Original Article

# Critical Role of Pleural Wrap and Post-operative Neonatal Protocol in Long-gap Oesophageal Atresia: A Team Effort

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## Abstract

**Background:** The objectives of this study were to bring out the results of application of pleural wrap in primary repair of tracheo - esophageal fistula (TEF) with long-gap oesophageal atresia (LGEA) and also define the role of neonatologists and paediatric intensivists in post-operative management in these patients by laying down standard neonatal management protocol. **Materials and Methods:** This was a retrospective descriptive observational study conducted between March 2011 and April 2019 on 23 cases of LGEA with TEF. The study was conducted at two tertiary care paediatric surgery centres in Northern part of India wherein these newborn babies were operated by two paediatric surgeons with variable experience of 8–12 years. It also describes the neonatal management protocol used in post-operative period. **Results:** Out of 23 patients, 15 were boys and 8 were girls, with a mean age of 32.25 weeks and a mean birth weight of 2.02 kg. The mean hospital stay was 23.5 ± 8 days. Eleven cases had gap between 3 and 3.5 cm, 8 cases between 3.5 and 4 cm and 4 cases had gap more than 4 cm. The incidence of associated anomalies was 52%. Anastomotic leak rate was 8.69%, and 3 (13.04%) patients died in the post-operative period. All the operated patients were managed postoperatively as per strict neonatal management protocol exclusively by the team of neonatologists and neonatal intensivists. **Conclusion:** Application of pleural wrap over anastomosis following primary repair of LGEA with TEF significantly reduced the incidence of anastomotic leak in our study. Apart from the pleural wrap, the key to successful outcome also is contributed by the little prolonged, controlled ventilation and patience and perseverance in post-operative feeds. This post-operative management protocol that has been followed by us in our study is easily reproducible and can be adopted by paediatric surgeons working alongside neonatologists as a team.

**Keywords:** Anastomotic rate, long-gap oesophageal atresia, neonatal management protocol, neonatologists, pleural wrap, tracheal oesophageal fistula

## Introduction

Oesophageal atresia (EA) is a congenital defect in which the upper oesophagus ends in a blind pouch and is not connected to the lower oesophagus. It is often associated with a tracheo-oesophageal fistula (TEF) that represents an abnormal opening between the trachea and the oesophagus.[1] EA is divided into long-gap oesophageal atresia (LGEA) and non-LGEA. LGEA with TEF is defined by the gap length between the upper and lower oesophageal segments of more than 3 cm or more than two vertebral bodies making the gap too big to repair by primary anastomosis.[1-6] This distance ultimately decides the timing and ease of repair. LGEA with TEF is associated with high morbidity, and there is a lack of consensus regarding surgical management.[7]

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Preservation of the native oesophagus is the surgeon's priority because it represents the best conduit, even if its peristaltic activity is usually abnormal. Delayed repair requires a long hospitalisation, but it enables the growth of the two oesophageal stumps, either by external manoeuvres or spontaneously.[8] Children whose oesophagus is preserved seem to have a better outcome in terms of swallowing function and gastro-oesophageal reflux.[9] The pulmonary status of these children remains fragile and with high risk of aggravation after surgery (whether primary repair or delayed reconstruction).[10] When a primary anastomosis is not possible, oesophageal

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replacement becomes necessary. Many techniques exist for oesophageal replacement: gastric transposition, interposition of the colon, the tubularized stomach,[9] the reversed gastric tube[11] or the small intestine with a free[12] or pedicle graft.[13,14] Colonic interposition still represents one of the most commonly used techniques for oesophageal replacement in children.[15]

Under primary repair of LGEA with TEF, proximal stump mobilisation and myotomy is by far the most preferred technique. However, a combination of proximal and distal circular myotomies to achieve oesophageal lengthening facilitating primary tension-free repair has also been reported.[16,17] These procedures have a potential risk of serious vascular compromise with a subsequent oesophageal leak.[18] This stems from the fact that blood supply to the oesophagus is unique such that it has a segmental blood supply [Figure 1a]. The cervical portion is supplied by the inferior thyroid artery. The thoracic portion is supplied by bronchial and oesophageal branches of the thoracic aorta. The abdominal portion is supplied by ascending branches of the left phrenic and left gastric arteries. Proximal pouch blood supply follows a superior to inferior course in the submucosa[19] potentially making its mobilisation and circular myotomy a relatively safe procedure.[20-22] On the other hand, distal oesophageal pouch receives its blood supply through vessels which run horizontally with insufficient vascular anastomoses between the various branches.[16] This raises concerns for potential ischaemia secondary to distal pouch mobilisation, due to which circular myotomy is rarely recommended for the distal stump.[19]

The anastomotic leak rate in LGEA with TEF has been reported to be as high as 100%.[23] Several factors play a role in pathophysiology of anastomotic leak such as friable lower segment, ischaemia of the oesophageal ends, sepsis, poor handling of the oesophageal ends, poor suturing techniques, type of suture used and excess anastomotic tension.[7]

Surgical repair is the only definitive treatment with good outcome in the majority of the patients.[24] Right posterolateral thoracotomy (PLT) through extrapleural approach through fourth intercostal space is a common technique of surgery.[25]

Pleura is a serous membrane that folds back on itself to form a two-layered membranous pleural sac. The outer layer is called the parietal pleura and attaches to the chest wall. The inner layer is called the visceral pleura and covers the lungs, blood vessels, nerves and bronchi. The visceral pleura receives its blood supply from the bronchial circulation, while the parietal pleura receives its blood supply from the intercostal, thoracic and musculophrenic arteries [Figure 1b].[26]

In our study, we have utilised the fact that rich vascularity of pleura can be used to augment the vascularity of the under-tension oesophageal ends and thus the strength of oesophageal anastomosis in primary repair of LGEA with TEF which can reduce the rate of anastomotic leak and result in better outcome including survival. We have also brought out the importance of neonatologists and neonatal intensivists as an integral part of the team in post-operative period which has a crucial role in overall outcome of the surgery.

## Materials and Methods

This was a retrospective descriptive observational study conducted between March 2011 and April 2019 on 23 cases which include 15 girls and 8 boys between 29 weeks and 35.5 weeks with birth weight ranging between 950 g and 3.1 kg. This study was conducted at two tertiary care paediatric surgery centres in Northern part of India wherein the newborn babies were operated by two paediatric surgeons with variable experience of 8–12 years.

### Management protocol

A right PLT was done for all cases with extrapleural approach. After ligation of the azygous vein, the lower pouch fistula was delineated. Gap between the upper and lower pouches was measured by introducing a stiff rubber tube through oral route by an anaesthetist, and the distance between the gently stretched/pushed upper pouch and the lower pouch prior to the fistula division was measured.

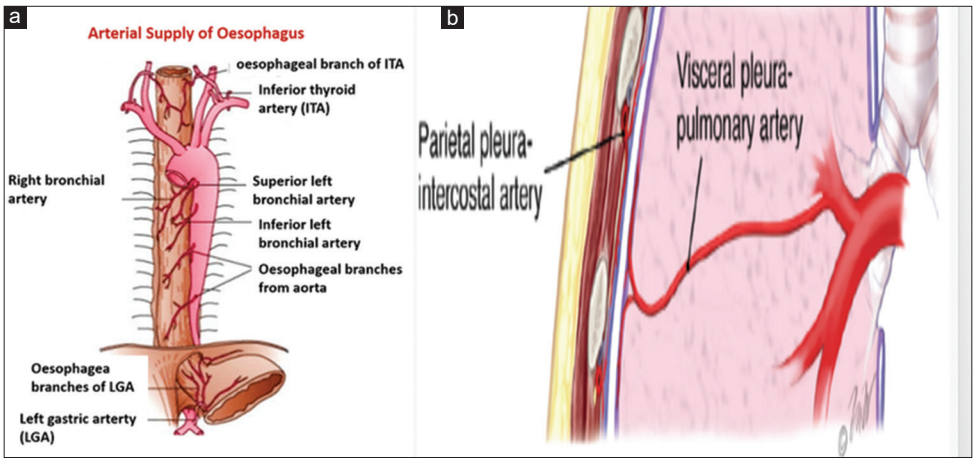



**Figure 1:** Blood supply of esophagus (a) and pleura (b)

After full mobilisation of the upper pouch up to the root of neck, additional mobilisation of the lower pouch right up to the diaphragm was also done ensuring minimal gentle handling of the oesophageal segments and least amount of compromise to the vascularity of lower pouch. Circular myotomy was not done in any of the cases. However, a lazy 'S' myotomy was performed in 9 (39.13%) cases to achieve adequate length. This was adopted with an aim to preserve maximum vascularity of upper pouch as the blood supply to the oesophagus runs parallel to the wall before penetrating [Figure 1]. Hence, giving a circular incision may result in complete disruption of blood supply to that part whereas lazy S would presumably avoid complete division of the vessels [Figure 2]. The anastomosis was completed using the conventional operative steps over 6 F infant feeding tube with interrupted 5/0, round-bodied, polyglactin sutures. Once the anastomosis was completed, the pleura was purposefully opened with the intent of mobilising a vascularised flap to encircle the oesophageal anastomosis in a posteroanterior fashion [Figure 3]. The rest of the pleura were opened up all around so that there was no entrapment of air in the dead space. All patients were electively ventilated in post-operative period by the team of neonatologists and intensivists and managed as per our post-operative neonatal management protocol [Figure 4].

## Immediate post-operative period (up to 3–6 days)

### *Ventilation*

Neonates were ventilated on pressure control synchronised intermittent mandatory ventilation mode for a variable period of time ranging from minimum 3 days to 6–7 days in some cases. Ventilation targets were a pre-ductal saturation on pulse oximetry (SpO2) between 92% and 95% while maintaining the partial pressure of carbon dioxide between 35 and 50 mmHg. Weaning of ventilator pressure and inspired oxygen concentration (FiO2) was done as tolerated by the neonates. The team of neonatologists ensured that the babies were intentionally ventilated for little longer than usual practice in order to avoid neck extension and excessive swallowing in an awake baby.

### *Analgesia and neonate position*

All neonates were given thoracic epidural anaesthesia and sedated using midazolam infusion. Injection morphine at 50–100 µg/kg IV 6–8 hourly was preferred over fentanyl as the latter may cause board-like rigidity of chest and affects ventilation. Meticulous care was taken to prevent extension of neck, accidental dislodgement of transanastomotic gastric feeding tube. Airway clearance was done using aseptic technique on a case-to-case basis while routine decompression of stomach was done in all neonates.

### *Fluid therapy with supplements*

Infusion of electrolyte-free 10% dextrose solution with calcium was given as per the maintenance requirement. Intravenous preparation of amino acids (10% Aminoven Infant) was added after 24 h beginning at 2 g/kg/day. Addition of sodium and potassium to infusion was deferred till the end of 72 h. Intravenous lipid preparation (20% Intralipid/soyabean oil 30%, medium MCT 30%, olive oil 25% and fish oil 15% [SMOF]) was initiated alongside dextrose-amino acid mixture, beginning at a rate of 1 g/kg/day. Volume/volume (v/v) replacement of gastric aspirates was done using half-strength saline.

## Post-extubation period (post-operative days 4–8)

### *Physiotherapy*

Neonates were directly extubated to head-box oxygen with avoidance of non-invasive ventilation once FiO2 reached 0.28. Gentle tapping chest physiotherapy and nebulisation with normal saline were done.

### *Intercostal drain*

ICD was monitored for movement of the water column, colour, nature and volume of the discharge. Neonates were weaned off oxygen while maintaining the SpO2 of 92%–95%. As a protocol, ICD was removed after the result of oral contrast esophagogram. However, in 2 (8.69%) cases, the ICD got pulled out accidentally around 7–9$^{th}$ post-operative day, and in 2 (8.69%) cases with anastomotic leak, ICD was not removed.

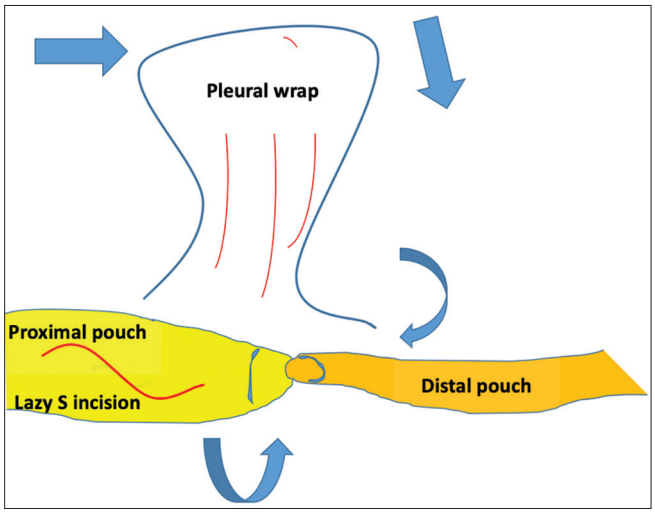



**Figure 2:** Lazy S incison on proximal pouch

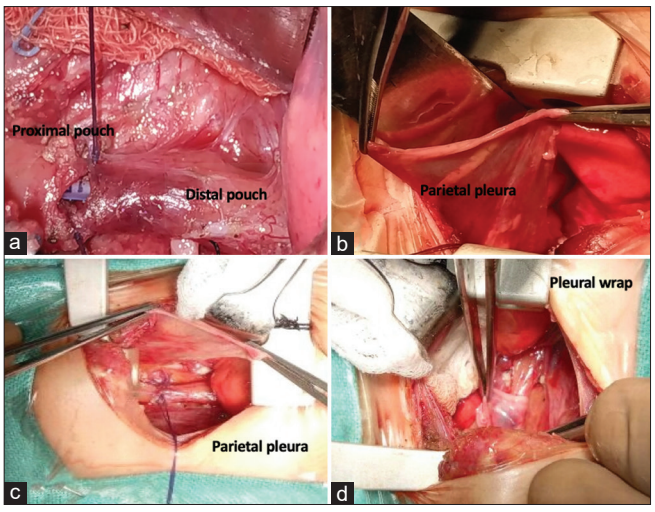



**Figure 3:** Pleural wrap reflected to cover the anastomosis

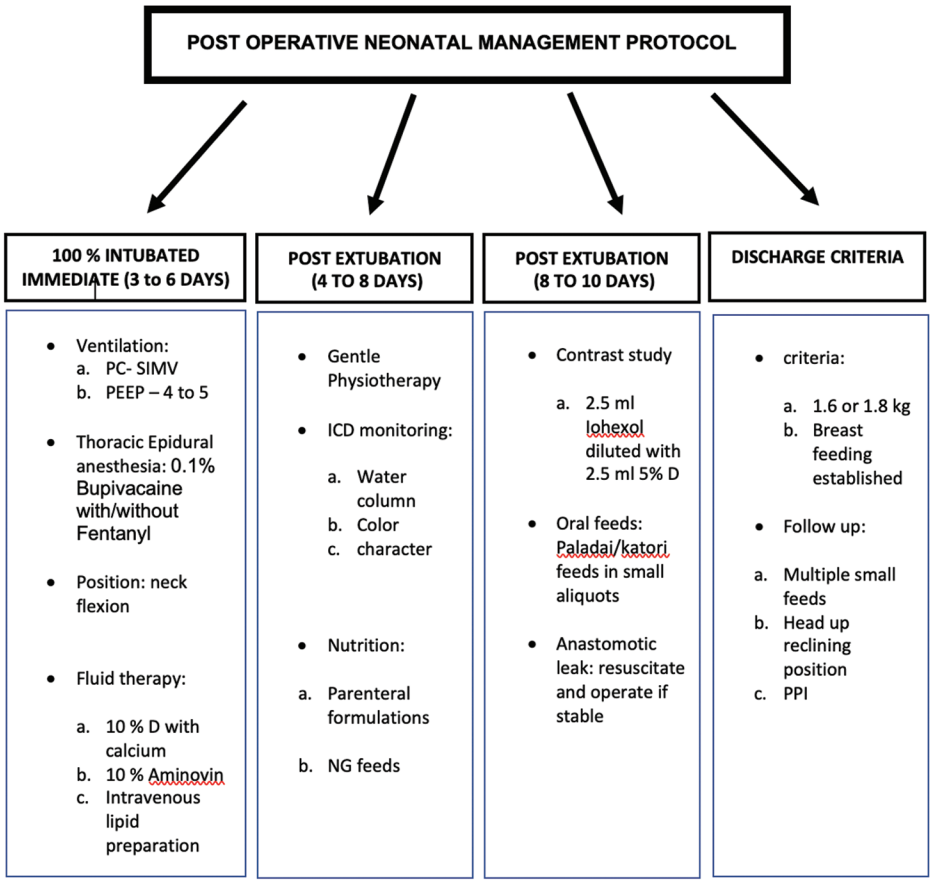



**Figure 4:** Post-operative neonatal management protocol

### *Parenteral nutrition*

Dextrose-electrolyte, amino acid and vitamin mixture was continued with both amino acid and lipid dose increasing to 3 g/kg/d. A 1F or 2F percutaneously inserted central catheter (PICC) line was inserted for continuation of parenteral nutrition. Tropic nutrition through the nasogastric tube with expressed breast milk (EBM) was initiated for gut priming. Feeds were increased by 15 mL/kg/day after examining for bowel motility by auscultation for bowel sounds and spontaneous passage of meconium.

## Post-extubation period (post-operative days 8–10)

### *Contrast study*

It was performed orally using 2.5 mL iohexol diluted with 2.5 mL of 5% D between the 8$^{th}$ and 10$^{th}$ post-operative days when the chances of anastomotic leak are expected to be low [Figure 5].

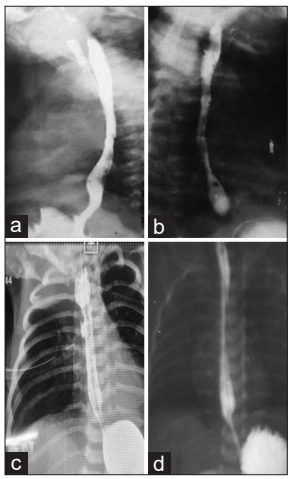



**Figure 5:** Contrast study on post-operative day 8 showing no anastomotic leak

### *Oral feeds*

The nasogastric tube was used for starting the enteral feeds in small aliquots for a longer period of time. The nasogastric tube was removed after confirming that the baby was active and resilient enough to tolerate oral feeds. A strict vigilant eye was kept on any regurgitation of oral feeds since the chances of stricture formation are quite high in these patients. Three (13.04%) babies required reinsertion of the feeding tube due to intolerance of oral feeds, and these babies were exclusively fed by nasogastric tube for a prolonged period of time even after discharge. These three cases required early intervention for oesophageal stricture in the form of early dilatation. Apart from oral feeds being initiated and increased in small aliquots, extreme was taken in respect of posture of the baby and frequent burping was done.

### *Anastomotic leak and management*

Patients who had anastomotic leak (8.6%) were managed as per surgical protocol. One of the patients was taken up for diversion in the form of cervical oesophagostomy, thoracic toilet and feeding gastrostomy whereas the other baby could not be resuscitated and stabilised for the diversion. Both the babies succumbed to the complication of anastomotic leak.

## Pre-discharge period

### *Oral feeds*

Parenteral nutrition was discontinued once enteral intake was >50% of the total daily maintenance requirement. Oral feeding with paladai/katori-spoon was given till removal of the ICD, after which neonates were initiated on direct breastfeeding. The mothers were trained and supervised to feed the baby in shorter intervals, more frequently, and disconnect the baby from the breast within 1–2 min followed by a session of burping. This was done with the intent to avoid overloading of the baby's stomach resulting in reflux and aspiration.

### *Anti-reflux positioning*

Neonates were kept in right lateral and head-end elevation position for a variable period of times during follow-up. In selected cases, car seat propping, feed thickening and oral domperidone were given to decrease gastro-oesophageal reflux disease (GERD).

## Discharge criteria

### *Weight gain*

Newborn baby (NBB) (especially the low birth weight and very low birth weight [VLBW]) was discharged after it had achieved 1.8 kg and pre-mature babies after breastfeeding were established. Most importantly, in all cases, the neonate had to be active, feeding well, gaining weight and the mother and other attendants were comfortable and confident in baby care before the NBB was declared fit for discharge.

### *Advise on discharge*

Slow, multiple small feeds were advised to be given while maintaining a head-up reclining position and low-dose proton-pump inhibitor (PPI) to avoid GERD.

All the patients were followed up for at least 2 years for any post-operative complications such as barking cough, GERD, dysphagia due to stricture formation, voice changes and recurrent wheeze-associated respiratory infection (WARI).

# Results

Out of 23 patients, 15 were boys and 8 were girls, with a mean age of 32.25 weeks ranging between 29 and 35.5 weeks. The mean birth weight was 2.02 kg ranging from 950 g to 3.1 kg. The mean hospital stay was 23.5 ± 8 days. Eleven cases had gap between 3 and 3.5 cm, 8 cases between 3.5 and 4 cm and 4 cases had gap more than 4 cm [Table 1].

The incidence of associated anomalies was 52% which included patients with duodenal atresia (2), anorectal malformation (1), triple anomaly (2) and VACTERL (7) [Table 2].

Anastomotic leak was present in 2 (8.69%) cases. Both of the patients subsequently died due to mediastinitis and sepsis. One of these patients also had associated duodenal atresia who underwent cervical oesophagostomy and gastrostomy on post-operative day 9 following a major leak and the other patient succumbed without diversion due to poor general condition.

During the study period, 3 (13.04%) patients died in the post-operative period. Two (8.69%) patients died due to anastomotic leak and one patient died on post-operative day 17 due to pre-maturity (30 weeks), VLBW (1150 g) and sepsis without any evidence of anastomotic leak on esophagogram.

Patients were followed up for the next 6 months and found to have complications such as barking cough (12), GERD (18), difficulty in swallowing (16), voice changes (2) and recurrent WARI (5) [Table 3]. Patients who had dysphagia (52.17%) were managed with oral contrast study followed by multiple oesophageal dilatations (in the deserving candidates) ranging from 5 to 24 times. Out of these 16 patients, the youngest child was of 5 months who underwent 24 dilatations (initially once every 15 days followed by SOS basis with interval periods of observation till 3 years of age).

All the operated patients were managed postoperatively as per strict neonatal management protocol exclusively by the team of neonatologists and intensivists [Figure 4].

**Table 1: Division of long-gap oesophageal atresia cases based on gap length**

| Gap length (cm) | No |
|---|---|
| 3–3.5 | 11 |
| –4 | 8 |
| >4 | 4 |

**Table 2: Associated conditions**

| Conditions | No |
|---|---|
| Duodenal atresia | 2 |
| Anorectal malformation | 1 |
| Triple anomaly | 2 |
| VACTERL | 7 |
| Total, *n* (%) | 12 (52) |

**Table 3: Post-operative complications**

| Complications | No, *n* (%) | Mortality |
|---|---|---|
| Immediate | | |
| Anastomotic leak | 2 (8.6) | 3 (13.04) |
| Delayed (at 6 months) | | |
| Barking cough | 12 (52.17) | |
| GERD | 18 (78.26) | |
| Voice changes | 2 (8.69) | |
| Swallowing difficulty alone | 16 (69.56) | |
| Recurrent WARI | 5 (21.73) | |

GERD: Gastro-oesophageal reflux disease, WARI: Wheeze-associated respiratory infection

## Discussion

Surgical repair is the only definitive treatment of neonates with LGEA with TEF.[24] Primary repair of LGEA with TEF is associated with complications such as stricture formation, anastomotic leaks, sepsis, GERD in the long term, pneumonia and oesophageal motility issues,[4,7,27] with incidence of anastomotic leak ranging from 7.69% to 100%.[28-30] In our study in the first 4 cases, there was inadvertent opening of parietal pleura which was used as a buttressing layer over the anastomotic repair with a presumption that it would provide additional vascularity over the anastomosis by the vascularised flap of pleura. Following successful outcome in these two cases, this technique of pleural wrap was applied to all cases of LGEA with TEF and we observed that only two cases with anastomotic leak (8.6%) which is less as compared to previous studies [Table 4].[7,29,30]

Studies conducted on lgea by Mckinnon and Kosloske[31] ($n$=26) and Askarpour *et al*.[32] ($n$=14) had anastomotic leak rates of 7.69% and 35.6%, respectively. Another study conducted by Upadhyaya *et al*.[7] and Gupta *et al*.[30] on 5 cases of LGEA with TEF anastomotic leak rate was found to be 80% and 40%, respectively. A study conducted on 12 cases of LGEA with primary repair by Hagberg *et al*.[29] had a 100% anastomotic leak rate. Our study had 23 patients with LGEA and comparatively low incidence of anastomotic rate (8.69%) which may be attributed to the advantages of placing a highly vascular pleural wrap over the primary anastomosis. The incidence of associated anomalies was higher in our study (52.17%) as compared to other studies, 40%[7] and 37.5%,[30] with lesser incidence mortality of only 8.69% as compared to other studies [Table 4].

We have used a novel technique of lazy S myotomy [Figure 3] with an aim to minimise the disruption of vascularity of proximal pouch for better anastomotic healing as circular myotomy does not decrease the incidence of anastomotic leaks, and it also promotes deleterious changes in anastomotic healing.[33]

In our study, 52.17% of patients had post-operative anastomotic stricture which is comparable to the study conducted by Boyle *et al*.[34] The incidence of GERD is as high as 60% as seen in a study conducted by Boyle *et al*.[34] Our study has high incidence of post-operative GERD (17%) at 6-month follow-up.

Post-operative management of patients following LGEA repair has been described in world literature with focus on only management of GERD with PPI therapy.[35] In a study by Syed *et al*.,[36] early post-operative management of a neonate has been described in terms of head-up positioning, lateral positioning, anti-reflux formula milk, pro-kinetic medication and PPIs; however, specifications of post-operative ventilation, parenteral nutrition, fluid therapy, timing of esophagogram, criteria for discharge and post-operative advise have not been highlighted in any study which we have described in detail which is very important for successful outcome following primary LGEA with TEF repair.

Likely factors contributing to favourable outcome apart from pleural wrap in our study include maintenance of strict asepsis protocol in terms of hand hygiene, hand rubs chlorhexidine-impregnated dressings, parenteral nutrition preparation under laminar airflow, central line bloodstream infection and ventilator-associated pneumonia care bundles. Also avoiding routine invasive procedures such as prolonged placement of urinary catheters and umbilical indwelling catheters with preferential use of PICCS for intravenous fluids and total parenteral nutrition led to decrease in the risk of infection. Avoiding invasive ventilation preoperatively and non-invasive ventilation postoperatively with epidural analgesia and initiation of early parenteral nutrition and early introduction of small-volume enteral feeds through the transanastomotic feeding tube with gradual use of EBM instead of formula milk are some of the important factors leading to successful outcome.

## Conclusion

It is common knowledge that the incidence of anastomotic leak following primary repair of LGEA with TEF is quite high and decreased vascularity of the anastomosis (amongst others) remains one of the potential causes for the same.[28,29] The parietal pleura which has a rich blood supply should be used as a routine in all cases of LGEA with TEF wherever the native oesophagus is being salvaged and used for primary anastomosis. This will ensure nearly 90% success of anastomosis as witnessed in our study. Furthermore, as brought out in this index study, it is emphasised that the neonatologists must remain integral part of the paediatric surgical team since the role of intensive care

**Table 4: Cochrane review of previous study and their results in comparison to this study**

| Parameters | Author 1: Mckinnon *et al*.[36] | Author 2: Askarpour *et al*.[35] | Author 3: Upadhaya *et al*.[7] | Author 4: Mahajan *et al*.[30] | Author 5: S Hagberg *et al*.[29] | Our study |
|---|---|---|---|---|---|---|
| Age of NBB | 30–40 weeks | 9.50±7.22 days | 10 h–9 days | 1.85 days (mean age) | - | 29–35.5 weeks |
| Associated anomalies (%) | 54.68 | - | 40 | 37.5 | - | 52.17 |
| Birth weight | 950 g–4 kg | 27 kg±710 g | 1.1–3.1 kg | 2.43 kg (mean weight) | 2.2 kg | 950 g–3.1 kg |
| Surgical gap >3 cm (cases) | 26 | 14 | 5 | 5 | 10 | 23 |
| Leak (%) | 7.69 | 35.7 | 80 | 40 | 100 | 8.69 |
| Mortality (%) | 30.8 | - | 80 | 20 | 1 | 13.04 |

NBB: Newborn baby

provided by neonatal intensivists is of paramount importance for a successful outcome. Apart from the pleural wrap, the key to successful outcome also is contributed by the little prolonged, controlled ventilation and patience and perseverance adopted by the neonatal nurses in post-operative feeds. This post-operative management protocol that has been followed by us in our study is easily reproducible and can be adopted by paediatric surgeons working alongside neonatologists as a team. Cochrane review of literature shows that the results in our study were significant in comparison with other such studies.

## Informed consent

Informed consent was obtained prior to performing the Procedure.


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Nil.


## Conflicts of interest

There are no conflicts of interest.

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