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Native Esophageal Preservation via Intraluminal Bougienage Elongation for Long-Gap Esophageal Atresia: Success, Complications, and Long-term Trade-offs-A Multicenter Cohort Study

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Abstract

Purpose

Preservation of the native esophagus is the preferred goal in long-gap esophageal atresia (LGEA), yet the full clinical picture – success rate, morbidity burden, and long-term trade-offs – remains incompletely defined. This study aimed to evaluate real-world outcomes of a native esophagus-preserving strategy based on intraluminal bougienage elongation (IBE) followed by thoracoscopic primary anastomosis, and to identify factors that influence the success and postoperative morbidity.

Methods

A retrospective multicenter cohort study included 44 LGEA patients treated with an IBE-based strategy (2019–2023). Native esophagus preservation was defined as achieving esophageal continuity after the IBE strategy. Outcomes included successful anastomosis, perioperative morbidity, stricture burden (endoscopic balloon dilation, EBD), feeding status (Functional Oral Intake Scale, FOIS), and growth (Z-scores for weight/height/BMI). Multivariable logistic regression identified factors associated with failed primary anastomosis/anastomotic leakage, high EBD burden (≥15 dilations), and pathological Z-scores (< –2 SD).

Results

Native esophagus preservation was achieved in 41/44 patients (93.2%). However, postoperative morbidity remained substantial: anastomotic leakage in 25.0%, GERD in 45.0% (20.0% required fundoplication), and refractory esophageal stricture (RES) in 76.2%. The median number of dilations required to achieve long-term clinical success was 13.5, with 37.5% requiring ≥15 dilations. At follow-up, all patients achieved full oral feeding, although pathological Z scores remained common. On multivariable analysis, shorter post-elongation overlap length was independently associated with failed primary anastomosis or anastomotic leakage (p=0.011), whereas GERD (p = 0.011) and long-segment stricture (p = 0.016) were independently associated with a

high EBD burden. Older age at anastomosis (p=0.040) was independently associated with pathological Z scores.

Conclusion

An IBE-based strategy enables native esophagus preservation in the vast majority of LGEA patients, but it imposes a high burden of anastomotic complications, refractory esophageal stricture, with residual growth impairment in many children. Shorter post-elongation overlap, GERD, long-segment stricture, and delayed anastomosis identify patients at risk for unfavorable outcomes.

Keywords

Long-gap esophageal atresia; Native esophageal preservation; Intraluminal bougienage elongation; Risk factors.

What is Known:

- Preservation of the native esophagus remains the preferred reconstructive goal for long-gap EA.

What is New:

- This multicenter study demonstrates that intraluminal bougienage elongation achieves native esophagus preservation in 93% of long-gap esophageal atresia patients.
- Postoperative morbidities were substantial, including anastomotic leakage, GERD, refractory esophageal stricture, and residual growth impairment.
- Shorter post-elongation overlap length, GERD, long-segment stricture, and older age at anastomosis are independently associated with adverse outcomes, providing actionable risk factors for clinical decision-making.

1. Introduction

Long-gap esophageal atresia (LGEA) remains one of the most challenging conditions in pediatric surgery. Although no universally accepted definition exists, LGEA is generally understood as esophageal atresia in which safe primary end-to-end anastomosis cannot be achieved at birth[1,2]. LGEA most commonly occurs in patients with Gross type A or B defects, although selected type C variants with a very distal tracheoesophageal fistula may also behave as long-gap lesions[3].

Preservation of the native esophagus remains the preferred reconstructive goal whenever feasible, because esophageal replacement is technically demanding and associated with lifelong functional morbidity[4]. Delayed primary repair is supported by the observation that spontaneous esophageal growth is greatest during the first 8 to 12 weeks of life[5,6]. However, not all infants become suitable candidates for anastomosis after this period. Several elongation strategies have therefore been developed, including the Foker process, staged internal traction, Kimura technique, and magnetic compression anastomosis[7-9]. Although these techniques may facilitate native esophageal reconstruction in selected patients, many are technically demanding, require repeated thoracic interventions or prolonged intensive care, or remain limited by a high rate of postoperative stricture[9].

Intraluminal bougienage elongation (IBE) has been proposed as a less invasive alternative means of stimulating esophageal growth[10]. Early clinical experience from our center suggested that repeated bougienage could lengthen both esophageal segments sufficiently to permit delayed native esophageal anastomosis in patients with LGEA[11]. Nevertheless, published evidence remains limited, largely single-center, and focused primarily on technical feasibility rather than comprehensive perioperative and long-term outcomes. Importantly, the true “cost” of native esophagus preservation – including anastomotic complications, refractory stricture burden, repeated endoscopic interventions, and residual growth impairment – has not been systematically evaluated in a multicenter cohort.

Against this background, the present multicenter study was designed to evaluate an IBE-based strategy followed by thoracoscopic primary anastomosis in patients with LGEA. Specifically, we aimed to: (1) determine the success rate of achieving native esophageal continuity; (2) quantify the clinical and resource burdens after EA repair; (3) evaluate long-term feeding and growth outcomes; and (4) identify risk factors that predict adverse outcomes, thereby informing individualized decision-making for LGEA.

2. Materials and Methods

2.1 Study design

A retrospective multicenter cohort study was conducted at Beijing Children's Hospital and Jiangxi Provincial Children's Hospital. All infants with esophageal atresia (EA) admitted to the 2 centers between January 2019 and December 2023 were screened for eligibility. During the study period, 132 patients with EA were admitted to Beijing Children's Hospital and 120 to Jiangxi Provincial Children's Hospital. Long-gap esophageal atresia (LGEA) was functionally defined as EA in which safe primary end-to-end esophageal anastomosis could not be achieved at birth. Using this definition, 35 patients at Beijing Children's Hospital and 28 patients at Jiangxi Provincial Children's Hospital were initially identified as having LGEA. After excluding patients who subsequently achieved esophageal continuity by spontaneous growth or by alternative elongation strategies, such as the Kimura technique, a total of 44 patients were included in the study and underwent an intraluminal bougienage elongation (IBE)-based strategy as the initial esophageal lengthening approach, including 24 patients from Beijing Children's Hospital and 20 from Jiangxi Provincial Children's Hospital. The detailed screening process is shown in **Figure 1**. This study was approved by the Ethics Committee of Beijing Children's Hospital (2019-k-333) and was conducted in accordance with the Declaration of Helsinki.

2.2 Data collection

Clinical data were collected retrospectively from the medical records of the 2

participating centers. Baseline variables included sex, gestational age, birth weight, associated anomalies, and EA subtype. Variables related to the IBE strategy included age at initiation of IBE, duration of elongation, pre-elongation gap length, post-elongation overlap length, and age at definitive anastomosis. All length measurements during the IBE process were assessed radiographically using plain X-ray imaging. Perioperative variables included operative time, duration of postoperative mechanical ventilation, length of intensive care unit (ICU) stay, and postoperative length of hospitalization.

2.3 IBE strategy

All included patients underwent IBE as part of a native esophagus-preserving treatment strategy. In our centers, IBE was performed once daily by experienced pediatric surgeons at a fixed time point, with each session lasting approximately 5 to 10 minutes. The procedure was carried out at the bedside without imaging guidance. The goal of bougienage was not forceful advancement of the esophageal ends, but rather the application of sustained, controlled axial tension to promote elongation of both the proximal and distal esophageal pouches (**Figure 2**).

After an adequate period of elongation, patients underwent thoracoscopic reassessment for definitive repair. Thoracoscopic esophageal anastomosis (TEA) was attempted when the proximal and distal esophageal ends could be approximated with acceptable tension on intraoperative assessment. In patients in whom excessive anastomotic tension persisted after IBE, staged thoracoscopic internal traction was considered as an alternative native esophagus-preserving strategy.

2.4 Clinical outcomes

The primary outcome was successful native esophageal reconstruction after an IBE-based strategy followed by thoracoscopic esophageal anastomosis. Secondary outcomes included factors associated with failure of primary anastomosis or development of anastomotic leakage, a high endoscopic balloon dilation (EBD) burden,

and pathological Z scores. Long-term clinical success was defined as the ability to tolerate solid food without requiring further dilation for at least 12 months after the final dilation procedure.

2.5 Postoperative complications and follow-up

Postoperative complications included anastomotic leakage, tracheomalacia, pneumothorax, recurrent tracheoesophageal fistula, esophageal diverticulum, gastroesophageal reflux disease (GERD), and esophageal stricture. The presence of GERD was evaluated by 24-hour pH monitoring performed at least 5 days after discontinuation of proton pump inhibitor therapy. Refractory esophageal stricture (RES) was defined as failure to maintain an age-appropriate esophageal lumen, referenced to the transverse diameter of the thumb, together with dysphagia requiring more than 5 dilations at 1-2 week intervals[12]. Esophageal stricture was assessed by consensus review between an experienced radiologist and a senior clinician. Stricture-related variables included stricture length, stricture diameter, upper pouch stricture index (U-SI), stricture level, and the number of EBDs. The stricture level was classified into 3 categories, and stricture length was categorized as focal (<1 cm) or segmental (≥1 cm). The U-SI was calculated as (D-SD)/D*100%, where D represented the diameter of the esophagus measured 1.5 cm proximal to the stricture and SD represented the diameter of the stricture[13].

Follow-up outcomes included feeding status and growth. Feeding status at the last follow-up was assessed using the Functional Oral Intake Scale (FOIS; range, 1-7), with scores of 1-3 indicating tube feeding dependence and scores of 4-7 indicating full oral feeding[14]. Growth parameters included weight-for-age, height-for-age, and body mass index (BMI)-for-age Z scores. Height and weight were analyzed using World Health Organization Anthro software, and pathological Z scores were defined as values below −2 standard deviations. In the present study, failure of primary anastomosis or development of anastomotic leakage, a high EBD burden (≥15 dilations), and pathological Z scores were defined as adverse outcomes.

2.6 Statistical analysis

Continuous variables are presented as mean ± standard deviation or median with interquartile range, as appropriate. Categorical variables are expressed as number and percentage. Univariable and multivariable logistic regression analyses were performed to identify factors associated with adverse outcomes. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. A 2-sided p-value < 0.05 was considered statistically significant.

3. Results

3.1 Patient characteristics

Between January 2019 and December 2023, a total of 44 patients with LGEA who underwent an IBE-based strategy were included in this study. The cohort comprised 27 males (61.4%) and 17 females (38.6%). Mean gestational age was 37.0 ± 2.0 weeks, and 17 infants (38.6%) were born preterm. Mean birth weight was 2376.10 ± 629.21 g, with 15 patients (34.1%) classified as low birth weight and 8 (19.5%) as very low birth weight. Associated malformations were present in 14 patients (31.8%), most commonly involving the digestive system (13.6%) and cardiovascular system (9.1%). Prenatal diagnosis was established in 17 cases (38.6%), and VACTERL association was identified in 5 patients (11.4%). Thoracoscopic repair was performed at Beijing Children's Hospital in 24 patients (54.5%) and at Jiangxi Provincial Children's Hospital in 20 patients (45.5%).

Notably, Gross type A/B esophageal atresia accounted for 84.1% of the LGEA cohort. Among these patients, 5 had previously undergone unsuccessful esophageal lengthening attempts at referring institutions, including the Foker procedure, the Kimura technique, and magnetic compression anastomosis. In addition, 7 patients had Gross type C esophageal atresia; because of excessive tension between the proximal and distal esophageal segments at birth, primary anastomosis was not feasible, and only tracheoesophageal fistula ligation plus static internal traction was performed initially

(Table 1).

3.2 Success of native esophageal preservation

The median age at initiation of IBE was 2.6 months (IQR, 1.7–3.7). The median pre-elongation gap was 5.0 vertebral bodies (IQR, 4.0–6.0), corresponding to 20.1 mm (IQR, 11.3–38.1) in the tension state. After IBE, the median post-elongation overlap length was 0.6 vertebral bodies (IQR, 0.5–1.1), corresponding to 5.0 mm (IQR, 2.7–8.8) in the tension state. The median duration of elongation was 40.0 days (IQR, 17.5–93.0). Primary esophageal anastomosis was achieved in 41 patients (93.2%) at a median age of 4.5 months (IQR, 3.7–6.3); 1 of these patients died postoperatively of bilateral recurrent laryngeal nerve injury. Primary esophageal anastomosis was not achieved in 3 patients; 2 subsequently underwent staged procedures and ultimately achieved definitive native esophageal repair, whereas 1 died of bilateral recurrent laryngeal nerve injury.

3.3 Perioperative and postoperative outcomes

Forty patients who underwent TEA successfully following IBE were analyzed for perioperative outcomes. The median operative time was 200.0 minutes (IQR 128.0, 232.5). Postoperatively, the median duration of mechanical ventilation was 183.0 hours (IQR 145.5, 250.5), with a median ICU stay of 11.0 days (IQR 8.0, 13.0) and a median hospitalization of 26.0 days (IQR 18.0, 41.5).

Postoperative complications were common: anastomotic leak occurred in 10 patients (25.0%), pneumothorax in 14 (35.0%), and tracheomalacia in 16 (40.0%). Recurrent tracheoesophageal fistula (rTEF) and esophageal diverticulum were observed in 6 (15.0%) and 7 (17.5%) patients, respectively. Gastroesophageal reflux disease (GERD) was diagnosed in 18 patients (45.0%), of whom 8 (20.0%) required fundoplication. (**Table 2**).

3.4 Esophageal stricture burden and long-term outcomes

Esophageal stricture was one of the most important long-term morbidities in this cohort. More than three-quarters of patients developed refractory stricture, and the median number of dilations required to achieve long-term clinical success was 13.5, with 37.5% of patients requiring at least 15 dilations. At follow-up, all patients achieved full oral feeding, and the mean FOIS score was favorable. However, pathological Z scores remained common, indicating persistent nutritional and growth impairment in a substantial proportion of patients.

3.5 Risk factors for adverse outcomes

Univariable and multivariable logistic regression analyses were performed to identify factors associated with adverse outcomes (Table 3). For the composite outcome of failed primary anastomosis or development of anastomotic leakage (n=44), univariable analysis showed that longer pre-elongation gap length, shorter post-elongation overlap length, and a lower distal pouch level were significantly associated with poor outcome. On multivariable analysis, shorter post-elongation overlap length remained independently associated with failed primary anastomosis or anastomotic leakage (OR 1.84, 95% CI 1.15-2.94, p=0.011).

For high EBD burden (≥15 dilations, n=40), univariable analysis identified older age at initiation of IBE, GERD, long-segment stricture, and U-SI as significant factors. On multivariable analysis, GERD (OR 90.91, 95% CI 2.82-317.46, p=0.011) and long-segment esophageal stricture (OR 33.33, 95% CI 2.01-932.84, p=0.016) remained independent predictors of a high EBD burden.

For pathological Z scores, univariable analysis identified longer pre-elongation gap length and older age at esophageal anastomosis as significant factors. On multivariable analysis, older age at esophageal anastomosis (OR 1.41, 95% CI 1.02-1.96, p=0.040) remained independently associated with pathological Z scores.

4. Discussion

To our knowledge, this is the largest multicenter cohort study to provide a

comprehensive risk-benefit profile of native esophagus preservation using an IBE-based strategy for LGEA. The principal findings are threefold. First, IBE enabled successful native esophageal continuity in 93.2% of patients, confirming its high anatomical success rate. Second, the cost of this success was substantial: anastomotic leakage in 25%, GERD in 45%, refractory stricture in 76%, a median of 13.5 dilations, and residual growth impairment in a significant subset. Third, shorter post-elongation overlap length, GERD, long-segment stricture, and older age at anastomosis independently predicted worse outcomes, providing actionable markers for clinical decision-making.

Some authors have suggested that primary anastomosis should be avoided when the initial gap exceeds 4 vertebral bodies because excessive tension may predispose to anastomotic failure[15,16]. A central finding of the present study is that IBE created the anatomical conditions necessary for primary repair in more than 90% of patients with LGEA. Specifically, the median gap decreased from 5.0 vertebral bodies before elongation to an overlap of 0.6 vertebral bodies in the tension state after IBE. This marked reduction made primary native esophageal reconstruction feasible even in patients with very long gaps. Preservation of the native esophagus remains the preferred reconstructive goal whenever possible, because esophageal replacement is technically demanding and associated with lifelong morbidity[17]. In this context, several elongation strategies have been developed to facilitate native esophageal preservation, including the Foker procedure, staged thoracoscopic internal traction, the Kimura cervical esophageal elongation technique, and magnetic compression anastomosis[8,18,19].

Compared with other native esophagus-preserving elongation strategies, IBE offers several practical advantages. Although the Foker technique is an established active elongation method, it is technically demanding, often requires repeated operations or prolonged sedation, and is highly dependent on institutional and surgeon experience[9,20,21]. Compared with these, IBE is less invasive – performed at the bedside without imaging guidance – and does not require repeated thoracic operations or

prolonged sedation. In our cohort, even patients who had failed prior elongation methods (Foker, Kimura, magnetic compression) achieved further lengthening with IBE, supporting its role as both a primary and a salvage option. However, the 93.2% success rate should not be interpreted as a universal indication for native preservation. Three patients could not undergo primary anastomosis despite IBE, and two deaths resulted from bilateral recurrent laryngeal nerve injury – a devastating complication likely related to excessive tension and extensive mobilization. Thus, native preservation is not always safe or feasible; knowing when to abandon it is as important as knowing how to perform it.

Another clinically important observation is that post-elongation overlap length in the tension state, rather than initial gap length, was independently associated with failed primary anastomosis or anastomotic leakage. This finding has important conceptual implications. It indicates that the technical endpoint of elongation should not merely be "some reduction" in gap length, but rather sufficient overlap to permit a low-tension anastomosis. From a surgical standpoint, the post-elongation anatomy likely reflects the combined effects of baseline defect severity, tissue compliance, and the practical limits of traction-induced growth. Therefore, post-elongation overlap length after IBE may be more informative for operative decision-making than baseline gap length alone[22]. In patients with insufficient post-elongation overlap between the proximal and distal esophageal ends, alternative lengthening strategies should be considered, because anastomosis under excessive tension appears to substantially increase the risk of leakage or failure. In the present cohort, three patients were found intraoperatively to have excessive tension between the proximal and distal esophageal ends after IBE and therefore did not meet the criteria for primary esophageal anastomosis. These patients subsequently underwent staged thoracoscopic internal traction; two ultimately achieved esophageal continuity with normal oral feeding, whereas one died postoperatively of bilateral recurrent laryngeal nerve injury. Based on this experience, staged thoracoscopic internal traction appears to be a reasonable alternative in selected patients

with insufficient post-elongation overlap after IBE[3,7,23].

Although the rate of successful primary repair was encouraging, postoperative morbidity remained substantial, including anastomotic leakage, pneumothorax, tracheomalacia, recurrent tracheoesophageal fistula, esophageal diverticulum, and GERD[24]. These findings underscore that, in LGEA, restoration of esophageal continuity is only the first step, and postoperative management remains challenging, particularly after long-gap reconstruction. In our centers, postoperative mechanical ventilation was generally maintained for more than 5 days to reduce tension on the anastomosis. Notably, previous reports have suggested that bilateral recurrent laryngeal nerve injury may occur at a relatively high rate after LGEA repair. In the present study, two patients died after thoracoscopic esophageal anastomosis because of bilateral recurrent laryngeal nerve injury[25]. This complication may be related to the extensive mobilization of both esophageal ends and the tension associated with reconstruction, which may increase the risk of direct, traction-related, or thermal injury to both recurrent laryngeal nerves[26,27]. Accordingly, perioperative management should emphasize low-tension reconstruction and avoidance of excessive circumferential dissection. Our center has also begun to implement intraoperative recurrent laryngeal nerve monitoring during esophageal surgery in selected high-risk patients with esophageal atresia in an effort to reduce the incidence of nerve injury.

Esophageal stricture was one of the most important long-term morbidities in this cohort. More than three-quarters of patients developed refractory stricture, and the median number of dilations required to achieve long-term clinical success was 13.5, with 37.5% of patients requiring at least 15 dilations. These findings highlight that, even when native esophageal preservation is achieved, the subsequent treatment burden remains substantial[12,28]. Importantly, multivariable analysis identified GERD and long-segment stricture as the two independent predictors of a high EBD burden. This is consistent with prior reports. Reflux may perpetuate mucosal injury and fibrosis at the anastomotic site, thereby promoting restenosis and the repeated need for dilation[29,30].

Likewise, longer strictures represent a greater extent of scar tissue and may be less responsive to endoscopic remodeling than short-segment focal strictures[31]. Clinically, these findings suggest that patients with GERD or long-segment stricture should be regarded as a high-risk subgroup requiring closer surveillance and earlier optimization of anti-reflux therapy. In patients with GERD refractory to medical therapy, anti-reflux surgery may need to be considered at an earlier stage[32].

We also evaluated long-term functional outcomes in patients with LGEA. All patients ultimately achieved full oral feeding, and the mean FOIS score was favorable, indicating that most patients eventually attained meaningful swallowing function after reconstruction[14]. This represents an important advantage of native esophageal preservation and suggests that satisfactory feeding outcomes may still be achieved over time despite early postoperative complications and repeated dilations. However, pathological Z scores remained relatively common[33]. Restoration of oral feeding does not necessarily equate to normalization of nutritional status. Even after anatomical continuity has been restored and full oral feeding achieved, patients with LGEA may continue to experience impaired growth because of inefficient feeding, recurrent reflux, intermittent dysphagia, and respiratory comorbidities[34,35].

Multivariable analysis further showed that older age at anastomosis was associated with pathological Z scores. Delayed definitive repair may prolong the period of restricted feeding, dependence on alternative nutritional routes, and recurrent aspiration risk, thereby adversely affecting early infant growth. This finding suggests that once LGEA has been diagnosed and gastrostomy established, the IBE strategy should be initiated as early as possible to create favorable conditions for anastomosis and restore esophageal continuity at an earlier stage. Based on our experience, the first 8 to 12 weeks of life represent the critical window for spontaneous esophageal growth, and initiation of bougienage stimulation as early as 1 month of age may help shorten the age at definitive repair[6]. In our cohort, the age at initiation of bougienage was relatively late (median, 2.6 months), likely reflecting limited awareness of this disease and

treatment strategy at referring institutions. At the same time, although adequate IBE-based elongation is necessary, a very small subset of patients appears relatively insensitive to this approach. In such patients, if more than 3 months of bougienage fails to create favorable conditions for anastomosis, alternative elongation strategies, such as staged thoracoscopic internal traction, should be considered[11].

Several limitations should be acknowledged. First, this was a retrospective study from two centers with a relatively small sample size, which limits statistical power and may explain the wide confidence intervals observed in some multivariable analyses. Second, no direct comparison group was available, such as patients managed with delayed primary anastomosis alone, Foker-type traction, or esophageal replacement, precluding definitive conclusions regarding comparative superiority. Third, although medium-term feeding outcomes were encouraging, longer follow-up is needed to evaluate late dysmotility, quality of life, reflux-related sequelae, and long-term growth. Finally, some study endpoints, particularly EBD burden and pathological Z scores, may have been influenced not only by the reconstructive technique itself but also by family, social, and other nonoperative factors. Future prospective multicenter studies are warranted to validate the predictive value of post-elongation overlap length and to define the optimal threshold and timing for safe anastomosis after IBE.

5. Conclusion

In conclusion, IBE followed by thoracoscopic primary anastomosis appears to be an effective minimally invasive, native esophagus-preserving strategy for LGEA, achieving a high rate of successful reconstruction after substantial reduction of gap length. Nevertheless, postoperative morbidity, particularly anastomotic leakage, GERD, and refractory stricture, remains common. Shorter post-elongation overlap length, GERD, long-segment stricture, and delayed anastomosis are associated with worse outcomes. These findings suggest that optimal outcomes in LGEA require attention to the entire continuum of care, including operative strategy, perioperative management, postoperative complications, and long-term nutritional follow-up.

DATA AVAILABILITY

The datasets during and/or analysis during the current study are available from the corresponding author upon reasonable request.

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AUTHOR CONTRIBUTIONS

C.P.X., S.S.L. and J.S.H. designed the research; C.P.X., W.Q.Y., D.D.W, S.S.L., Y.Z., J.M.L., Y.C.G. and Y.N.Z. conducted data collection and follow-up; C.P.X., D.Y.S., and S.S.L analyzed the data; K.Y.H., and J.S.H. conceived and directed the project; C.P.X. wrote the manuscript with the assistance and feedback of all the other co-authors.

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COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Ethics Committee of Beijing Children's Hospital (2019-k-333), and the patient informed consent requirements were waived.

CONSENT FOR PUBLICATION

Not applicable

Figure Legend

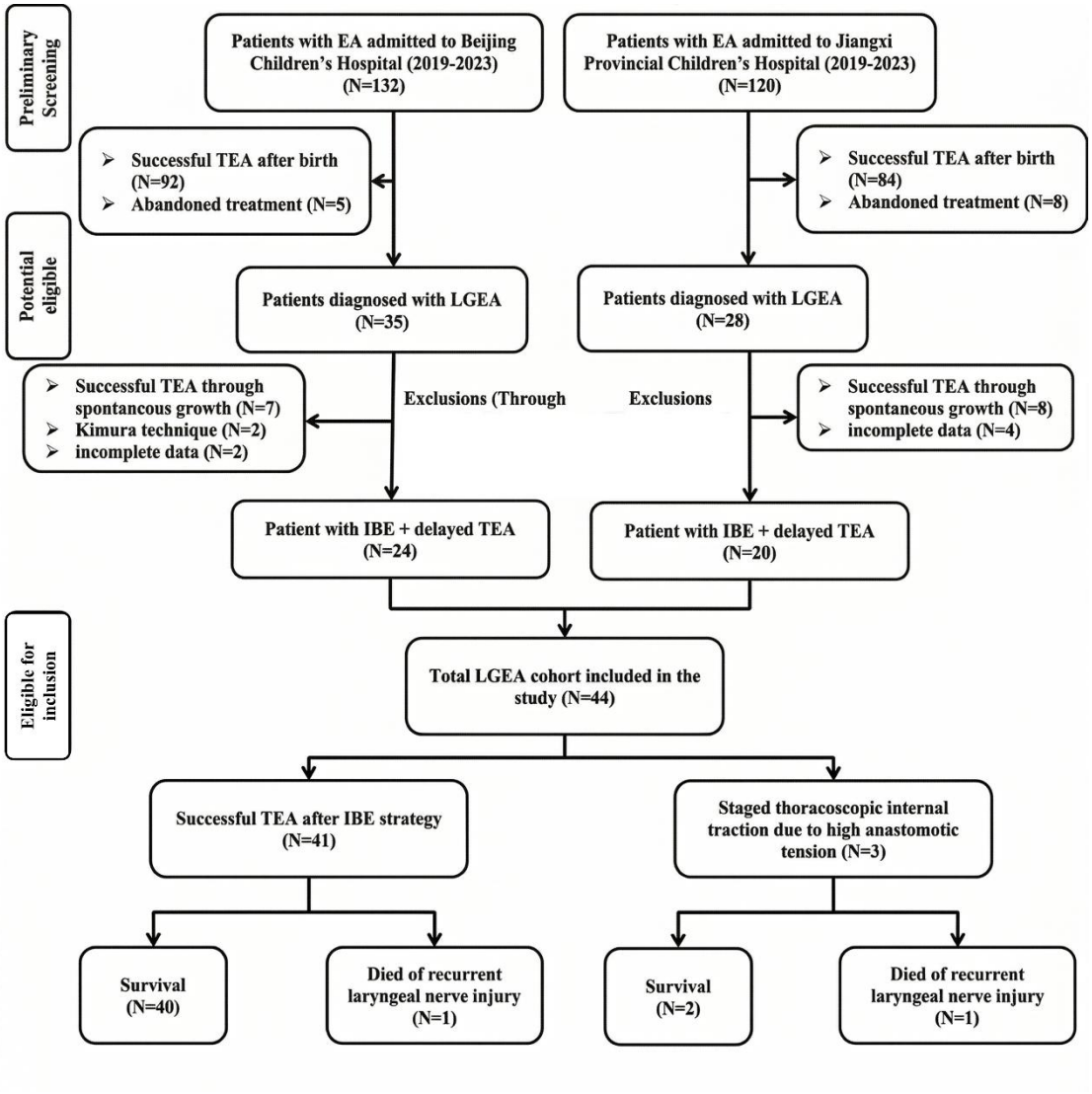


Figure 1. Flow chart of patient selection and outcomes in the LGEA cohort treated with an IBE-based strategy

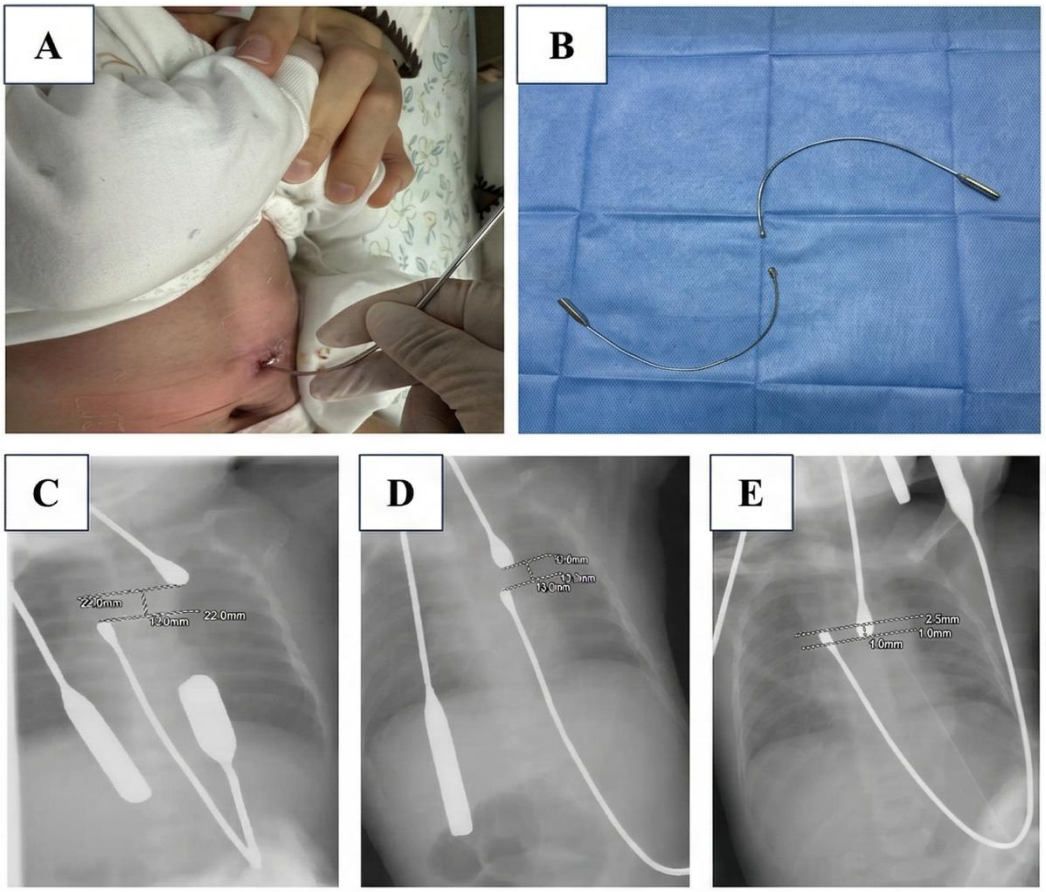


Figure 2. Intraluminal bougienage elongation (IBE) procedure and radiographic assessment of esophageal elongation. (A) Bedside intraluminal bougienage performed through the gastrostomy site and oral site. (B) Modified bougies with a blunt, rounded tip used for the IBE procedure. (C) Representative radiograph before elongation showing the initial gap between the proximal and distal esophageal pouches. (D) Radiograph obtained during the elongation process demonstrating progressive approximation of the esophageal ends. (E) Radiograph after elongation showing further reduction of the gap and achievement of post-elongation overlap in the tension state.

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