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Association of operative approach with outcomes in neonates with esophageal atresia and tracheoesophageal fistula

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ABSTRACT

Purpose: We sought to evaluate the impact of thoracoscopic repair on perioperative outcomes in infants with esophageal atresia and tracheoesophageal fistula (EA/TEF).
Methods: The American College of Surgeons National Surgical Quality Improvement Program pediatric database from 2014 to 2018 was queried for all neonates who underwent operative repair of EA/TEF. Operative approach based on intention to treat was correlated with perioperative outcomes, including 30-day postoperative adverse events, in logistic regression models.
Results: Among 855 neonates, initial thoracoscopic repair was performed in 133 (15.6%) cases. Seventy (53%) of these cases were converted to open. Those who underwent thoracoscopic repair were more likely to be full-term ($p = 0.03$) when compared to those in the open repair group. There were no significant differences in perioperative outcome measures based on surgical approach except for operative time (thoracoscopic: 217 min vs. open: 180 min, $p<0.001$). A major cardiac comorbidity (OR 1.6, 95% CI 1.2–2.1; $p = 0.003$) and preoperative ventilator requirement (OR 1.4, 95% CI 1.0–1.9; $p = 0.034$) were the only risk factors associated with adverse events.
Conclusions: Thoracoscopic neonatal repair of EA/TEF continues to be used sparingly, is associated with high conversion rates, and has similar perioperative outcomes when compared to open repair.
Level of evidence: III

List of Abbreviations

EA/TEF	Esophageal atresia
NSQIP-P	National Surgical Quality Improvement Program- Pediatric
TEF	Tracheoesophageal fistula

1. Introduction

Successful treatment of EA/TEF, which requires surgical repair by ligation of the fistula and construction of an esophagoesophagostomy, was first performed by open thoracotomy in 1941 [1]. Although contemporary in-hospital mortality rates following EA/TEF repair are approximately 5%, postoperative morbidities continue to be substantial [2, 3].

In an effort to reduce some of these short- and long-term complications, thoracoscopic repair has been touted as a viable alternative by some pediatrics surgeons over the past 30 years [4, 5]. In addition to the potential long-term musculoskeletal and cosmetic advantages associated with minimally invasive thoracoscopic surgery [6], several single center and multi-institutional studies have suggested that thoracoscopic EA/TEF repair is associated with more favorable short-term outcomes when compared to open repair [4, 7-10]. However, concerns have been raised as to whether these reported outcomes may simply be a reflection of patient selection, surgeon expertise in advanced endosurgery, and other factors [11]. National comparative studies of EA/TEF outcomes based on operative approach have also been lacking [12].

The purpose of this study was to characterize national practice patterns in the United States with respect to operative approach in neonates with EA/TEF, and to evaluate the impact of thoracoscopic repair on perioperative outcomes. We hypothesized that thoracoscopic repair would be performed in larger neonates with fewer comorbidities, thereby being associated with fewer postoperative adverse events and reduced hospital lengths of stay when compared to those undergoing open repair.

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2. Methods

2.1. Data source

An exemption was granted by the Johns Hopkins Institutional Review Board for this retrospective cohort study using the American College of Surgeons National Surgical Quality Improvement Program Pediatric (NSQIP-P) database. This dataset includes a wide array of clinical information for calculating risk-adjusted adverse event rates among 140+ member hospitals [13].

2.2. Study cohort

Patients diagnosed with EA with or without TEF between January 1, 2014 and December 31, 2018 were identified based on diagnosis codes (750.3 and/or 530.84) in accordance with the International Classification of Diseases, Ninth Revision, Clinical Modification (ICM-9-CM). Surgical repairs were identified by Current Procedural Terminology (CPT) codes, 43,312 and 43,314. Thoracoscopic repairs were defined by NSQIP-P using the "LAPTHOR" variable as a "laparoscopic/MIS only" approach. Conversion of thoracoscopic to open thoracotomy (herein referred to as converted) cases were defined as those listed as "laparoscopic/MIS and open". Open repairs were defined as those coded as "Open only or N/A". Patients were excluded if they had missing data on operative approach or underwent a cervical repair. To limit patient heterogeneity, we also excluded children with isolated EA without TEF, identified by the combination of ICD-9 (530.84) and CPT codes (43,310 or 43,313), and those who had their definitive operative repair beyond 30 days of age.

2.3. Patient characteristics and outcomes

Demographic variables included age, sex, race, weight, and gestational age at birth. Perioperative variables included preoperative nutritional support (defined as intravenous total parenteral nutrition or enteral feeding via gastrostomy, nasogastric, or jejunostomy tubes at the time of surgery), preoperative sepsis, preoperative ventilator requirement, trisomy 21, imperforate anus, intestinal atresia, and other major cardiac, respiratory, neurologic, gastrointestinal, renal, and hematologic comorbidities. Major cardiac risk factors were defined as status post repair of congenital heart defect with residual hemodynamic abnormality, uncorrected cyanotic heart disease, documented pulmonary hypertension, or ventricular dysfunction requiring medications. Minor cardiac risk factors were defined as cardiac conditions with or without medications (e.g., atrial septal defect, patent ductus arteriosus), or status post repair of congenital heart defect with normal cardiovascular function and no medications.

The primary outcome measure was number of 30-day postoperative adverse events, a composite morbidity variable that included any major complication or unplanned reoperation as defined by the NSQIP-P database. Complications included major neurologic, respiratory, gastrointestinal, and renal events, cardiac arrest, wound infections, and other systemic infections such as line-associated infections and sepsis. Secondary outcomes measures included operative time, operative blood loss, hospital length of stay, system-specific complications, readmission rates, and mortality with 30 days of operative repair. To assess the relationship between different operative approaches, patient characteristics, and postoperative outcomes, we used an intention-to-treat approach by comparing those where thoracoscopic repair was attempted compared to those who had a completely open repair. We also analyzed the converted and thoracoscopic groups separately to determine the association of patient variables with converting to an open approach as well as any association between conversion and post-operative outcomes.

2.4. Statistical analysis

Data were presented as the mean±standard deviation (SD) unless specified otherwise. The independent *t*-test, one-way analysis of variance, Mann-Whitney test, and Kruskal-Wallis test were used to compare the means and medians of normally and non-normally distributed continuous variables, as appropriate. Chi-square and Fisher's exact tests were used to compare frequencies of categorical variables. A p-value<0.05 was considered statistically significant. Univariate logistic regression was employed to determine unadjusted odds ratios (OR) between perioperative variables and outcomes. Those variables with p-values<0.20 were used in a multivariable logistic regression model to identify factors associated with outcome. All analysis was performed using STATA (version 14.2; Statacorp, College Station, TX).

3. Results

3.1. Study population

During the study period, 1148 children had a diagnosis code and corresponding procedural code consistent with operative repair of an EA/TEF. After excluding cases with missing data on operative approach ($n = 39$, 3.4%), definitive repair greater than 30 days ($n = 222$, 19.3%), cervical repair ($n = 2$, 0.2%), and isolated EA ($n = 30$, 2.6%), there were 855 (77.1%) patients included for further analyses (Fig. 1). There was a year-on-year increase in overall cases from 2014 to 2018, with 113, 139, 148, 193, and 181 total cases, respectively.

Preoperative demographic and comorbidity variables in neonates undergoing EA/TEF repair are shown in Table 1. Sixty-four percent ($n = 545$) were born full term. The mean operative age was 2.5 days (SD, 3.3 days), and the mean operative weight was 2.6 kg (SD, 1.3 days). Seventy-five percent ($n = 645$) had a major comorbidity, including 62% ($n = 527$) with major or severe cardiac disease. Twenty-seven percent ($n = 234$) required preoperative ventilator support.

3.2. Comparisons by operative approach

Data based on intention-to-treat analysis are shown in Table 1. There were 133 (16%) thoracoscopic, of which 70 (53%) were converted to open, and 722 (84%) open repairs. The relative proportion of thoracoscopic cases attempted or completed remained stable during the five-year study period (Fig. 2). There was an increase in converted cases from 7% to 15% ($p = 0.035$) relative to open cases, which comprised 86% of all cases in 2014 and 78% in 2018 ($p = 0.085$). Infants who underwent thoracoscopic repair were significantly more likely to be full term (74%, $p = 0.03$). There were no other differences in other demographic variables or comorbidities. When evaluating the converted group separately from the thoracoscopic group, those who underwent conversion were less likely to be full term (66% versus 83%, $p = 0.03$) and weighed less at the time of surgery (2.6 kg vs 2.9 kg, $p = 0.04$) compared to the purely thoracoscopic group (Table 2).

Perioperative outcomes data based on intention to treat are shown in Table 3. The mean operative time for the entire cohort was 186 min (SD, 76 min). The operating time was significantly longer during thoracoscopic and converted repair (217 min, respectively) compared to open repair (180 min, $p<0.001$). There were no differences in intraoperative blood transfusion amounts. The mean length of stay was 27.3 days (SD, 20 days), the readmission rate was 1.2%, and the mortality was 1.8% (Table 3). There were no

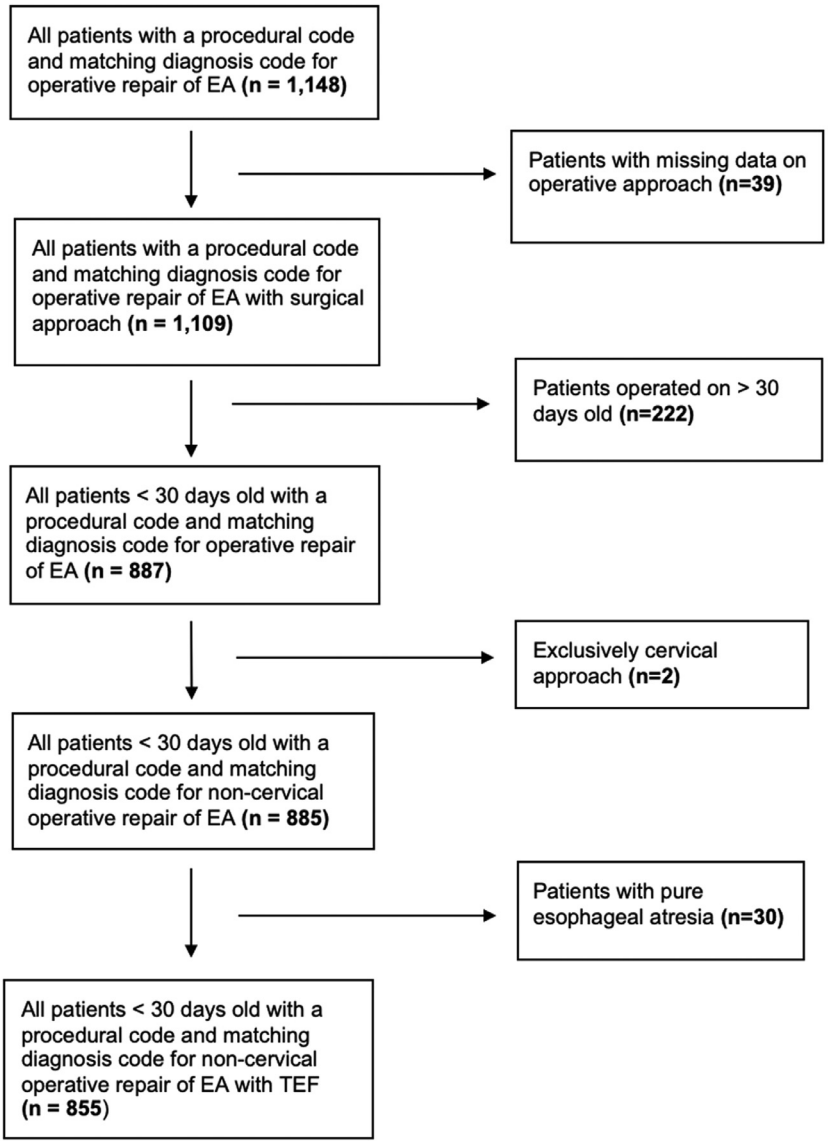

Fig. 1. Flow diagram of inclusion and exclusion criteria for neonates undergoing esophageal atresia (EA) with tracheoesophageal fistula (TEF) repair.

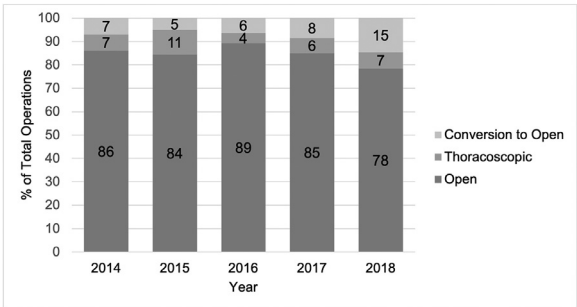

Fig. 2. Vertical bar graph showing trends in operative approach for neonatal esophageal atresia with tracheoesophageal fistula repair, 2014–2018.

differences in complications, readmissions, deaths, total ventilator days, hospital length of stay based on operative approach. Among all patients, 231 (27%) had at least one postoperative adverse event. There were no significant differences in adverse events based on operative approach. Respiratory complications (n = 119, 14%) and wound infections (n = 59, 7%) were the most common morbidities across the entire cohort. When evaluating the converted group separately from the thoracoscopic group, there were no differences in outcome measures including complications (Table 4).

3.3. Risk factors associated with adverse events

Data on the association between perioperative variables and composite 30-day adverse events are shown in Table 5. Univariate logistic regression analysis revealed no association between operative approach and primary outcome. An increased rate of adverse events was associated with the presence of any major comorbidity (OR 1.94, 95% CI 1.3–2.9; p = 0.0006), a major cardiac risk factor (OR 1.66, 95% CI 1.2–2.3, p = 0.002), and a preoperative ventilator requirement (OR 1.49, 95% CI 1.1–2.1, p = 0.019). After excluding the composite variable “major comorbidity” and respiratory comorbidity to reduce collinearity, major cardiac risk factor (OR 1.58, 95% CI 1.2–2.1, p = 0.003) and a preoperative ventilator requirement (OR 1.4, 95% CI 1.0–1.9, p = 0.034) were the only risk factors significantly associated with more adverse events in multivariable logistic regression.

Table 1
Preoperative characteristics and comorbidity data in neonates with esophageal atresia, based on intention-to-treat operative approach.

	Total $n = 855$	Thoracoscopy only or Converted $n = 133$	Open $n = 722$	p-value
BASELINE CHARACTERISTICS				
Age in days, mean (SD)	2.5 (3.3)	2.3 (3.2)	2.6 (3.3)	0.34
Female, n (%)	346 (40)	47 (35)	299 (41)	0.19*
Race, n (%)				0.89
White	557 (65)	87 (65)	470 (65)	
Black	82 (10)	13 (10)	69 (10)	
Other	29 (3)	3 (2)	26 (4)	
Unknown	187 (22)	30 (23)	157 (22)	
Hispanic, n (%)	111 (15)	10 (9)	101 (17)	0.04*
Premature, n (%)				0.03*
No (full term)	545 (64)	98 (74)	447 (62)	
35–36 weeks	133 (16)	19 (14)	114 (16)	
31–34 weeks	150 (18)	12 (9)	138 (19)	
25–30 weeks	25 (3)	4 (3)	21 (3)	
Preoperative blood transfusion, n (%)	26 (3)	2 (1.5)	24 (3)	0.26
Preoperative nutrition, n (%)	465 (54)	72 (54)	393 (54)	0.95
Preoperative sepsis, n (%)	10 (1)	2 (1.5)	8 (1)	0.70
Preoperative weight, kg, mean (SD)	2.6 (1.3)	2.7 (0.6)	2.6 (1.4)	0.30
COMORBIDITIES, n (%)				
Any major comorbidity	645 (75)	100 (75)	545 (75)	0.91
Cardiac risk factors				0.06
None	142 (17)	27 (20)	115 (16)	
Minor	186 (22)	36 (27)	150 (21)	
Major	527 (62)	70 (53)	457 (63)	
Non-cardiac major comorbidity	311 (36)	56 (42)	255 (35)	0.14
Respiratory	213 (25)	44 (33)	169 (23)	0.02*
Neurologic	93 (11)	12 (9)	81 (11)	0.55
Gastrointestinal	7 (1)	1 (0.8)	6 (1)	1.00
Renal	1 (0.1)	0 (0)	1 (0.1)	1.00
Hematologic	56 (7)	5 (4)	51 (7)	0.18
Preoperative mechanical ventilation	234 (27)	32 (24)	202 (28)	0.40
Imperforate anus	71 (8)	7 (5)	64 (9)	0.23
Duodenal atresia	14 (2)	1 (0.8)	13 (2)	0.71
Trisomy 21	10 (1)	0 (0)	10 (1)	0.38

Abbreviations: SD, standard deviation.
*$p<0.05$ is considered statistically significant.

4. Discussion

In this NSQIP-P cohort study containing 855 neonates with EA/TEF, we directly compared perioperative outcomes between thoracoscopic and open repair. Thirty-day mortality rates were uniformly low (1–2%) among the different operative approaches. Despite over one-fourth of neonates in our study experiencing a major 30-day adverse event, there was scant evidence that operative approach made an impact on complications. Contrary to our original hypothesis, there were no differences in most early outcome metrics, including perioperative blood transfused, complications, total ventilator days, mortality, and hospital length of stay. To our knowledge, our analysis represents the first study of its kind using a large national database. Although these data did not fa-

Table 3
Perioperative and postoperative outcomes in neonates with esophageal atresia, based on intention-to-treat operative approach.

	Total $n = 855$	Thoracoscopy only or Converted $n = 133$	Open $n = 722$	p-value
PERIOPERATIVE				
Operative time, minutes, mean (SD)	186 (76)	217 (86)	180 (73)	<0.001*
Blood transfused, mL/kg, mean (SD)	18 (10)	21 (14)	18 (9)	0.31
COMPLICATIONS, n (%)				
Any adverse event[a]	231 (27)	33 (25)	198 (27)	0.60
Any major complication	190 (22)	27 (20)	163 (23)	0.65
Respiratory	119 (14)	18 (14)	101 (14)	1.00
Cardiac arrest requiring CPR	19 (2)	2 (1.5)	17 (2)	0.75
Neurologic	12 (1)	3 (2)	9 (1)	0.41
Renal	4 (0.5)	0 (0)	4 (0.5)	1.00
Infectious	25 (3)	4 (3)	21 (3)	1.00
Wound	59 (7)	7 (5)	52 (7)	0.58
Unplanned reoperation	77 (9)	13 (10)	64 (9)	0.74
Unplanned readmission	7 (1)	2 (1.5)	5 (1)	0.30
Mortality	15 (1.8)	2 (1.5)	13 (2)	0.49
OTHER				
Total days on ventilator, mean (SD)	7.0 (8.4)	16 (11)	17 (12)	0.37
Unplanned reintubation, n (%)	106 (12)	16 (12)	90 (13)	1.00
Total hospital length of stay, days, mean (SD)	27 (20)	25 (18)	28 (20)	0.14

Abbreviations: SD, standard deviation; CPR, cardiopulmonary resuscitation.
* $p<0.05$ is considered statistically significant.
[a] Any adverse event is a composite variable of any major complication, unplanned reoperation or readmission, or mortality.

Table 2
Preoperative characteristics and comorbidity data in neonates with esophageal atresia, based on operative approach at conclusion of case.

	Thoracoscopy $n = 63$	Converted $n = 70$	Open $n = 722$	p-value
BASELINE CHARACTERISTICS				
Age in days, mean (SD)	2.5 (4.0)	2.1 (2.3)	2.6 (3.3)	0.46
Female, n (%)	20 (32)	27 (39)	299 (41)	0.30
Race, n (%)				0.88
White	44 (70)	43 (61)	470 (65)	
Black	5 (8)	8 (11)	69 (10)	
Other	2 (3)	1 (1)	26 (4)	
Unknown	12 (19)	18 (26)	157 (22)	
Hispanic, n (%)	6 (11)	4 (7)	101 (17)	0.11
Premature, n (%)				0.03*
No (full term)	52 (83)	46 (66)	447 (62)	
35–36 weeks	8 (13)	11 (16)	114 (16)	
31–34 weeks	2 (3)	10 (14)	138 (19)	
25–30 weeks	1 (1.5)	3 (4)	21 (3)	
Preoperative blood transfusion, n (%)	2 (3)	0 (0)	24 (3)	0.30
Preoperative nutrition, n (%)	34 (54)	38 (54)	393 (54)	1.00
Preoperative sepsis, n (%)	1 (1.5)	1 (1)	8 (1)	0.99
Preoperative weight, kg, mean (SD)	2.9 (0.6)	2.6 (0.7)	2.6 (1.4)	0.04*
COMORBIDITIES, n (%)				
Any major comorbidity	49 (78)	51 (73)	545 (75)	0.80
Cardiac risk factors				0.16
None	11 (17)	16 (23)	115 (16)	
Minor	17 (27)	19 (27)	150 (21)	
Major	35 (56)	35 (50)	457 (63)	
Non-cardiac major comorbidity	29 (46)	27 (39)	255 (35)	0.21
Respiratory	22 (35)	22 (31)	169 (23)	0.06
Neurologic	6 (10)	6 (9)	81 (11)	0.85
Gastrointestinal	1 (1.5)	0 (0)	6 (1)	0.49
Renal	0 (0)	0 (0)	1 (0.1)	1.00
Hematologic	3 (5)	2 (3)	51 (7)	0.39
Preoperative mechanical ventilation	12 (19)	20 (29)	202 (28)	0.30
Imperforate anus	1 (2)	6 (9)	64 (9)	0.11
Duodenal atresia	0 (0)	1 (1)	13 (2)	0.85
Trisomy 21	0 (0)	0 (0)	10 (1)	1.00

Abbreviations: SD, standard deviation.
*$p<0.05$ is considered statistically significant.

Table 4
Perioperative and postoperative outcomes in neonates with esophageal atresia, based on operative approach at conclusion of case.

	Thoracoscopy $n = 63$	Converted $n = 70$	Open $n = 722$	p-value
PERIOPERATIVE				
Operative time, minutes, mean (SD)	220 (87)	216 (85)	180 (73)	<0.001*
Blood transfused, mL/kg, mean (SD)	21 (8.8)	22 (15.5)	18 (9)	0.39
COMPLICATIONS, n (%)				
Any adverse event	13 (21)	20 (29)	198 (27)	0.51
Any major complication	10 (16)	17 (24)	163 (23)	0.45
Respiratory	7 (11)	11 (16)	101 (14)	0.75
Cardiac arrest requiring CPR	1 (1.5)	1 (1)	17 (2)	1.00
Neurologic	1 (1.5)	2 (3)	9 (1)	0.35
Renal	0 (0)	0 (0)	4 (0.5)	1.00
Infectious	3 (5)	1 (1)	21 (3)	0.52
Wound	3 (5)	4 (6)	52 (7)	0.82
Unplanned reoperation	7 (11)	6 (9)	64 (9)	0.80
Unplanned readmission	0 (0)	2 (3)	5 (1)	0.19
Mortality	1 (1.5)	1 (1)	13 (2)	0.44
OTHER				
Total days on ventilator, mean (SD)	6.1 (8.4)	6.8 (7.3)	7.1 (8.5)	0.66
Unplanned reintubation, n (%)	6 (10)	10 (14)	90 (13)	0.73
Total hospital length of stay, days, mean (SD)	27.1 (20.5)	22.5 (13.3)	27.8 (19.9)	0.20

Abbreviations: SD, standard deviation; CPR, cardiopulmonary resuscitation.
* $p<0.05$ is considered statistically significant.

vor the thoracoscopic approach with the same degree as touted by uncontrolled studies with a median sample size of 40 patients [4, 7-10], our findings are consistent with other reports, systematic reviews, and meta-analyses based on smaller institutional series, which have found that thoracoscopic repair is associated with longer operating room times but with no major differences in most short- or moderate-term postoperative outcomes [14-20].

We found that the only factors associated with perioperative outcomes were the presence of a major cardiac risk factor and preoperative ventilator dependence. These results suggest that cardiopulmonary morbidity remains the most significant predictor of perioperative outcome after EA/TEF repair and is consistent with findings reported by several other studies, which identified congenital heart disease, other congenital anomalies, preoperative ven-

Table 5
Risk factors associated with 30-day postoperative adverse events after neonatal esophageal atresia repair.

	Univariable Logistic Regression		Multivariable Logistic Regression	
	Odds Ratio (95% CI)	p-value	Odds Ratio (95% CI)	p-value
BASELINE CHARACTERISTICS				
Age in days	0.99 (0.94–1.03)	0.55		
Female	1.01 (0.74–1.38)	0.94		
Race	1.07 (0.95–1.21)	0.25		
Hispanic	0.96 (0.61–1.53)	0.88		
Premature	1.08 (0.91–1.28)	0.36		
Thoracoscopic or thoracoscopic converted to open approaches	1.14 (0.75–1.75)	0.53		
Preoperative transfusion	1.21 (0.52–2.82)	0.67		
Preoperative nutrition support	1.22 (0.90–1.66)	0.19	1.14 (0.83–1.55)	0.37
Preoperative sepsis	1.81 (0.51–6.49)	0.36		
Preoperative weight	0.96 (0.84–1.11)	0.60		
COMORBIDITIES				
Any major comorbidity	1.93 (1.31–2.85)	<0.001		
Major cardiac risk factor	1.53 (1.23–1.91)	0.002	1.48 (1.18–1.85)	0.001
Non-cardiac major comorbidity	1.29 (0.94–1.75)	0.11	1.20 (0.87–1.65)	0.27
Respiratory	1.38 (0.98–1.93)	0.07		
Neurologic	1.05 (0.65–1.70)	0.83		
Gastrointestinal	1.08 (0.21–5.61)	0.93		
Hematologic	1.09 (0.60–1.98)	0.79		
Preoperative mechanical ventilation	1.49 (1.07–2.06)	0.019	1.47 (1.06–2.04)	0.034
Imperforate anus	1.2 (0.73–2.09)	0.44		
Duodenal atresia	0.73 (0.20–2.65)	0.64		
Trisomy 21	0.30 (0.04–2.26)	0.25		

Abbreviations: CI, confidence interval.
*$p<0.05$ is considered statistically significant.

tilator dependence, and low preoperative weight as independent predictors of morbidity [2, 21-24]. Based on our data, we did not find an association between birthweight and adverse events, which may have been due to our exclusion of patients who underwent delayed EA/TEF repair outside of the neonatal period secondary to extreme prematurity and very low birthweight.

Our data showed that thoracoscopic repair can be performed without any increase in short-term complications compared to open repair. Patient selection remains important with larger, full-term neonates more likely to undergo successful thoracoscopic repair. Indeed, the mean birthweight of those undergoing thoracoscopic repair based on a recent meta-analysis ranged from 2.5 to 3.3 kg [20]. Interestingly, neonates in our converted group had lower preoperative weights as well as higher rates of prematurity and preoperative ventilator use that were more similar to those in the open approach group. Although the feasibility of thoracoscopic repair in lower birthweight neonates has been demonstrated [25], our results suggest that low preoperative weight is a risk factor for conversion to open surgery, which was 53% in our series.

The national conversion rates were substantially higher than rates reported in single institutional studies [26], but other investigators have found similar conversion rates [27]. Fortunately, there was little evidence from our study that those who had a converted repair had endured excessively long operative times, adverse events, total ventilator days, or hospital length of stay when compared to those in the other repair groups. The results also support that the presence of a major cardiac risk factor should not be a major contraindication for thoracoscopic repair, a finding that has been suggested in other work [28].

Additional important findings from our study include the low annual rates of thoracoscopic EA/TEF repair being attempted nationwide (16%) and the additional operative time (mean, 40 min) required to complete a thoracoscopic repair. The impact of these prolonged anesthetic times on intraoperative acidosis and hypercapnia is unknown [29]. Moreover, our data revealed that only 7.4% for EA/TEF repairs were being completed thoracoscopically, which is consistent with regional North American data as described elsewhere [29, 30] but much lower than rates of 50% as documented in a survey report [3].

Although thoracoscopic repair may be associated with long-term musculoskeletal and cosmetic advantages compared to open repair, there are a paucity of studies in the literature to support this claim [6, 31, 32]. Additional barriers to more widespread adoption of the minimally invasive approach are multifactorial and likely include concerns about the steep learning curve, the requirement of an advanced endosurgical skill set, and identifying the optimal thoracoscopic repair candidates. Enthusiasts of the minimally invasive approach have touted the superior visualization and dissection the upper esophageal pouch afforded by thoracoscopy, but most surgeons would agree that performing a thoracoscopic anastomosis remains a technically challenging endeavor. The relative rarity of EA/TEF cases required to obtain advanced minimally invasive skills during fellowship training and clinical practice has also been suggested elsewhere [33]. Based on pediatric surgery data from the American Board of Surgery and others, the median number of EA/TEF cases per surgeon per year in the United States is one (interquartile range, 0–3; mean, 1.5) [34]. Some surgeons have recently suggested that ten thoracoscopic cases are required before the learning curve begins to flatten [35]. In the final year of data analyzed in our study, an attempt at thoracoscopic repair increased in 22% of cases, but the conversion rate also increased to 68%. Given the fact that thoracoscopic EA/TEF has now been performed for three decades, it is likely that both more widespread use and better outcomes with this technique will only be facilitated by more deliberate programmatic efforts to address the learning curve. Such strategies might include acquiring greater technical competence using high-fidelity simulators, increasing sub-specialization in EA/TEF repair, establishing formal proctoring of thoracoscopic EA/TEF cases within group practices, and/or developing novel technologies aimed at making the technical aspects of thoracoscopic repair less challenging [11, 36-40].

Although we believe that the aforementioned findings of our work are informative, several limitations should be acknowledged. First, our results may not apply to non-NSQIP-P centers that may have differing expertise and resources in the management of these complex patients. Second, despite our initial dataset of over one thousand patients, the study may still be susceptible to type II error since the number of thoracoscopic repairs within the co-

hort was still relatively low and some postoperative complications were uncommon. Third, as with all retrospective database studies, the data is susceptible to coding errors for procedure and other key variables. It is certainly possible that unmeasured factors may have influenced surgical outcomes and confounded the analysis. We were not able to account for surgeon/hospital case volume or experience, which may be critical for assessing clinical outcomes in these children. Finally, we are subject to shortcomings of NSQIP-P measured outcomes, which only include perioperative data within the first 30 days following surgery and do not record procedure-specific outcomes such as anastomotic leak and time to oral feeds [10]. Obviously, other key postoperative morbidities that can occur months or years after EA/TEF repair, such as anastomotic stricture, recurrent TEF, vocal cord paralysis, gastroesophageal reflux, and musculoskeletal morbidity, could not be assessed by our work [20, 31, 32, 41-46].

5. Conclusions

This comparative effectiveness study using NSQIP-P shows that thoracoscopic neonatal repair of EA/TEF continues to be used sparingly and is associated with high conversion rates to open repair. The mean additional operative time with thoracoscopic repair was 40 min, and the short-term impact of the procedure appears to be minimal when compared to open approach, despite evidence for a less premature cohort of patients undergoing minimally invasive repair. More widespread use of thoracoscopic EA/TEF repair and better postoperative outcomes will require more deliberate programmatic efforts to address the learning curve.

Disclosure statement

No competing financial interests exist, and all authors have nothing to disclose.

Declaration of Competing Interest

The authors indicate no potential conflicts of interest.

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