical outcomes are comparable to those reported for supercharged bowel grafts, our functional outcomes (dysphagia and reflux) are the most promising.

Our study identified a few factors that can correlate with complications and may lead to improved results in esophageal reconstruction. We think one exciting finding regards the 5 years DFS, which was previously never reported in the literature and gives an idea of the functional outcomes on the long run. However, we do recognize several limitations, the first, being the retrospective nature. Moreover, we compared only certain clinical and surgical features with complications that were available and can be reproducible along 15 years of follow-up. Lastly, due to the sample size, and the number of variables that might interfere, we were not able to derive a multivariate analysis to support our hypothesis. Comparing two homogeneous cohorts of gastrectomized patients that underwent esophageal reconstruction with and without supercharging the ileocolic the flap could be ideal.

Conclusion

The SICF is a safe option for total esophageal replacement when the stomach is not available. Despite being a technically demanding procedure, the functional outcomes are excellent, with acceptable morbidity and a reasonable life expectancy. Either cancer patients and noncancer patients benefit from the functional restoration that this flap provides. The retrosternal route seems to be the most reliable. The IGF is an adjunctive tool to demonstrate that supercharging the flap might be beneficial in the most critical area of the flap and is recommended when possible. Comparing the functional results from the literature review, we report a higher rate of full oral diet restoration.

Conflicts of Interest
None declared.

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