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Research Article

Thoracoscopic Repair of Congenital Diaphragmatic Hernia, relation of defect size and the ideal plan of repair

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Abstract

Background: The Congenital Diaphragmatic hernia (CDH) is considered one of the most problematic anomalies in neonates, it is known as a protrusion of abdominal contents through diaphragmatic defect into the thoracic cavity. It has certain sites for the defects, even posterolateral (Bockdalek), or anteriorly (Morgagni), it causes certain complications starting from dyspnea, cyanosis, lungs development affection and may be ended with death. Despite advancements in the care of congenital diaphragmatic hernia (CDH), the recurrence rate remains elevated. This study aims to assess the safety and strategies of thoracoscopic repair for CDH. **Patient and methods:** this are a prospective study rolled on 60 patients diagnosed by congenital diaphragmatic hernia during the period of May 2018 to March 2022, an admission sheet filled for every case data included personal history, full examination and any needed investigations, then a sheet with operative time, intraoperative hazards and post-operative follow up and complications was recorded. **Results:** Cases age ranged from first day of born to 6 years, males' ratio were 36 cases (60%) and 24 females (40%), Fifteen cases (25%) had a right-side lesion, whereas 45 cases (75%) had a left-side defect. The pH and $paCO_2$ levels before and after the procedure had no clinical significance, and the average operating duration was 90.66 minutes. We switched to open (laparotomy) in 6 (10%) of the cases, and there were 4 (15%) deaths and 5 (12%), re-occurred. **Conclusion**: Thoracoscopic repair is a safe method used for repair of CDH in selected patients, although there was no clinically significant difference in pH and $paCO_2$ levels pre- and post-operative and it is significantly reducing mechanical ventilation days, the high incidence of mortality or recurrence rates was related significantly to intraoperative surgical maneuver regarding size of defect and contents herniated which is crucial in post operative outcomes.

Key words: thoracoscopic repair, paCO2, post-operative, defect size, congenital diaphragmatic hernia

Introduction

Congenital Diaphragmatic Hernia (CDH) is defined as a defect through the diaphragm that occurred since birth, non-traumatic or iatrogenic in nature and causing to push intra-abdominal contents to migrate into the intra thoracic cavity. diaphragmatic rupture, acute obstructive symptoms, lungs hypoplasia, strangulation, cardiac complications or even death may occur. This abnormality may manifest as a syndrome or as an isolated anomaly. Despite improvements in CDH care, the death and morbidity rates are still high, with the prevalence of CDH being around 2.3/10,000 births and fluctuating in a small male predominance of population. [1]. CDH can be linked to gastrointestinal, cardiac, genito-urinary, or chromosomal abnormalities such

trisomies[2]. The majority of patients manifested solely or with persistent pulmonary hypertension of newborn (PPHN) and pulmonary hypoplasia due to an isolated abnormality.

The most prevalent kind (75%) are posterolateral hernias, also known as Bochdalek hernias, while Morgagni hernia is located posterolateral to the sternum is anterior diaphragmatic type with 22%, the other rare conditions as congenital hiatus hernia, congenital eventration or central hernias [3]. The left side is more common (85%), while the right side is less common (13%) and bilaterally (2%). Although CDH thoracoscopic repair has advantages over the conventional open laparotomy methods, Still, other studies also showed it as a challenging technique, and consumes it had a high mortality and recurrence ratios compared with conventional procedure. [4].

Patient and methods

The study is a prospective cross-sectional including 60 cases presented with congenital type of diaphragmatic hernia admitted to Minia University Hospitals, and Abo El-Resh pediatric hospitals, Cairo university emergency unit, all these cases were eligible for thoracoscopic repair, time was between May 2018 and March 2022. The aim of this study is to evaluate the preferences of thoracoscopic repair in reducing time and post operative hospital stay, especially in ICU as well as the effect of defect size and proper surgical repair on recurrence rate. a written consent was signed by parents after they were informed with all steps of procedure and outcomes that may be happened and all parents allowed their children to enroll in this study, which included patients from day one day of age up to 6 years of age with diaphragmatic hernias, only unilateral type and hemodynamic and pulmonary tension stabilization was secured and excluded patients with other parameters as non-congenital diaphragmatic hernias, hiatus hernia, or Patients with associated major congenital anomalies such as major cardiac anomalies, major GIT anomalies or for Patients who were set on ECMO support pre-operatively.

Each patient's preoperative evaluation included a thorough history collection, physical examination and investigations, a plain erect chest x-ray, C.T chest with oral and I.V contrast can delineate the presence of stomach inside the chest, usually needed in right side, rarely needed in a neonate with congenital diaphragmatic hernia. and ECHO or any other asked investigations ordered by pediatricians, After physiological stabilization, thoracic repair of the diaphragmatic defect was carried out., Preductal SaO_2 > 85% (a transient initial SaO_2 > 70% may be tolerated for ~2 hours, provided it is improving), adequate tissue oxygen delivery and perfusion (as determined by physical examination, urine output 1-2 mL/kg/h), $PaCO_2$ 45–70 mmHg (permissive hypercapnia), and pH 7.2 to 7.4 were the treatment's initial goals. If $PaCO_2$ consistently reaches 70 mmHg with a PIP of 26 and an RR of 60, or if Preductal oxygen saturation continuously falls below 85% with a PIP of 26 and a peak end expiratory pressure (PEEP) of 5, we switch to high-frequency oscillatory ventilation (HFOV). The pH range of 7.2–7.4 and oxygen saturation more than 85% were among the therapeutic objectives. with $FiO_2 \leq$ 50 %, UOP1-2 mL/kg/h, controllable arterial blood pressure, and resolution of pHTN.

Surgical techniques

General anesthesia and tracheal intubation are necessary for the thoracoscopic procedure; selective intubation is not essential. The patient is monitored conventionally, with continuous oxygen saturation monitoring being crucial, hypothermia control, and adequate venous access, and they should be manually ventilated or in conventional mode with limited insufflation pressures to prevent any pulmonary barotrauma. Utilizing a nasogastric tube to decrease the volume and quantity of stomach contents; two hours before the procedure, prophylactic administration of antibiotics was prescribed. The patient was placed in a semi-lateral position with modest, raised support beneath them. (Figure 1), The anesthesia set was situated at one side of the operating table with the scrub nurse on the opposite side, the monitor was at the side of patient's feet, and the operating surgeon and his assistant were near the patient's head.

As an optical port, the first 5 mm trocar is positioned beneath the scapular angle. A very posterior or extremely proximal port position will make instrument movements challenging. So, two additional operator trocars are introduced: one in the fourth intercostal space between the optical trocar and the spine, and one in the fifth intercostal space on the anterior axillary line (fig 2).

After inserting the telescope port via open access, CO2 is infused at a rate of 1-2 L/min up to a maximum pressure of 8 mmHg. The lung will then collapse, allowing the herniated material to be softly reintroduced into the abdominal cavity. The procedure started by reducing the herniated contents, in case of presence of a sac, the reduction can be achieved within a few minutes as the thoracic insufflation will be sufficient in most cases **(fig 3, 4)**.

If no sac is present on the left side, the reduction should be started by pushing down the stomach, the colon, and the small intestine, to be completed by the reintegration of the spleen, with a smaller defects spleen can be difficultly reduced and so a third trocar would be useful (**fig 5**).

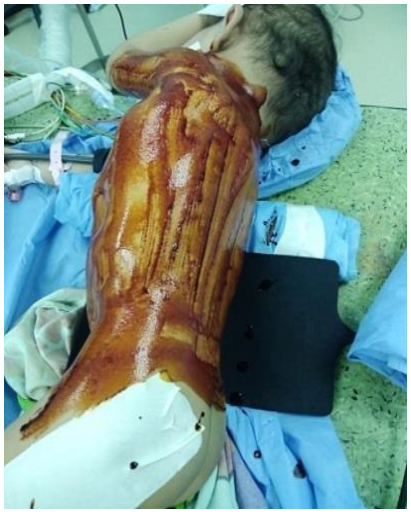

Fig. (1): Lateral Positioning of the child.

Fig. (2): Sites of Trocar placement

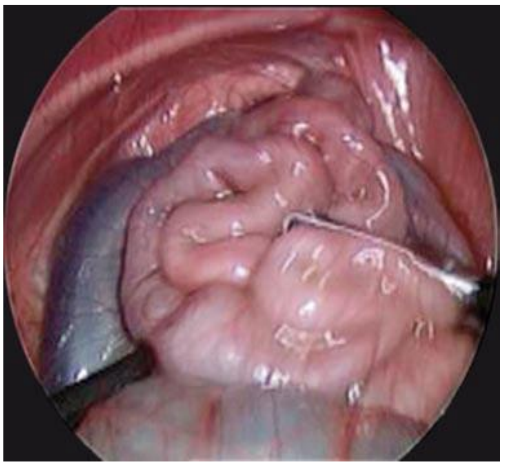

Fig (3): Two traumatic graspers are employed to successively reduce the herniated intestines.

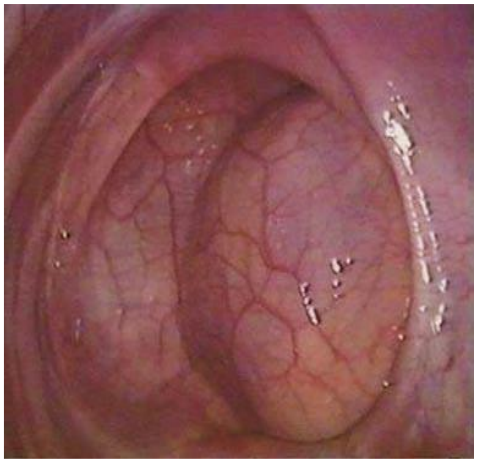

Fig. (1): spontaneous reduction after 5 min of insufflation.

Where a hernial sac existed, it hadn't been dissected; instead, the defect's edge was carefully coagulated using hook diathermy (fig 5).

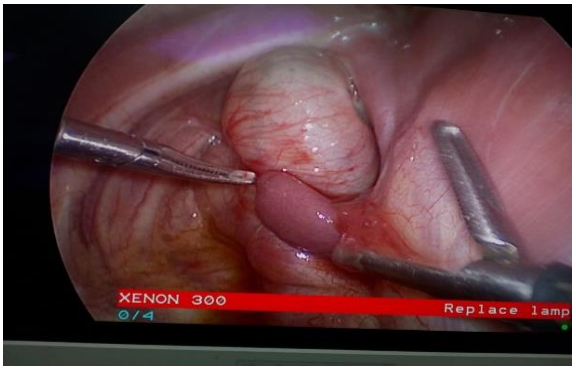

Fig. 5: Left CDH with the herniation of the entire spleen in the thoracic Cavity.

Afterwards, size of the defect should be measured using a metered tape or suture thread, the longest transverse and sagittal diameters were measured, the defect classified according to the site into anterolateral and posterolateral and classified according to the size into two groups, group A with size ≤3x3 cm and group B with size >3x3 cm and compared between the two group in number of cases, age, using mesh, conversion to open, mortality and recurrence, , no need for a resection of the sac we just carefully coagulate the defect edge with hook diathermy, and avoid extensive coagulation, which can damage diaphragmatic innervation or vascularization **(fig 6).** To determine the prospect of primary repair, the diaphragm's posterior flap was pulled forward. **(fig 6)**.

Measuring can be achieved by calculating the longest transverse and sagittal diameters, the defect classified according to the site into anterolateral and posterolateral and classified according to the size into two groups, group A with size ≤3x3 cm and group B with size > 3x3 cm and compared between the two group in number of cases, age, using mesh, conversion to open, mortality and recurrence, , In presence of a hernia sac, there is no need for a resection of the sac, the edge of the defect coagulated carefully to avoid extensive coagulation, which can damage diaphragmatic innervation or vascularization (fig 7, 8).

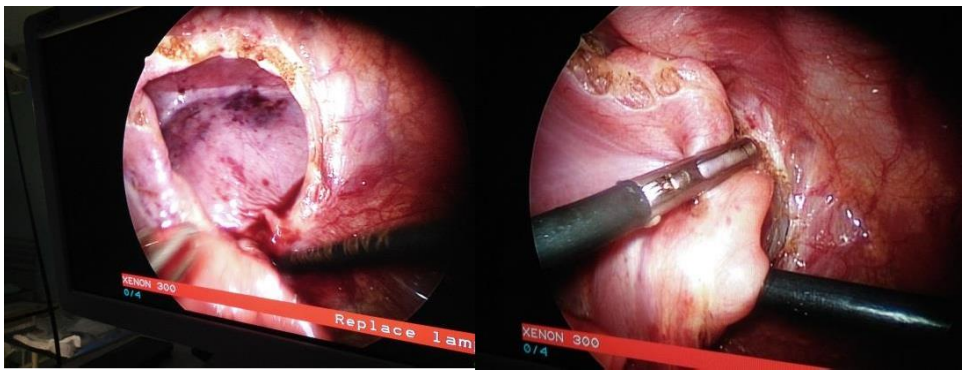

Fig. (6): The edge of the defect undermines Coagulation, then evaluation the feasibility of primary repair

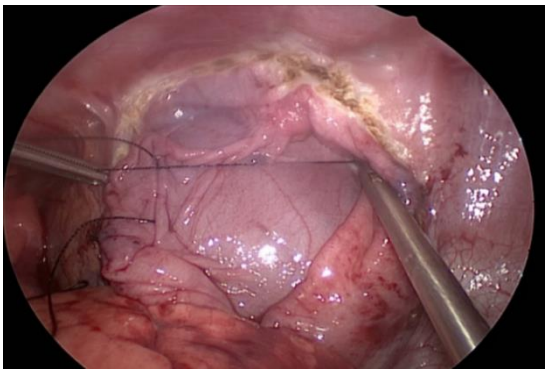

Fig. 2: Measurement size of the defect.

Interrupted non-absorbable sutures were used to seal the diaphragmatic defect. If the defect was large enough and closure with primary sutures is not a good choice, and a dual mesh insertion was done by passing it through one of the ports and then adjusting edges to fit the defect's measurements (fig. 8). A chest tube was frequently not necessary after the procedure was completed, then letting CO_2 pass out through one of the ports, and then we remove trocars and close abdominal wall and skin.

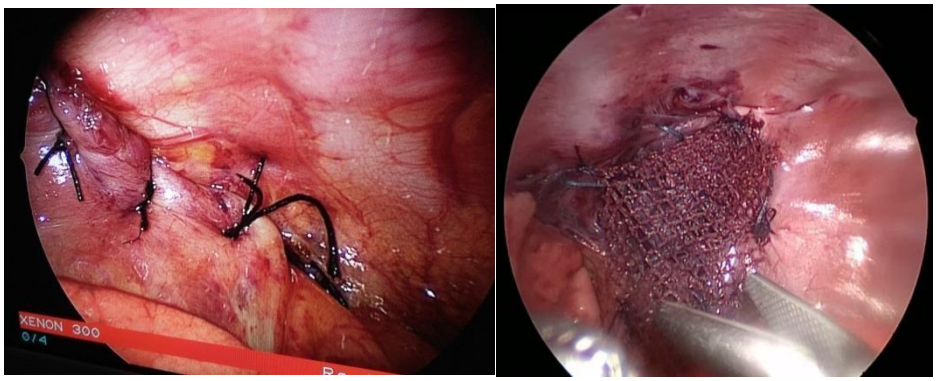

Fig 8: primary repair with sutures or by mesh

Following surgery Pain management with intravenous paracetamol was crucial, as were post-operative ABG (1 hour after surgery then daily), follow-up x-rays (12 hours after surgery then daily). If there was no reason for the chest tube, it was removed the following day, and the patient was permitted to eat within 24 hours. If the patient was on a ventilator, weaning was done gradually. Each patient had a follow up sheet with preoperative information such as complete medical history, examination, and investigations; intraoperative information such as operating time, defect characteristics, and any intraoperative complications; and postoperative information such as days spent on a ventilator, days spent in the ICU, length of hospital stay, allowing enteral feeding, post-operative ABGs and follow-up visits.

Statistical analysis:
Data were collected, revised, verified, coded, then entered PC for statistical analysis done by using IBM SPSS statistical package version 20.
Analytical statistics:

- Comparison of independent quantitative data among two groups by independent sample t- test
- Comparison of categorical data by Chi-squared and Fischer exact test
- Comparison of dependent quantitative data among two groups by dependent (paired) sample t- test

For all tests probability (p) was considered:

- Non-significant if ≥ 0.05
- Significant if < 0.05
- Highly significant if < 0.01
- Very highly significant if <0.001

Results

The age range of the patients in the study includes 2 days to 6 years; 42 (70%) of the cases were younger than 30 days, while 18 (30%) were older than 30 days. As table 1 illustrates, the range of all cases was (4-1240) days; 36 (60%) of the cases were male, and 24 (40%) were female.

Table (1): Statistics of patient's age.

Variable	Descriptive statistics
Age (days): **<30 days n(%)** **≥ 30 days n(%)**	 42 (70%) 18 (30%)
Mean ±SD (range)	126±33.7 (4-1240)

In 45 (75%) of the cases, the deficiency was on the left side, whereas in 15 (25%) it was on the right.

Table 2 indicates that the defect site was anterolateral in 9 (15%) and post-lateral in 51 (85%) cases.

Table (2): Relevance of diaphragmatic types.

Site: n (%)	Descriptive statistics
Anterolateral	9(15%)
Post-lateral	51(85%)

There was no iatrogenic injury, nine (15%) cases with a big defect had mesh, five (8.3%) had a chest tube placed, two had obstruction of the intestine for drainage, and three had desaturated during surgery. According to **Table 3**, the operative time is the amount of time from the beginning of the patient's sterilization to closing the trocar sites. The mean operative time was 90.66 minutes, with a range of 60 to 130 minutes, range of post-operative days requiring a ventilator was 0 to 15 days, with an average of 1.5 days. Table 4 indicates that the average number of post-operative days in the intensive care unit was five days, with a range of two to twenty days.

Table (3): Intraoperative statistical evaluation.

Variable	Results
Iatrogenic injury: n (%)	0 (0%)
Mesh: n (%)	9 (15%)
Chest tube: n (%)	5 (8.3%)
Operative time: Mean ±SD (range)	90.66±16.69 (60-130)

Table (4): Post-operative statistical evaluation.

Variable	Results
Days on vent: mean ±SD (range)	1.5±2.45 (0-13)
Days on ICU: mean ±SD (range)	5± 2.73(2-12)

The mean pH and paCO2 values before and after surgery did not differ in a way that was considered clinically or statistically significant., which are measured to assess the impact of CO2 insufflation. as displayed in **Table 5.**

Table (5): Blood gases study data of cases measured pre- and post-operatively.

Variable	Preoperative N=60	Postoperative N=60	p-value
	Mean ±SD Range	Mean ±SD Range	
pH	7.29±0.06 7.15-7.48	7.35±0.05 7.25-7.42	0.327
$paCO_2$	37.89±5.98 22-50	39.25±5.79 30-50	0.127

A conversion to open (laparotomy) was done in 6 (10%) cases due to difficult reduction, recurrence was 3(5%) cases while mortality was in 7 (11.33%) cases postoperatively, as shown in **figure 9.**

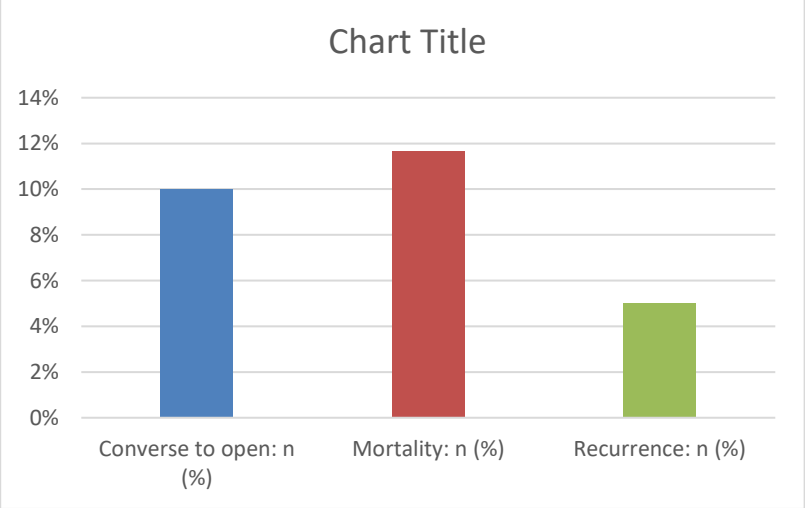

Fig. 9: Undesired outcome of repair.

Table 6: Classification of cases according to sizes of the defects

Variable	Group A Size≤ 3×3cm	Group B Size>3×3cm	p-value
Number of cases	24(40%)	36(60%)	0.075
Age: (range in days) Mean ±SD	(4-1440) 157.7±373.46	(4-860) 135.3±184.86	0.700
Mesh	0(0%)	9 (25%)	0.003
Conversion to open	2(8.33%)	4(11.11%)	0.05
Mortality	(0 %)	4 (13.89%)	0.044
Recurrence	1(4.2%)	4 (5.55%)	0.05

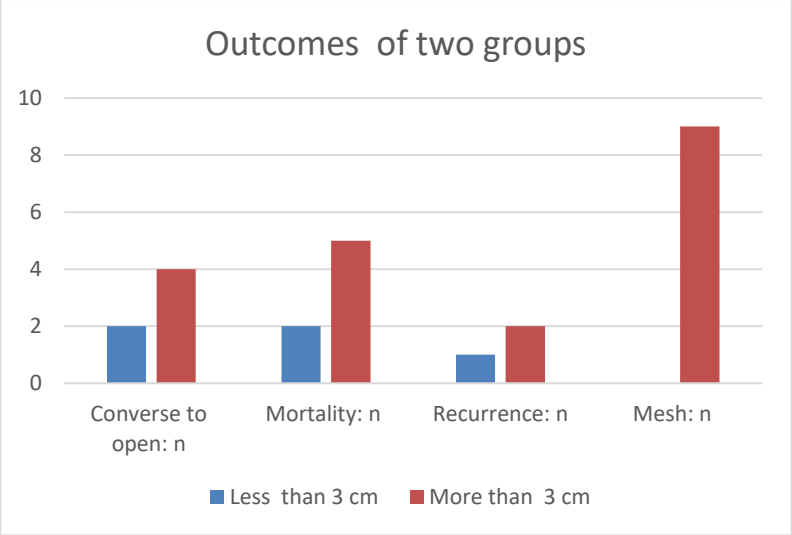

Fig. 10: Comparison of outcomes between the two groups.

Discussion

According to certain research, thoracoscopic repair of congenital diaphragmatic hernias (CDH) has several advantages, such as a notable decrease in hospital stays, less pain, tissue damage, and cosmetic deformity, a quicker time reaching goal feeds, and a decreased death rate [5]. Other research, also demonstrated that procedure was not that easy and need expert in thoracoscopic field with still high rates of mortality and recurrence [6].

Newborns with CDH have significant lung hypoplasia and chronic pulmonary hypertension due to a congenital diaphragmatic abnormality that pushes stomach contents into the thoracic cavity. We conducted 60 cases that were presented to Minia University Pediatric Hospital and Abo ElResh Pediatric Specialized Hospital of Cairo University and met the inclusion criteria between May 2018 and March 2022 to assess mortality, recurrence rates, and alterations in ABG both before and after thoracoscopic surgery of a congenital diaphragmatic hernia. We aimed to determine whether the maneuver performed was appropriate for the size of the defect and whether it significantly reduced the rate of recurrence and post-operative complications.

The average age of all the cases in our study was 176 days, with 42 (70%) cases being neonates and 18 (30%) cases were infants and children, with a range of the cases in our study 4 days to 6 years. The inclusion criteria requiring cardiorespiratory stability may be the

reason for our findings' relative rise in incidence. Delays in diagnosing CDH cases that were asymptomatic at birth provide an additional rationale. Of all CDH cases, the percentage of late-presenting cases ranges from 5% to 25% [7].

Out of the 30 patients in the Osama et al., study [8], 11 (36, 7%) were younger than 30 days, and 19 (63%) were older than 30 days. All cases had an average age of 313, 8 days. 53 instances (80%) were neonates younger than 30 days; 7 cases (11.7%) were older than 30 days, and 60 cases (ages ranging from 1 day to 10 months) were included in Huang et al.,'s study [9]. In line with the global consensus, the sex distribution of the patients in our investigation revealed a male predominance, with 24 (40%) cases being female and 36 (60%) cases being male [10]. There were 34 (45.5%) females and 41 (54.5%) males in the Costerus et al., [11] study. also, there were 31 (52.5%) men and 28 (47.5%) women in the Yuan et al., [12] study.

45 (75%) of the cases in our study had a deficiency on the left side, whereas 15 (25%) had a lesion on the right. Additionally, data supports the general assumption that the left side is more prevalent than the right. [10]. Thirteen (22.1%) and forty-six (77.9%) of the cases in Yuan et al., study [12] were on the right side. whereas 4 (11.4%) cases were on the right side and 31 (88.6%) cases were on the left in the study by Criss et al., [13].

51 (85%) of the cases in our study had a post-lateral defect, while 9 (15%) had an anterolateral defect. These findings are comparable to those of Osama et al., [8], who found that the defect site was anterolateral in 4 (13.3%) and post-lateral in 26 (86.7%) patients.

Same to the work done by Inoue et al., [14], having no iatrogenic injury, post operative investigation shows no iatrogenic injury during the thoracoscopic repair.

Nine (15%) of the cases with major deficiencies in our analysis required the use of mesh, whereas 44 (58.7%) of the cases in the Costerus et al., [11] study did so. Additionally, mesh was utilized in 9 (25%) of the cases in the Criss et al., [13] study, whereas 4 (50%) of the cases in the Inoue et al., [14] study required mesh.

Five (8.3%) of the cases in our study had a chest tube placed, 49 (83%) had one in the Yuan et al., study [12], and 16 (46%) had one in the Criss et al., study [13]. However, there was no chest tube in the Okazaki et al., trial [15].

The average operating time for our study was 90.66 minutes, with a range of 60 to 120 min. The average operation duration was 178 min, with a range of 105 to 260 min, in the study by Okazaki et al., [15], 217 min, with a range of 172 to 258 min, in the study by Inoue et al., [14], and 55 min, with a range of 30 to 100 min, in the study by Yuan et al., [12].

In our study, the range of post-operative days requiring a ventilator was 0 to 15 days, with an average of 1.5 days. The postoperative ventilator days in Huang et al.,'s study [9] varied from 0 to 6 days, with a mean of 3.24 days; however, Inoue et al.,'s study [14] had a mean of 6.5 days.

According to research by Huang et al., [9], the average length of stay in the critical care unit following surgery was 7.13 days, with a range of 3 to 16 days. Our analysis revealed a mean of 5 days, with a range of 2 to 20 days.

The study revealed that the mean pH before surgery was 7.29 with a range of 7.15 to 7.48 and the mean pH after surgery was 7.30 with a range of 7.19 to 7.39 and a p-value of 0.32, which is not clinically significant. The mean $paCO_2$ before surgery was 37.89 mmHg with a range of 22 to 50 mmHg and the mean $paCO_2$ after surgery was 39.25 mmHg with a range of 30 to 50 mmHg and a p-value of 0.127. It is not clinically significant as the mean pH in the study by Okazaki et al., [15] was 7.44 with a range of 7.29 to 7.61 while the mean pH after surgery was 7.41 with a range of 7.15 to 7.59. There was no clinically significant difference in the mean $paCO_2$ before and after surgery, which was 38.88 mmHg with a range of 22.8 mmHg to 59.9 mmHg and 37.7 mmHg with a range of 23.8 mmHg to 65.8 mmHg. The median pCO_2 rose from 5.54 to 5.93 and the median pH decreased from 7.37 to 7.31 in the Costerus et al., study [11].

The lack of variation in pH and pCO_2 before and after surgery in our analysis may be due to the exclusion of subjects requiring ECMO and the inclusion criteria that demanded cardiorespiratory stability.

Six (10%) of the cases in our study were converted to open (laparotomy); while 15 (20.3%) of the cases in Costerus et al.,'s study [11] were converted to open; five (25%) of the cases in Okazaki et al.,'s study [15] were converted to open; and two (5.7%) of the cases in Criss et al.,'s study [13] were converted to open.

As we included right-side congenital diaphragmatic hernias in this study, our study's mortality rate is higher than other studies'. The four cases included in Group B, and two of them died from their right-sided large defect, one had a large diaphragmatic hernia in right side with a hepato-pulmonary fusion, and one was desaturated during surgery. Costerus et al., [11] and Okazaki et al., [15] skipped over right-side congenital diaphragmatic hernias in their research. Additionally, the high mortality rate is a consequence of our units' lack of ECMO. On the other hand, recurrence occurred in 5 (5%) of the cases in our study, 6 (17.1%) of the cases in the study by Criss et al., [13], 14 (18.6%) of the cases in the study by Costerus et al., [11], and 1 (6.6%) of the cases in the study by Okazaki et al., [15].

Regarding the defect size, in our study, the sizes of the defects were measured and classified into two groups, group A with size ≤3x3 cm and group B with size >3x3 cm, no clinical difference between the two group in the number of cases, ages, Conversion to open and recurrence but the mortality is higher in group B compared to group A, there was no mortality in group A while mortality in group B was 4(25%) cases which is clinically significant (p-value 0.010), the mesh was not used in group A while used in 9 (31.2%)cases in group B which is also had a clinical significance (p-value 0.003).

In the study of Congenital Diaphragmatic Hernia Study Group [16] defect size is directly correlated with mortality rate, the mortality in small defects (type A, B defects) was 4 cases (, 55%) while the mortality in large defects (type C, D defects) was 182 cases (29%) with p-value <0.001 which is clinically significant.

Conclusion

Thoracoscopic repair is a safe method used for repair of CDH in selected patients, with reduced mechanical ventilation days, while an intraoperative surgical technique addressing the size of the defect and contents herniated is critical in post-operative outcomes, there is no meaningful changes in either pH or $paCO_2$ levels before and after surgery, and it is not linked to high mortality or recurrence rates.

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