Original Article

Evaluation of Risk Factors for Anastomotic Complications after Surgical Repair of Esophageal Atresia

Tamara Hasan Abdullah[1], Ali Egab Joda[2]

[1]Department of Pediatric Surgery, Child Central Teaching Hospital, Baghdad, Iraq, [2]Head of Pediatric Surgery Training Center, College of Medicine, Child Central Teaching Hospital, Mustansiriyah University, Baghdad, Iraq

Abstract

Background: The most common and significant complications following surgical repair of esophageal atresia (EA) are related to esophageal anastomosis, and it greatly affects the overall outcomes. Although several factors have been implicated in the development of esophageal anastomotic complications, it is still unclear how we can predict these complications and the best way to prevent or at least decrease them. **Objective:** To identify and evaluate the risk factors for anastomotic complications after primary repair of EA. **Patients and Methods:** This was a prospective study of neonates having EA with primary surgical repair treated in a child central teaching hospital from June 2020 to December 2022. Analysis includes assessment of demographic data and clinical variables with recording the incidence of complications related to esophageal anastomosis. The enrolled patients were divided into two groups: those with an anastomotic complication (Group AC), including stricture, leak, and recurrent tracheoesophageal fistula (TEF) and those with no anastomotic complications (Group NAC). Then, we compared these two groups regarding the influence of these variables as suggested risk factors affecting the outcomes. **Results:** Of the total 63 patients diagnosed with TEF, 39 of them met the inclusion criteria. Twenty-two patients (56.4%) had early anastomotic complications, 19 patients (48.7%) had anastomotic leaks, 11 patients (28.2) had anastomotic stenosis, and 1 patient (2.6%) developed a recurrent fistula. Multivariate logistic regression analysis among the complication group reveals that aggressive esophageal mobilization, intermediate gap, anastomosis under tension, type of sutures, and neck flexion have significant statistical value. **Conclusions:** There is no correlation between variables of sex, body weight, gestational age, time of repair, use of transanastomotic feeding tube, and type of approach with the development of anastomotic complications. Variables of aggressive esophageal dissection, anastomosis under tension, intermediate gap, the use of non-absorbable sutures, and absent neck flexion postoperatively were identified as risk factors for early anastomotic complications.

Keywords: Anastomotic complications, esophageal atresia, neonate

Introduction

Esophageal atresia (EA) is a congenital abnormality where the esophageal lumen is blocked, usually with the presence of a tracheoesophageal fistula (TEF) that forms an abnormal link to the trachea at one or more locations.[1]

The primary repair of the EA/TEF abnormality is considered the preferred surgical option and achieves the best results.[2] The surgical options for EA/TEF repair include open thoracotomy or video-assisted thoracoscopic surgery.[3] The standard approach remains a right posterior-lateral, muscle-sparing thoracotomy in the 4th interspace adopting an extrapleural approach.[3,4]

In open thoracotomy, traditionally, subcutaneous tissues and chest wall muscles are divided to elevate the scapula over the fourth intercostal space. Many surgeons now prefer a muscle-sparing technique that spreads rather than divides the serratus anterior and latissimus dorsi muscles, in an attempt to decrease postoperative pain and the long-term morbidity of chest wall and spinal deformities.[4]

Complication rates after EA/TEF repair may be considered as a normal scenario rather than a consequence. Common complications that occur shortly after surgery include the leakage

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Address for correspondence: Prof. Ali Egab Joda, College of Medicine, Child Central Teaching Hospital, Mustansiriyah University, Baghdad, Iraq.
E-mail: ali.egab.joda@gmail.com

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of the anastomotic site, stenosis of the surgical anastomosis, and the recurrent fistulous connection between the trachea and esophagus. On the other hand, long-term complications that may arise after surgery include gastroesophageal reflux disease, respiratory problems, and difficulties with the peristalsis of the esophagus (esophageal dysmotility).[1]

Aim of the study

To identify and evaluate the risk factors for esophageal anastomotic complications after primary repair of EA with or without TEF.

Patients and Methods

The ethical approval for the proposal of this study was obtained by the Iraqi board for medical specialization and hospital authority in addition to the verbal consent that was taken from all patients' parents and caregivers for enrollment in the study.

The study was conducted at a single center and included neonates and infants who were diagnosed with TEF and underwent a primary surgical anastomosis. The research was carried out for 30 months, starting in June 2020 and concluding at the end of December 2022.

Inclusion criteria

Both male and female eligible patients were included in the study. They were treated surgically with thoracotomy, primary esophageal anastomosis, division, and ligation of the TEF if present, followed up for 6 months for the development of anastomotic complications.

Exclusion criteria

The following patients were not included in the study:

1. Those who underwent only TEF ligation without primary esophageal anastomosis
2. Patients had gastrostomies only
3. Patients with lost follow-up
4. Patients who died preoperatively or shortly postoperatively due to nonanastomosis complications.

The variables included in the dataform were selected based on previous research that highlighted their association with outcomes.

The outcomes of interest were mortality and complications specifically related to anastomoses. To ensure accuracy and consistency, clear and validated definitions were provided for all variables and complications whenever possible.

The enrolled patients were divided into two groups: Those with an anastomotic complication (Group AC), including esophageal anastomotic stricture EAS, esophageal anastomotic leak EAL, or recurrent TEF and those without any anastomotic complications (Group NAC). Then, we compared these two groups regarding the influence of these variables as suggested risk factors on the outcomes by subjecting the data to statistical analysis and logistic regression tests.

Clinical assessment and workup of patients

All patients underwent a complete evaluation, which included a careful history, physical examination, and confirmative radiological films. We also check for other associated anomalies, such as imperforate anus, skeletal anomalies, or cardiac problems. The patient's weight and vital signs were recorded.

Preoperative workup consists of blood tests, giving humidified oxygen, glucose-containing maintenance fluids, and maintenance of body temperature, a cross-match blood test is obtained for the preparation of blood, and a NICU bed should be available to the patient if needed preoperatively and for postoperative follow-up and management. With the use of a suction tube during neonatal care preoperatively, the upper esophageal pouch is continuously suctioned using a small NG tube, which is connected to a continuous low-pressure suction of 15–35 cm H_2O to avoid aspiration pneumonia.

Surgical technique

We use Lanman's right posterolateral retropleural thoracotomy approach at the 4th intercostal space as the usual approach of surgery. On entering the mediastinum, we ligate the azygos vein and divide it so we can identify the fistula site.

Identification and ligation of the fistula proximal to its attachment to the trachea by a 2-0 silk suture, then we disconnect the fistula from the trachea. The upper pouch of the esophagus is mobilized using a nontouch technique, where the tissue surrounding the pouch is grasped instead of the esophagus itself.

Dissection is made easier by placing a 5-0 suture at the lowest point of the upper pouch to prevent traction without the need for instruments. Due to the abundant submucosal blood supply, a generous dissection of the upper pouch is performed.

Blunt dissection by Lehi is another method that yields good results. Anastomosis of the posterior wall of the esophagus by watertight suturing, we pass TAFT for early postoperative gavage feeding (according to the surgeon's preference). The sutures used in this study were either 5-0 or 6-0, absorbable suture material (Vicryl), or non-absorbable (silk) according to surgeon preference.

Proton pump inhibitors (omeprazole in a dose of 1 mg/kg/day) are routinely used in the postoperative treatment of patients. After the surgery, the baby is taken back to the neonatal intensive care unit while being ventilated and with the neck kept flexed to minimize tension on the anastomosis. Our goal was to minimize the need for reintubation during the postoperative period. It is important to perform regular suctioning of the mouth, in the first few days after the surgery.

To ensure clarity, the suction catheter is clearly labeled for both the family and nursing staff to prevent the tube from being passed to the site of the anastomosis and causing damage. Early transnasogastric feeding is started as soon as possible. A contrast swallow examination (esophagogram) is done

routinely 5–7 days after anastomotic surgery, and feeding starts afterward if normal.

Outcomes and anastomotic complications

Various early postoperative complications were documented, including anastomotic leakage, anastomotic stricture, and recurrent TEF. Significant anastomotic leaks manifest when a substantial amount of contrast medium seeps from the anastomosis into the mediastinum, resulting in symptoms such as drainage from the chest tube, rapid deterioration accompanied by life-threatening pneumothorax, fluid accumulation, or sepsis.

While minor leaks were noticed during the contrast study done prefeeding. Anastomotic stricture AS was defined during follow-up visits as narrowing in the esophageal lumen on contrast study with symptomatic difficulty in swallowing that required dilatation. The initial esophagogram was conducted between the 5th and 7th days after surgery to exclude any anastomotic disruption or leakage and commence enteral feeding once the patient had been extubated and it was deemed safe to do so.

Subsequent esophagograms were carried out during follow-up appointments to monitor for complications, particularly anastomotic strictures, or as deemed necessary based on the patient's clinical condition, such as difficulty in feeding, regurgitation, vomiting, or inadequate weight gain. Recurrent TEF or undiagnosed second TEF was suspected in infants with feeding difficulties and recurrent chest infections and confirmed by bronchoscopy or contrast study.

Results

A total of 63 patients diagnosed with different types of EA were managed in our pediatric surgical center, as shown in Figure 1.

39 patients of 63 met the inclusion criteria and underwent TEF closure with primary esophageal anastomosis. Early postoperative death was the most frequent cause of exclusion from this study ($n = 16$), followed by preoperative death ($n = 3$), need for multistaged operations ($n = 2$), lost follow-up ($n = 2$), and 1 patient discharged on his responsibility preoperation. The patient's demographic and operative characteristics are outlined in Table 1.

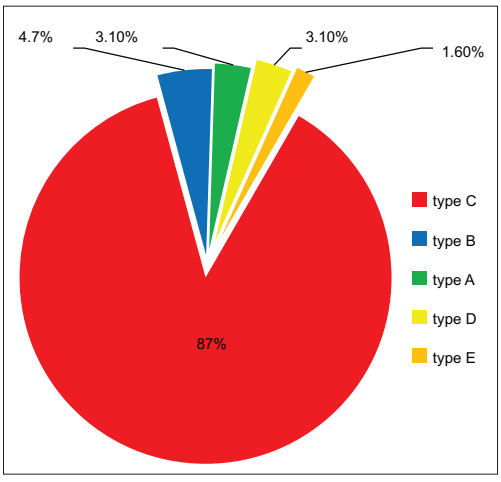

Figure 1: Types of esophageal atresia

Table 1: The demographic, operative characteristics, and early postoperative outcomes of patients

Variables	Frequency (%)
Gender	
Male	22 (56.4)
Female	17 (43.6)
Gestational age (weeks)	
<37	5 (12.8)
≥37	34 (87.2)
Weight (g)	
<2500	12 (30.8)
≥2500	27 (69.2)
Age at time of repair (days)	
<3	18 (46.2)
≥3	21 (53.8)
TAFT	
Yes	35 (89.7)
No	4 (10.3)
Approach	
Extrapleural	32 (82.1)
Transpleural	7 (17.9)
Esophageal mobilization	
No touch	32 (82.1)
Aggressive	7 (17.9)
Gap	
Intermediate	28 (28.2)
Short/overlapping	11 (71.8)
Anastomosis under tension	
Yes	12 (30.8)
No	27 (69.2)
Type of suture	
Absorbable	34 (87.2)
Nonabsorbable	5 (12.8)
Number of sutures	
<8	17 (43.6)
≥8	22 (56.4)
Neck flection	
Yes	32 (82.1)
No	7 (17.9)
Anastomotic complication	
Yes	22 (56.4)
No	17 (43.6)
Leak	
Yes	19 (48.7)
No	20 (51.3)
Stenosis	
Yes	11 (28.2)
No	28 (71.8)
Recurrent fistula	
Yes	1 (2.6)
No	38 (97.4)

TAFT: Transanastomotic feeding tube

The *P* value obtained from statistical analysis was found to be statistically significant. This information is presented in the accompanying Table 2. The results of multivariate logistic regression analysis among the complication group are used to predict the relationship between dependent outcomes and independent variables. It calculates the probability of the development of anastomotic complications depending on sets of variables. Table 3 demonstrated that the logistic regression analysis of risk factors for anastomosis complications was as follows:

aggressive esophageal mobilization (odd ratio 0.43) (confidence interval [CI] =0.039–0.837), intermediate gap (odd ratio 0.001) (CI = 1.000–1.004), anastomosis under tension (odds ratio 0.039) (CI = 2.931–87.354), type of sutures (odd ratio 0.001) (CI = 1000–1.004), and neck flexion (odds ratio 0.037) (CI = 2.023–12.84).

Discussion

Enhancing outcomes in esophageal surgery can be efficiently achieved by reducing errors caused by human factors. By predicting the possible risk factors for the development of anastomotic complications and attempting to alleviate them,[2] several articles have examined variables that could potentially forecast both immediate and long-lasting complications associated with the EA and its surgical correction.[5,6]

The most extensive data compilation on anastomotic complications comes from a study conducted by the surgical department of the American Academy of Pediatrics, which involved 747 patients. This study revealed a significant enhancement in the survival rate over the last 25 years. Despite this progress, anastomotic complications continue to persist,

Table 2: Statistical analysis of patient's variables as risk factors for development of anastomotic complications

Variables	No complications group (*n*=17), *n* (%)	Complication group (*n*=22), *n* (%)	*P*
Gender			
Male	10 (58.8)	12 (54.54)	0.523
Female	7 (41.2)	10 (45.45)	0.332
Weight (g)			
<2500	6 (35.2)	6 (27.27)	0.108
≥2500	11 (64.8)	16 (27.27)	0.672
Gestational age (weeks)			
<37	4 (23.2)	1 (4.45)	0.375
≥37	13 (76.8)	21 (95.54)	0.085
Age at time of repair (days)			
<3	8 (47.1)	10 (45.45)	0.481
≥3	9 (52.9)	12 (54.54)	0.383
TAFT			
Yes	15 (88.2)	20 (90.9)	0.175
No	2 (11.8)	2 (9.1)	1.000
Approach			
Extra-pleural (32)	13 (76.8)	19 (86.4)	0.678
Trans-pleural (7)	4 (23.2)	3 (13.6)	0.210
Esophageal mobilization			
Aggressive	0	7 (31.8)	0.043*
No touch	17 (100)	15 (68.2)	0.347
Gap			
Intermediate	7 (41.1)	21 (95.54)	0.001*
Short	10 (58.9)	1 (4.45)	0.102
Tension anastomosis			
Yes	2 (11.8)	10 (45.45)	0.039*
No	15 (88.2)	12 (54.54)	1.000
Type of suture			
Non absorbable	0	5 (22.7)	0.001*
Absorbable	17 (100)	17 (77.3)	0.023*
Number of sutures			
<8	7 (41.1)	10 (45.45)	0.481
≥8	10 (58.9)	12 (54.54)	0.383
Neck flection			
Yes	15 (88.2)	17 (77.3)	0.037*
No	2 (11.8)	5 (22.7)	0.045*

*Less than 0.05 is significant value. TAFT: Transanastomotic feeding tube

Table 3: Logistic regression analysis between risk factors and anastomotic complications

Variables	Significant	CI	Lower limit	Upper limit
Esophageal mobilization	0.043*	0.181	0.039	0.837
Gap	0.001*	1.002	1.000	1.004
Tension anastomosis	0.039*	16.000	2.931	87.354
Type of suture	0.001*	1.002	1.000	1.004
Neck flection	0.037*	1.003	2.023	12.84

*Less than 0.05 is significant value. CI: Confidence interval

with leakages occurring in approximately 20% of cases, strictures in 15% of cases, and recurrent TEF in 5% of cases.[7]

Our rates of anastomotic complications were higher: 48.7% for leaks (including major and minor), 28.2% for strictures, and 2.6% for recurrent TEF. Our relatively higher incidence of strictures since early postoperative contrast esophagograms is a standard policy utilized before oral feeding was initiated in our center; asymptomatic minor leaks are readily evaluated. The difference in these results may also be due to the differences in the definition of the complications, in addition to the confounding factors among the variables in the study.

In our analysis, the rate of complications was higher in males (n = 54.54%) compared to females (n = 45.45%), with P = 0.523 for males and P = 0.323 for females; gender of the patient did not impact anastomosis complications incidence. The same results in Okata *et al.*'s and Kumar *et al*.'s data analysis for gender impact on postoperative AC.[6,8] Prematurity is strongly associated with low birth weight. Therefore, the postoperative outcome of EA/TEF patients has been commonly evaluated relating to body weight at birth.[9,10] Durkin *et al*. supported the surgical repair of a primary anastomosis in VLBW or ELBW in the absence of other significant malformation infants with EA/TEF.[11] A recent risk analysis did not identify any association between birth weight and the occurrence of anastomotic complications following repair of EA/TEF,[6] This is the same result we reached in our research.

Timing of correction did not impact the postrepair AC, in our analysis of the results, although the ratio of early repair complications was 45.45%) which is lower than the late repair, which is more than 3 days of the patient's age (54.54%). On the contrary, in 2009 Nasher *et al.* concluded that delayed repair is associated with lower complication risk in EA patients.[10] The benefits of repairing EA/TEF early are widely acknowledged, including the establishment of early esophageal continuity, reduced risk of aspiration, earlier enteral feeding, and avoidance of additional interventions. Gap length is quite variable.[2-11]

Our data analysis demarcated the gap length to be a significant factor in predicting AC with a P = 0.001 for the intermediate gap group. Dudley and other workers considered a length of >2 cm gap to be an LGEA and found it to have a high risk of postoperative anastomotic leak.[5,12] In 2022, Hong *et al*. developed a new predictive index for anastomotic leak after anastomosis of EA and concluded that gap length and birth weight are important predictors of anastomotic leak.[13] Shah *et al*. also concluded that the gap length between the two ends of the esophagus is an important factor that can predict the likelihood of developing esophageal strictures.[14] Anastomotic tension is a subjective variable, yet no specific tool has been developed to measure the tension across esophageal anastomosis. Historically reports that anastomosis under tension was the only independent risk factor of esophageal ACs.[13] Okata also reported that anastomosis tension was one of the significant risk factors affecting postoperative AC in EA.[6] Our study here showed that tension anastomosis is one of the factors that affect early postoperative complications with P = 0.001.

The classic learning is to avoid extensive dissection of the distal esophageal pouch due to its segmental blood supply from the thoracic aorta. In 1950, an esophageal anatomy study stated that only 20% of esophageal blood supply originated from the segmental thoracic aorta branch and that the abdominal esophagus provides it with rich collateral blood supply mainly from the left gastric artery and left inferior phrenic artery.[14,15] Based on this report, dissection of the esophagus is feasible.[15] Our patients who needed dissection and mobilization of esophageal the distal pouch had a significant positive predictive value producing postoperative AC, and this result supports the classical thesis.

The role of the suture materials utilized in the anastomosis has been suggested to be significant in the formation of a subsequent stricture.[16] A study indicated that the use of braided silk sutures was linked to a higher occurrence of postoperative anastomotic leakage in comparison to polyglycolic acid or polypropylene sutures.[16] According to Touloukian's study, the use of fine (5-0) silk sutures was associated with a low stricture rate of 6%. This suggests that the choice of suture material, specifically fine silk sutures, may have a positive impact on reducing the incidence of stricture formation. According to the reports, there was no correlation found between the type of suture material (absorbable or non-absorbable) used in the anastomosis and the rate of stricture formation. In addition, there was no correlation found between the size of the suture utilized in the anastomosis and the development of stricture formation.[17] In 2007, St Peter *et al*. concluded that the selection of sutures employed for esophageal anastomosis during EA repair does not seem to be the most crucial determinant in the development and severity of postoperative stricture formation.[18] In our cases, the type and size of sutures used for anastomosis were silk or vicryl sutures, either 5-0 and/or 6-0, according to the surgeon's preference and suture availability. This study has demonstrated a clear association between the use of braided silk and an increased incidence of anastomotic complications. This suggests that the choice of suture material may play a significant role in the development of complications in the anastomosis (P = 0.001), whereas absorbable sutures like polyglycolic acid and polypropylene sutures (P = 0.023),

while the number of sutures used in the anastomosis didn't influence the AC incidence with *P* values (0.481 and 0.383).

The extrapleural approach is more preferred than the transpleural; Batekhe concluded that there was no significant difference between the two approaches regarding mortality, but higher rates of pneumothorax in the transpleural approach were recorded.[19] In this study, 82.1% of cases were transpleural, and 87% of them are AC groups. While 17.9% of the cases were transpleurally approached and 12.5% of them had anastomotic complications, no significant effect was noticed when determining the *P* value for either approach. However, the length of the surgical procedure was observed to be shorter in the transpleural approach as a result of the time required for delicately separating the pleura from the chest wall in the extrapleural approach. Nevertheless, a comprehensive investigation is necessary to assess the effectiveness of the extrapleural approach in facilitating spontaneous closure in the event of leakage. LaRusso *et al*. conducted a multicenter study on 244 patients with EA/TEF and concluded that the utilization of TAFT is linked to a notably increased likelihood of postoperative stricture after the repair of EA/TEF, while it does not reduce the duration of total parenteral nutrition.[20] In our cases, TAFT use was according to the surgeon's preference, and the TAFT use had no major effect on anastomotic complications.

This study offers initial evidence regarding the potential benefits of trans-anastomotic tubes. However, it is important to note that larger prospective studies will be necessary to definitively establish and demonstrate these benefits. In addition to previously mentioned preoperative or intra-operative surgical techniques, it was reported that postoperative head flexion will push the previously mobilized proximal pouch (2.5–3) cm distally, this decreases anastomotic tension. The neck flexion technique has a significant effect on postoperative anastomotic complications, with $P = 0.037$ for neck flexed patients, and a $P = 0.045$ for patients who needed re-intubation postoperatively, either due to tube blockage or dislodgement.

There are several limitations in this study.

- Many factors contribute to the timing of repair for patients with EA/TEF, such as early diagnosis, available rapid transportation to pediatric surgery centers, and the availability of NICU beds or ventilators
- Limitation of resources in theater
- It was difficult to measure precisely the gap length and the timing of measuring the gap between the esophageal pouches. The evaluation of tension is a matter of personal judgment, and all researchers usually faced challenges in accurately measuring this factor.

Conclusions

- There are several perioperative risk factors with statistically significant value associated with the development of esophageal anastomotic complications like aggressive dissection and/or mobilization of the esophageal pouch, intermediate gap between the upper and lower esophageal pouches, anastomosis under tension, use of non-absorbable sutures and absent neck flexion in the postoperative period
- Other risk factors like birth weight, gender, gestational age, time of repair, use of TAFT, surgical approach, and number of sutures used in anastomoses were not statistically significant predictors for anastomotic complications
- Reduction in complication rate especially related to esophageal anastomosis can be done by correcting some modifiable perioperative risk factors.

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Conflicts of interest

There are no conflicts of interest.

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