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Surgical outcomes of different approaches to esophageal replacement in long-gap esophageal atresia

A systematic review

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Abstract

Background: Esophageal replacement (ER) surgery has been widely used in long-gap esophageal atresia (LGEA) over the past few decades. The most commonly used surgical approaches in many pediatric surgical centers include colon interposition (CI), gastric pull-up (GPU), jejunal interposition (JI), and gastric tube reconstruction (GTR). However, there is no systematic evidence on which is the optimal conduit for the native esophagus. The aim of this systematic review was to evaluate the short- and long-term outcomes among these 4 replacement approaches in LGEA cases based on current evidence.

Methods: PubMed, Web of Science, Cochrane Library, and EMBASE were searched for relevant literature on November 18 2016. Studies on ER in LGEA were reviewed and selected according to eligibility criteria. We focused on surgical outcomes regarding to different replacement approaches, including postoperative complications and long-term follow-up. Both detailed descriptions of single studies and pooled data analysis were conducted. Data were computed by Reviewer Manager 5.3.

Results: Twenty-three studies were included (4 comparative retrospective, 3 prospective, and 16 retrospective) with a total of 593 patients (393 LGEA, 66.3%). The number of patients with available data for analysis was 534 (90.1%), including 127 patients (98 LGEA) of GPU, 335 (223 LGEA) of CI, 45 (all LGEA) of JI, and 27 (all LGEA) of GTR. Follow-up information was provided in 15 studies. Anastomotic leak and stricture, respiratory problems, and gastroesophageal reflux were analyzed as major postoperative complications. Long-term follow-ups were concentrated on growth and feeding conditions.

Conclusion: Current evidence on short- and long-term outcomes of ER in LGEA patients was limited, and proper prospective comparative studies were lacking. This present systematic review indicates CI and GPU as comparable and favorable approaches, especially CI in the long-term outcomes. Studies on JI and GTR were limited, which need larger sample size to assess their validity and outcomes.

Abbreviations: BMI = body mass index, CI = colon interposition, ER = Esophageal replacement, GPU = gastric pull-up, GTR = gastric tube reconstruction, JI = jejunal interposition, LGEA = long-gap esophageal atresia, NOS = Newcastle–Ottawa scale scores, PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses, RRs = Relative risks, VACTERL = vertebral, anal, cardiac, tracheal, renal, limb malformations.

Keywords: esophageal replacement, long-gap esophageal atresia, outcomes, systematic review

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1. Introduction

Esophageal replacement (ER) surgery has been widely used in long-gap esophageal atresia (LGEA) over the past few decades. As a major indication, definition of "long-gap" varied from different studies [1–13] (Table 1). As there is no standard measure technique or specific numerical definition for the distance between the esophageal ends, "long-gap" was usually considered as "not possible for primary anastomosis or attempted but failed" in a functional way.[4,7,10–12]

Although the time-honored dictum "the native esophagus is the best esophagus" was abided by most surgeons, long-term complications and certain conditions made ER to be the only alternative choice.[7] The ideal conduit was thought to closely resemble the esophagus in size and function, as well as simple surgical techniques with endurable complications.[9,14]

Several techniques of ER have been developed, including colon interposition (CI), gastric pull-up (GPU), jejunal interposition (JI), and gastric tube reconstruction (GTR). However, there is no systematic evidence on which is the optimal conduit for the native esophagus, and current studies were mainly retrospective and small sample sized. The aim of this present systematic review was to evaluate the short- and long-term outcomes among these 4

Table 1

Definitions of "long gap" in esophageal atresia.

Author (Year)	Long-gap definition
Mitchell et al[1]	>6 cm
Hirschl et al[2]	>3 cm
Hadidi[3]	>4–5VB
Tannuri et al[4]	Functional
Al-Shanafey and Harvey[5]	Functional
Holland et al[6]	Gap under tension >4VB
Hunter et al[7]	Functional, >2 cm or 2–3VB, ultra long-gap if >3.5 cm
Bagolan et al[8]	>3VB
Spitz[9]	>6VB
Lee et al[10]	Functional
Gallo et al[11]	Functional
Von Allmen and Wijnen[12]	Functional
Jonsson et al[13]	>4VU

Functional: Primary anastomosis was not possible or attempted but failed.
1VU = 1vertebral body+1disc, VB = vertebral body.

replacement approaches in LGEA cases based on current evidence.

2. Methods

This study was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. As it was based on previous publications, ethics approval or signed informed consent was not necessary.

2.1. Search strategy

A systematic literature search of database (PubMed, Web of Science, Cochrane Library, and EMBASE) was conducted on November 18 2016. Medical terms "esophageal atresia"/ "EA," "tracheoesophageal fistula"/"TEF,' '"long-gap," "esoph-agoplasty," "replacement," "interposition," "substitution," "-graft," and their combinations were used, limited to human studies, without restrictions to publication date. We also carried out a manual search of reference lists of those searched out articles.

2.2. Study selection

Only full-length original articles were considered. Two authors (JL and YFY) independently screened all the studies and selected the articles in agreement according to the eligibility criteria: included LGEA children; surgical approach was one of the replacement strategies (CI, GPU, JI, GTR); surgical outcomes of patients underwent ER were reported, and these related data were available. We excluded the following studies: conference abstracts or unpublished studies, case reports, review articles, earlier reports republished by the same center, no sufficient outcome data for analyses.

2.3. Data extraction and quality assessment

We recorded the candidates and extracted the data using an extraction sheet by one of the authors (JL), and checked by another author (YFY) to reach agreements. Extracted information was as follows: first author, publication year; study design, replacement approaches; number of cases and sample demographics; length of follow-up and outcome data for analyses. The quality of comparative studies was assessed using NOS (Newcastle–Ottawa scale) scores; studies with 6 scores or more were considered to be high quality.

2.4. Statistical methods

We divided the included studies into 4 groups: GPU, CI, JI, and GTR. Given the current data quality, we analyzed them in the following 2 ways: gave an overall description for single studies included; and performed statistical analysis using the pooled available data extracted from all included studies.

All statistical analyses were performed using Reviewer Manager 5.3 (RevMan, Copenhagen, Denmark). We chose random-effects model to avoid overestimation or underestimation related to studies' sizes. Data were pooled using the Mantel–Haenszel method for dichotomous outcomes, which were presented in relative risks (RRs). As most commonly used and reported, CI was chosen to be the standard when computing RRs, to which the other 3 ER groups were compared. This implies that 1 approach was beneficial if its RR was less than 1, and was disadvantageous if its RR was more than 1.

3. Results

3.1. Literature research and characteristics of studies

The flow diagram of the literature search process is presented in Fig. 1. A total of 404 articles were identified through database searching and reference retrieval of relevant publications. After screening titles and abstracts, full texts of 31 studies were assessed for eligibility. Eight articles were excluded, mostly because not focused on LGEA patients or not classified by different surgical replacement approaches. Thus, the rest 23 studies (4 comparative retrospective, 3 prospective, and 16 retrospective) were included and their characteristics are listed in Table 2.[1,2,4,6,7,10,11,14–29] Among them, 10 studies were focused on GPU, 8 on CI, 5 on JI, and 4 on GTR.

Most of the included studies were retrospective and non-comparative. There were only 4 comparative studies included; their NOS scores were 8,[4] 9,[7] 7,[6] and 8,[11] respectively.
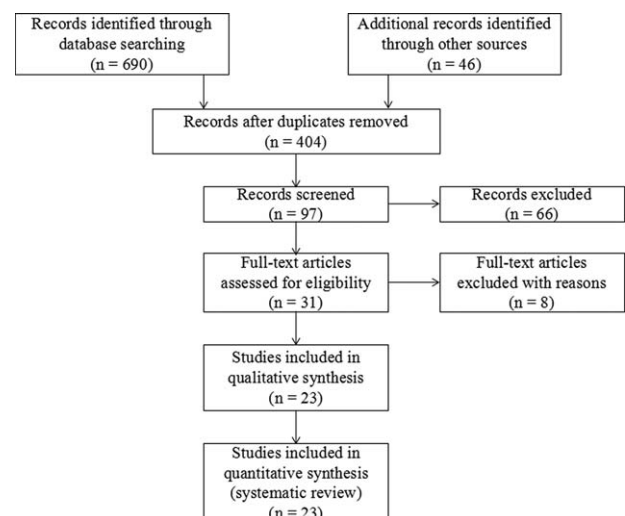
Figure 1. The PRISMA 2009 flow diagram for articles inclusion of this systematic review.

Table 2

Articles included in the present systematic review.

Author	ER type	Study type	Patient no.	LGEA	Follow-up time
Hunter et al[7]	GPU/CI/GTR	Retrospective, Comp	2/9/3	2/9/3*	4.2 y (0.5–11.5 y)
Holland et al[6]	GPU/CI	Retrospective, Comp	20/5	20/5*	9 y (>22 m)
Gallo et al[11]	GPU/JI	Retrospective, Comp	9/15	9/15*	10.25 y (1—19 y)
Tannuri et al[15]	GPU	Retrospective	35*	27	7m–19 y
Hirschl et al[2]	GPU	Retrospective	41	10*	6.5±0.8 y (5m–18y)
Reismann et al[16]	GPU	Retrospective	9	9*	6.2±3.1 y (1.4–10.2y)
Stanwell et al[17]	GPU (LA)	Retrospective	12	5*	—
Esteves et al[18]	GPU (LA)	Prospective	4	4*	7–25m
Gupta et al[19]	GPU	Prospective	27*	6	40.6m (6–85m)
Sharma and Gupta[20]	GPU	Prospective	6	6*	—
Tannuri et al[4]	CI	Retrospective, Comp	115*	89	—
Hamza[21]	CI	Retrospective	97*	21	1—20 y
Coopman et al[22]	CI	Retrospective	17	17*	14m–20.75 y
Mitchell et al[1]	CI	Retrospective	79*	69	—
Ure et al[23]	CI	Retrospective	9	9*	22 y (19–26 y)
Seguier-Lipszyc et al[24]	CI	Retrospective	4	4*	31.75m (32–34m)
Bax[14]	JI	Retrospective	32	19*	5.5 (1–17.5 y)
Cauchi et al[25]	JI	Retrospective	8	4*	—
Cusick et al[26]	JI	Retrospective	6	2*	2.75–5 y
Spicer and Cusick[27]	JI	Retrospective	5	5*	—
Pedersen et al[28]	GTR	Retrospective	3	3*	—
Lee et al[10]	GTR	Retrospective	14	14*	—
McCollum et al[29]	GTR	Retrospective	7	7*	4.5 y (4m–12y)

LGEA = long-gap esophageal atresia, LA = laparoscopically assisted, m = month, no. = number, y = year.
* Data available for analysis; —: not mentioned.

However, their sample sizes, surgical approaches, and outcomes were different from each other, leading to significant heterogeneity, which made it unreasonable for meta-analysis. Therefore, we performed a systematic review and presented the results by both single study descriptions and pooled data analysis.

3.2. Patients' demographics

There were altogether 593 patients (393 LGEA, 66.3%) in the 23 included studies. We extracted the information for analysis following the principles: all about ER in LGEA patients, or ER mostly in LGEA patients with a little partial of other indications (such as corrosive stricture) that cannot be eliminated (5 articles with 141 non-LGEA patients). Thus, the number of patients with available data for analysis was 534 (90.1%), with 393 LGEA (73.6%) and 141 non-LGEA (26.4%) such as other types of esophageal atresia and other indications (Table 2). Among them, 127 patients (23.8%) underwent GPU, 335 (62.7%) CI, 45 (8.4%) JI, and 27 (5.1%) GTR.

The characteristics of included studies and patients' demographics are listed in Table 3. The characteristics of studies included study years (14 articles, range from 1960 to 2010), gastrostomy performance before surgery (14 articles), and follow-up time (15 articles, with an average more than 1 year). The patients' demographics included patients' gender (10 articles), birth weight (11 articles, with a great portion of low birth weight), gestational age (8 articles, mostly premature), and age at ER surgery (20 articles, with a wide range from 4.5 days to 41.5 months).

Several combined malformations had been described in 13 articles, including VACTERL (vertebral, anal, cardiac, tracheal, renal, limb malformations, 5 articles), Down syndrome (9), DiGeorge syndrome (1), duodenal atresia (6), cardiac anomalies (include Fallot, atrial septal defect, ventricular septal defect, pulmonary hypertention, 8 articles), bilateral anophthalmia (1), anorectal abnormality (5), CHARGE association (1), cleft lip and palate (1), intestinal malrotation (1), and mentally related malformations (2). Moreover, in 4 studies on GPU, pyloroplasty[6,17,30] (3 studies with 27 patients) and pyloromyotomy[17,20] (2 studies with 8 patients) were also mentioned.

3.3. Perioperative data

In GPU, JI, and GTR group, no death or graft loss related to ER surgery was reported, while in the CI group, there were 7 surgical-related deaths, mainly because of leaks and sepsis[21–23]; 7 graft loss, and additional 3 graft ischemia and 1 graft necrosis, mostly defined by reoperation and exploration.[1,4,7,22]

As for intubation duration and hospital stay length, data were recorded in less than half of all the included studies, which made it impossible for comparison between different ER approaches. Detailed data are listed in Table 4.

3.4. Postoperative complications

A great deal of postoperative complications was reported in the included studies. However, there was no uniform definition for each complication. Furthermore, the boundary of early, late, and long-term complications was obscure. Among these recorded complications, anastomotic leak, anastomotic stricture, respiratory problems, and gastroesophageal reflux were reported in most studies of 4 ER groups, which we defined as major complications. Meanwhile, we also listed all the other complications mentioned in each study as minor complications in Table 5.

Data of major complications were extracted, summarized, analyzed, and compared among the 4 ER groups. It is worth mentioning that anastomotic stricture was commonly recorded

Table 3

Characteristics of included studies and patients' demographics.

Author	Co-mal	Gastrostomy	Age at ER	Gestational age	Sex	Birth weight, g
Hunter et al[7]	√	—	—	—	—	—
Holland et al[6]	√	—	7m (1d–20m)	34 (27–40)w	22M, 3F	2327 (905–3390)
Gallo et al[11]	√	√	87.3d (1–323d)	34.6 (29–41.2)w	17M, 7F	2017 (1030–3755)
Tannuri et al[15]	—	√	32.5±29m (11m–14y)	—	—	—
Hirschl et al[2]	—	—	0.85±0.12y	—	—	—
Reismann et al[16]	√	√	11.4±10.9 (0.4–27.4)w	37.3 (32.7–39)w	6M, 3F	2462±658 (1330–3140)
Stanwell et al[17]	√	√	20m (5–37m)	—	3M, 2F	—
Esteves et al[18]	√	—	11m (8–13m)	—	2M, 2F	—
Gupta et al[19]	√	—	6.08d (2–50d)	—	—	2320 (1860–3000)
Sharma and Gupta[20]	—	√	4.5d (3–7d)	—	—	2100 (1900–2700)
Tannuri et al[4]	—	√	41.5±39m (11m–18y)	—	—	—
Hamza [21]	—	√	8m (5–20m)	—	57M, 40F	—
Coopman et al[22]	—	√	11m (0.5–61m)	—	7M, 10F	—
Mitchell et al[1]	—	√	0.9y (0.5–2y)	—	—	—
Ure et al[23]	—	—	15.1m (5–32m)	—	—	3081 (2000–4100)
Seguier -Lipszyc et al[24]	√	√	113.5d (92–135d)	38.2 (37–39.6)w	—	2960 (2350–3400)
Bax (2007)	√	√	76d (6–1080d)	—	—	—
Cauchi et al[25]	√	√	13.25m (9–21m)	—	3M, 1F	—
Cusick et al[26]	—	—	9.5m (8–11m)	35.5 (35–36)w	—	2500 (2400–2600)
Spicer and Cusick[27]	—	—	—	—	—	—
Pedersen et al[28]	√	√	82d (36–120d)	32 (28–34)w	2M, 1F	1497 (1290–1900)
Lee et al[10]	√	√	—	—	11M, 3F	—
McCollum et al[29]	√	×	62d (38–131d)	37 (35–39)w	2M, 5F	2382 (1635–2997)

Co-mal=combined malformations, d=days, ER=age at esophageal replacement surgery, F=female, M=male, m=months, w=weeks, y=years.
—: not mentioned

both in early and late postoperative times, so we analyzed these data separately and integrally (Table 6). Anastomotic leak was mostly reported in early postoperative time, which usually during hospital stay or within 1 month after ER surgery, while respiratory problems and gastroesophageal reflux were in late postoperative time (Table 7).

Nineteen studies showed available data for anastomotic leak, in which GTR (25.9%) and JI (37.8%) had higher incidence than CI (19.7%). But most leaks were described as minor and healed spontaneously. Respiratory problems were reported in 14 studies, including pneumonia, pneumothorax, pleural effusion, acute respiratory distress syndrome, and chest infection, which were much more frequent after GTR (29.6%) and JI (22.2%) than CI (14.3%), while GPU (11.0%) had the lowest event rate. Gastroesophageal reflux was mentioned in 13 studies and significant difference in its occurrence was discovered; GTR group (48.1%) had the highest rate and JI (6.7%) had the lowest.

As for anastomotic stricture, commonly defined as need for dilatations, 21 studies were involved. Among these studies, stricture can be resolved mostly by (repeated) dilatations, and only a small part needs surgical interventions. In GTR group, only

early strictures were mentioned, which had the highest incidence overall (48.1% vs 15.2% CI). While in the other 3 groups, they were recorded both in early and late postoperative times. In general, CI showed the lowest stricture rate. As compared with CI, early stricture incidence was slightly lower after GPU (10.2% vs 11.9% CI), but late incidence was significantly higher after GPU (15.7% vs 3.3% CI) and JI (15.6%).

3.5. Long-term follow-up

The duration of follow-up was reported in 15 studies (65.2%), with means varying from 2.65 to 10.25 years. The main long-term outcomes were growth and feeding condition or swallowing ability. Growth was mentioned in 13 papers, mostly described as "grow well" or "normal." Some studies recorded the growth situation in detail by percentiles of height, weight, and body mass index (BMI), using the growth curves.

As for feeding condition or swallowing ability, information can be extracted from 18 papers. Most patients could tolerate oral feeding and had normal diet. In JI group, all 5 papers recorded feeding condition, 90.9% had normal oral feeding, while 7.5% need partial gastrostomy supplement and 2.5% had dysphagia. In the other 3 groups, only brief descriptions such as "normal diet" or "feeding/swallowing well/good" were mentioned. Dysphagia, regurgitation, and gurgling were recorded but rare. Some studies further made explicit evaluation such as measuring gastric transit time, graft peristalsis and clearance, mean resting/peak pressure, recording eating habit (meals per day and kinds of food), and dysphagia grading with correspondence standards.

4. Discussion

This study presented a systematic review on the short- and long-term outcomes among the 4 ER approaches in LGEA patients based on current evidence. Twenty-three studies were included,

Table 4

Perioperative data from related studies.

Author	ER type	Patient number	Hospital stay length	Intubation duration
Stanwell et al[17]	GPU	5	19.2d (13–36d)	—
Gupta et al[19]	GPU	27	32.6d (9–87d)	10.6d (2–40d)
Sharma and Gupta[20]	GPU	6	14.6d (13–20d)	5.3d (2–7d)
Gallo et al[11]	GPU	9	24d (15–233d)	8d (3–36d)
Reismann et al[16]	GPU	9	34.3d (9.1–119d)	4.8d (1–11d)
Ure et al[23]	CI	9	141.4d (77–294d)	—
Gallo et al[11]	JI	15	32d (13–189d)	7.5d (1–25d)
Bax (2007)	JI	19	—	5d (1–43d)

Table 5

Minor complications mentioned in all included studies.

ER	Early complications, n	Late complications, n
GPU	Abdominal evisceration, 2	Delayed gastric empty, 5
	Abdominal dehiscence, 1	Dumping syndrome, 1
	Wound infection, 1	Vomiting, 1
	Perforation, 1	Barrat esophagus, 1
	Mediastinitis, 1	Bolus impaction, 1
	Vomiting, 2	Small bowel obstruction, 2
	Axial torsion of stomach, 3	Pyloric stenosis, 1
	Gastroenteritis, 1	Vovulus, 1
	Hiatus hernia, 2	Vertigo-induced headaches, 1
	Horner syndrome, 1	Tracheomalacia, 1
	Arrhythmia, 1	
	Rectual bleeding, 1	
	Discrete esophagitis, 1	
	Capillary leak syndrome, 1	
	Femoral vein thrombosis, 1	
CI	Abdominal evisceration, 10	Graft redundancy, 9
	Wound dehiscence, 4	Dumping syndrome, 2
	Wound infection, 2	Functional obstruction, 16
	Fistula, 5	Perforation, 1
	Sepsis, 3	Ulceration, 8
	Vocal cord paralysis, 1	Diarrhea, 44
	Arrhythmia, 1	Portal hypertension, 1
	Mediastinitis, 1	Bezoars, 3
	Diaphragm hemiparalysis, 1	Nausea, 4
		Anemia, 8
		Colitis, 3
		Peritonitis, 1
JI	Wound dehiscence, 2	Graft redundancy, 1
	Fistula, 1	Ulceration, 4
	Horner syndrome, 1	Perforation, 1
	Temporary diaphragm hemiparalysis, 1	Functional obstruction, 7
		Food bolus obstruction, 2
		Dysphagia, 1
GTR	Wound infection, 2	Food obstruction, 8
	Fistula, 2	Dysphagia, 6
	Staple line bleeding, 1	Choking, 3
	Empyema, 1	Vomiting, 3
	Esophageal hiatus narrow, 1	Chest wall deformity, 1
		Cough, 6
		Asthma, 3

CI = colon interposition, ER = esophageal replacement, GPU = gastric pull-up, GTR = gastric tube reconstruction, JI = jejunal interposition.

with a number of 534 patients available for data analysis. Proper prospective comparative studies with a large sample size were lacking.

As "the native esophagus is the best esophagus," there was no "perfect" conduit. Every replacement has its advantages and disadvantages[1,2,4,7,9,14,15,19,20,25–27,29,31–36] (Table 8). Even the

native esophagus or elongation by traction (such as Foker or Kimura) had limitations, such as higher rate of stricture and poor weight gain in the long run, 1 to 2 years intensive treatment, and repeated hospitalizations or additional operations.[2,7,12,19,37–39] A number of patients with these procedures even need subsequent replacements.

The choice of graft mainly depends on the surgeon preference and experience.[7,18,21] Among these ER approaches, GPU was most preferred and satisfied by surgeons.[5,24,40] Moreover, surgical techniques varied from different studies, such as retrosternal or posterior mediastinal positions of grafts,[4] left or right or transverse part of colon used, and anti-reflux surgical techniques.[24] In GPU group, pyloroplasty and pyloromyotomy was mentioned in 4 studies. Pyloromyotomy was considered as a good choice, sufficient to provide drainage, while pyloroplasty was not preferred, as it may reduce the length of stomach.[4,20] All these above made it more difficult for comparison and assessment among different studies.

Definitions of short- and long-term outcomes also added to the difficulty. Most studies did not mention an accurate boundary between early, late, or long-term postoperative complications, and some indicated early as during hospital stay or within first month after operation, late as 1 month to 1 year or more than 1 year postoperatively, and long-term as more than 1 year.[6,22] Also, definitions for each complication were not unitized. As for long-term follow up, different assessments were used, such as standard scoring system, barium swallow, and endoscopic evaluations. However, these approaches may be affected by interpersonal bias and were not performed routinely in asymptomatic patients with uncomplicated courses.[4] These made the comparison of long-term outcomes obscure.

In our study, we classified complications into early and late postoperative time according to the way they were reported in the included studies. Thus, anatomostic leak was recorded as early complications, anastomotic stricture both in early and late times, while respiratory problems and gastroesophageal reflux as late complications.

After pooled data analysis, we found CI and GPU as comparable and favorable approaches for ER in LGEA patients, especially CI in long-term outcomes. First described by Sweet in 1984, GPU was popularized by Spitz as a preferred method for ER in the mid-1980s, while CI remains one of the standard techniques for ER for more than 60 years as well.[17]

Among the 4 ER groups, CI was used in most cases and had lower rates in almost all major complications. This may be because CI could offer adequate graft length but occupy little space in chest, cutting down the possibilities of respiratory problems. However, its inactive function and likely of becoming gangrenous may add the risk of gastroesophageal reflux and ulceration.[19,29] In contrast, JI group showed significant

Table 6

Anastomotic stricture among 4 ER groups.

ER type	Early postoperative		Late postoperative		Early+Late	
	Events/Total (Rate%)	RR (95% CI)	Events/Total (Rate%)	RR (95% CI)	Events/Total (Rate%)	RR (95% CI)
CI	40/335 (11.9%)	1.00 [0.66–1.51]	11/335 (3.3%)	1.00 [0.44–2.77]	51/335 (15.2%)	1.00 [0.70–1.43]
GPU	13/127 (10.2%)	0.86 [0.47–1.55]	20/127 (15.7%)	4.80 [2.37–9.72]	33/127 (26.0%)	1.71 [1.16–2.51]
JI	8/45 (17.8%)	1.49 [0.75–2.98]	7/45 (15.6%)	4.74 [1.94–11.59]	9/45 (20%)	1.31 [0.70–2.48]
GTR	13/27 (48.1%)	4.03 [2.48–6.57]	—	—	13/27 (48.1%)	3.16 [1.98–5.04]
Total	74/534 (13.9%)	1.51 [0.70–3.26]	38/507 (7.5%)	2.84 [1.02–7.92]	106/534 (19.9%)	1.63 [0.97–2.73]

CI = confidence interval, RR = relative risk.

Table 7

Major complications among 4 ER groups.

ER type	Anastomotic leak		Respiratory problems		Gastroesophageal reflux	
	Events/Total (Rate%)	RR (95% CI)	Events/Total (Rate%)	RR (95% CI)	Events/Total (Rate%)	RR (95% CI)
CI	66/335 (19.7%)	1.00 [0.74–1.36]	48/335 (14.3%)	1.00 [0.69–1.45]	46/335 (13.7%)	1.00 [0.68–1.46]
GPU	29/127 (22.8%)	1.16 [0.79–1.70]	14/127 (11.0%)	0.77 [0.44–1.35]	21/127 (16.5%)	1.20 [0.75–1.93]
JI	17/45 (37.8%)	1.92 [1.24–2.96]	10/45 (22.2%)	1.55 [0.85–2.84]	3/45 (6.7%)	0.49 [0.16–1.50]
GTR	7/27 (25.9%)	1.32 [0.67–2.58]	8/27 (29.6%)	2.07 [1.09–3.91]	13/27 (48.1%)	3.15 [2.18–5.64]
Total	119/534 (22.3)	1.27 [0.94–1.72]	80/534 (15.0%)	1.21 [0.81–1.81]	83/534 (15.5%)	1.30 [0.62–2.71]

CI = confidence interval, ER = esophageal replacement, GPU = gastric pull-up, GTR = gastric tube reconstruction, JI = jejunal interposition, RR = relative risk.

advantage of lower reflux incidence. This may be because of its peristaltic activity, which was desirable for normal transit and minimization of stasis and reflux.[25] However, JI is a more demanding technique, considering its precarious blood supply and need for 3 anastomoses, while anastomotic complications such as leak were more common.

GTR had higher rates in almost all major complications. As a complicated technique, GTR need long suture lines, which is prone to leaks and strictures.[15] The anastomosis at neck also increases the risk of respiratory problems. As for GPU, it had similar complication rates with CI group, while had unique advantages of single anastomosis, immune to acid exposure better, and muscular gastric wall thick enough to withstand mediastinal infection.[19,20,29]

In addition, these results may also be affected by study number and different sample sizes. For example, researches for JI and GTR approaches were inadequate, and improvement of surgical techniques such as fundal tube was making up for some of those disadvantages.

For patients' demographics, perioperative data, and long-term follow-up, we only made a brief description because no specific data could be extracted from included studies. Age at ER surgery

varied with a wide range among different studies; some may be affected by blending in non-LGEA patients such as corrosive stricture, and some may due to different concept on suitable ER ages. Some surgeons advocated for early ER surgery, mainly because it can avoid diversion, repeated surgical procedures, prolonged hospital stay and costs, and reduce complications associated with performing esophagostomy and gastrostomy.[19,20,29,41] However, there were also concerns that newborns may not withstand such major surgical procedure, increased risk of respiratory and cardiac problems, and limited options for substitution procedure.

Besides these included studies, some long-term complications were also reported in other papers. A gastric tube-pericardial fistula was recorded in a GTR case 20 years after initial repair.[42] Hematemesis due to fistula from anastomotic ulcer was reported in a 22-year-old man of CI.[43] Redundancy also gained much attention that could worsen reflux and lead to ulceration, mainly because of the reluctance to resect excess colon before final anastomosis and colon elongating more rapidly than child's thorax growth.[41]

Our study had limitations. First, there was no randomized controlled trial, while only 3 prospective, noncomparative studies

Table 8

Advantages and disadvantages of different ER approaches.

ER	Advantages	Disadvantages
CI	1. Better long-term outcome 2. Low risk of reflux 3. Adequate length 4. Occupies little space in chest	1. Precarious blood supply 2. More frequent gastroesophageal reflux 3. Likely to become redundant 4. Absent peristalsis, drain by gravity 5. Need for three anastomoses
GPU	1. Technically easy procedure 2. Reliable blood supply 3. Adequate graft length 4. Single anastomosis in the neck 5. Thick muscular to stand infection 6. Immune to acid exposure 7. Lower short-term morbidity 8. General good long-term outcomes	1. Bulk of stomach in chest 2. High risk of reflux 3. Dlayed gastric emptying 4. Dumping syndrome 5. Absent peristalsis, drain by gravity 6. Distal portion of esophagus is sacrificed.
JI	1. Enough length 2. Peristaltic activity, normal transit, 3. Similar diameter, occupies less space 4. Microvascular technique assistance 5. Free from inherent disease processes	1. Precarious blood supply 2. Limited length, restricted by vascular 3. Technically demanding 4. Need for three anastomoses 5. Hard to bring jejunum that high to neck 6. Anastomotic complications more common
GTR	1. Adequate graft length 2. Good blood supply 3. Retains tubular shape 4. Rapid food transit. 5. Reversed gastric tube technique 6. Fundal tube technique	1. Long suture lines, prone to leaks and strictures 2. Anastomosis at neck risk of complications 3. Complicated technique 4. Neonatal stomach too small to make a tube 5. Acid reflux lead to esophagitis or Barrett

CI = colon interposition, ER = esophageal replacement, GPU = gastric pull-up, GTR = gastric tube reconstruction, JI = jejunal interposition.

and 4 comparative but retrospective studies were included, which made meta-analysis unreasonable. Next, most studies were small sample sized, especially in JI and GTR groups, and group allocations were based on patients' conditions and surgeon's experience. Moreover, heterogeneity and publication bias should not be ignored. Therefore, pooled data analysis should be considered cautiously.

We advocate for further well-designed prospective comparative studies with larger sample sizes. Standard or unitized definition of surgery indications, postoperative complications, and long-term outcome assessments should also be established.

5. Conclusions

This present systematic review indicates CI and GPU as comparable and favorable approaches for ER in LGEA patients, especially CI in long-term outcomes. However, advantages of JI and GTR should not be ignored, such as lower reflux rate in JI group. Studies on these 2 valid approaches were limited, which need larger sample size to assess their validity and outcomes. Current evidence on short- and long-term outcomes of ER in LGEA patients was limited, and proper prospective comparative studies were lacking.

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