

# Congenital Diaphragmatic Hernia in Neonates: Open Versus Thoracoscopic Repair

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## Abstract

**Background:** There are no standard criteria to select patients for thoracoscopic repair of congenital diaphragmatic hernia (CDH). The objective of this study was to compare open laparotomy versus thoracoscopic repair of CDH in neonates. **Patients and Methods:** This retrospective study included 41 patients who had repair of CDH from 2011 to 2019. Patients were divided into two groups according to the surgical approach; open laparotomy ( $n = 30$ ) and thoracoscopic repair ( $n = 11$ ). Study endpoints were duration of post-operative mechanical ventilation, hospital stay and the return to full enteral feeding. **Results:** Patients who had thoracoscopic repair were significantly younger (3 [25<sup>th</sup>- 75<sup>th</sup> percentiles: 3-3] vs. 4 [3-5] days;  $P = 0.004$ ). Other pre-operative variables were comparable between both groups. The duration of surgery was significantly longer in the thoracoscopic repair (174 [153-186] vs. 91 (84-99) min;  $P < 0.001$ ). The use of pre-operative nitrous oxide inhalation was associated with prolonged ventilation ( $P = 0.004$ ), while the thoracoscopic repair was associated with shorter mechanical ventilation ( $P = 0.006$ ). Hospital stay is lower in the thoracoscopic approach but did not reach a significant value ( $P = 0.059$ ). The use of pre-operative nitrous oxide was associated with a prolonged hospital stay ( $P = 0.002$ ). Younger age (HR: 1.33,  $P = 0.014$ ) and open approach (HR: 3.56,  $P = 0.004$ ) were significantly associated with delayed feeding. **Conclusions:** The thoracoscopic approach is safe and effective for repairing the CDH. It is associated with shorter mechanical ventilation and rapid return to enteral feeding. Proper patient selection is essential to achieve good outcomes.

**Keywords:** Congenital diaphragmatic hernia, open repair, thoracoscopic repair

## INTRODUCTION

Congenital diaphragmatic hernia (CDH) results from inadequate closure of the fetal diaphragm during embryonic development. CDH occurs mostly on the left side, with the formation of a hernia sac that contains abdominal organs.<sup>[1,2]</sup> Abdominal organs compress the lung leading to pulmonary hypoplasia and abnormal morphology of pulmonary vasculature, which determine the prognosis of the disease.<sup>[3,4]</sup>

Open surgical repair, either through thoracotomy or laparotomy, was the traditional approach for CDH. However, the advancement of surgical technology and techniques had expanded the use of the minimally invasive approach to patients with CDH.<sup>[5]</sup> In a survey of 161 pediatric surgeons, the thoracoscopic approach was performed by 89% of them; however, there was a lack of consensus on standard operative indications, and the optimum candidate for this approach was not defined.<sup>[6]</sup>

The outcome of surgical repair of CDH had improved recently; however, the optimal surgical approach is still debatable.<sup>[7]</sup> Shorter hospital stays, early return to full feeding and lower mortality were reported in the thoracoscopic repair of CDH in selected patients.<sup>[8]</sup>

In neonates, the associated pulmonary hypertension and other congenital anomalies may limit the use of the minimally invasive approach.<sup>[3]</sup> The selection criteria were the subject of several reports, yet there are no standard criteria to assign the patients to either approach.<sup>[9,10]</sup>

The objective of this study was to compare open laparotomy versus thoracoscopic repair of CDH in neonates.

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## PATIENTS AND METHODS

### Design and patients

This retrospective study included all neonates who were treated for CDH between 2011 and 2019. The Institutional Review Board approved the chart review for this study and waived the need for patients' consent. We excluded high-risk neonates not fit for surgery, neonates with severe pulmonary hypertension, and those < 1.5 kg. Forty-one patients had repair of CDH; 11 patients had thoracoscopy, and 30 patients had open laparotomy. Two patients were converted to open repair because of hepatopulmonary fusion in one patient and a large defect requiring patch repair in the second patient. The converted patients were analysed in the open laparotomy group. We chose neonates for the thoracoscopic approach if they have stable hemodynamics and respiratory condition, with low oxygen requirement ( $\text{FiO}_2 < 50\%$ ), and they can tolerate changing positions on mechanical ventilation with no major congenital heart disease. Figure 1 shows the study flow diagram.

### Preoperative evaluation

All patients were subjected to a thorough pre-operative evaluation, including routine laboratory investigations, and chest X-ray. The position of the stomach and liver in the abdomen was confirmed by ultrasound and nasogastric tube position in the stomach preoperatively. Further investigations were done to exclude other congenital anomalies, including echocardiography.

### Data collection and endpoints

Pre-operative data collected included the gender, gestational age, birth weight, age at surgery, the need for pre-operative ventilation and inhalational nitrous oxide, and the laterality of the hernia. Operative data included the approach, type of repair (primary or patch repair) and duration of surgery. Post-operative data included complications and mortality.

The study endpoints were duration of hospital stay and mechanical ventilation and the time to return of full feeding.

### Surgical technique

#### Thoracoscopic repair

Lateral decubitus position was used in all patients with the side of the defect uppermost. Trocars were placed through the 4<sup>th</sup> intercostal space midaxillary line, and the second was placed in the same space lateral to the tip of the scapula. A third trocar was placed in the 5<sup>th</sup> intercostal space in the anterior axillary line. We used CO<sub>2</sub> insufflation at a pressure of 5–6 mmHg and a flow of 1.5 L/min. The contents were reduced, and the defect was repaired with non-absorbable interrupted sutures; the first knot was a sliding knot followed by an intracorporeal knot. In patients with no posterior rim, we sewed the anterior rim to the thoracic wall. The last stitch laterally was used to suture the two borders of the diaphragm to the chest wall [Figure 2]. After repair, we inserted a drain via the posterior port, and the drain was removed 24–48 h after a satisfactory routine chest X-ray.

### Open repair

Open repair was performed through a left subcostal abdominal incision, and the contents were reduced into the abdominal cavity. The defect was repaired either directly or with a patch. A chest drain was inserted in the 5<sup>th</sup> intercostal space in the midaxillary line, and the wound is closed in layers.

All patients were followed after hospital discharge at the out-patient clinic for 1 year after the repair.

### Statistical analysis

All analyses were performed using Stata 16.1 software (Stata Corp, College Station, Texas, USA). Quantitative variables were described as 25<sup>th</sup>, 50<sup>th</sup> (median) and 75<sup>th</sup> percentiles and compared using the Wilcoxon test. Qualitative variables were presented as number and per cent and compared with the Chi-square test or Fisher exact test when appropriate. Negative binomial regression was used to identify risk factors for prolonged hospital stay and ventilation. Time to event outcome was plotted using the Kaplan-Meier curve, and a comparison of the distribution was made by the Log-rank test. Cox regression was used for multivariable analysis.

## RESULTS

### Preoperative data

Patients who had thoracoscopic repair were significantly younger ( $p = 0.004$ ). Other pre-operative variables were comparable between both groups. The left-side hernia was more common in both approaches [Table 1].

### Operative and post-operative outcomes

All patients in the thoracoscopic group had a primary repair, and two patients in the open group had a patch repair (6.67%). The duration of surgery was significantly longer in the thoracoscopic repair ( $P < 0.001$ ) [Table 2].

There was no difference in post-operative complications and mortality between groups. One patient in thoracoscopic repair had a recurrence, which was fixed through an open approach.

### Risk factors of prolonged ventilation

The use of pre-operative nitrous oxide inhalation was associated with prolonged ventilation postoperatively, while the thoracoscopic repair was associated with shorter mechanical ventilation. Pre-operative high-frequency oscillating ventilation (HFOV) preoperatively was associated with prolonged mechanical ventilation postoperatively but did not reach a significant value [Table 3].

### Risk factors of prolonged hospital stay

The hospital stay was lower in the thoracoscopic approach but did not reach a significant value. The use of pre-operative nitrous oxide was associated with a prolonged hospital stay.

### Time to full enteral feeding

The median time to full feeding in the open approach was 9 (6–15) days, and in the thoracoscopic approach was 7 (5–9) days (Log-rank = 0.016) [Figure 3].

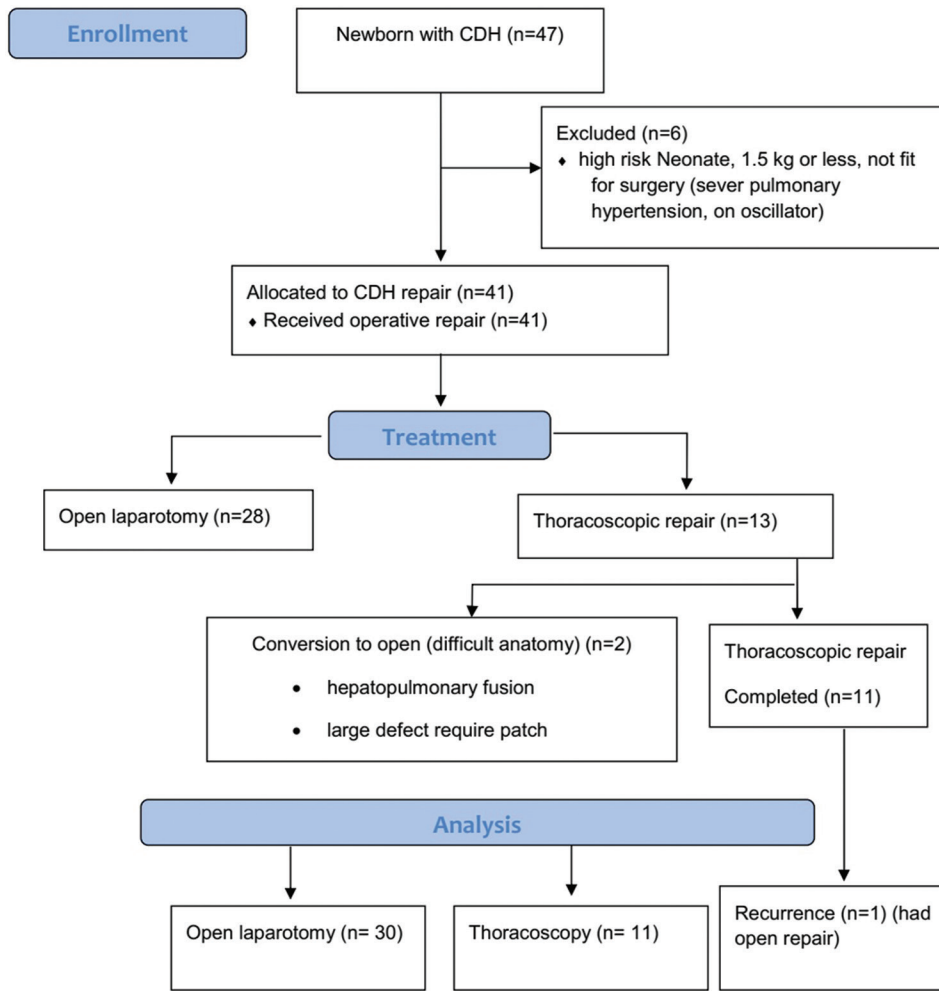


Figure 1: Study flow diagram

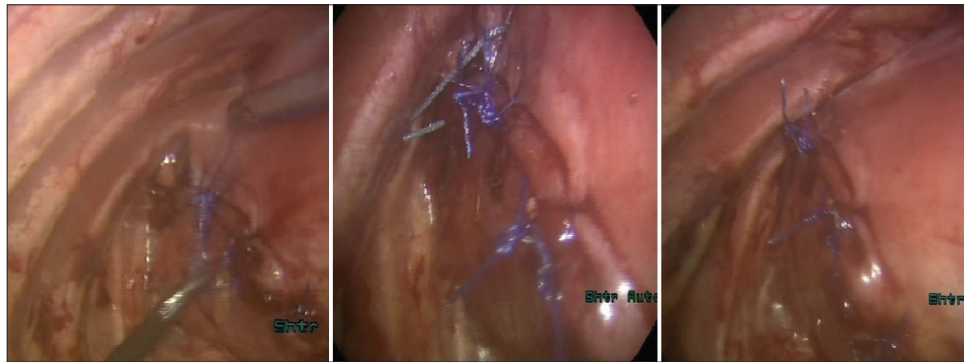


Figure 2: Lateral stitch to the chest wall during thoracoscopic repair

Younger age and open approach were significantly associated with delayed feeding [Table 4].

## DISCUSSION

Thoracoscopic repair of CDH has gained popularity recently.<sup>[11,12]</sup> The thoracoscopic approach is technically challenging due to the small workspace, which could

prolong the operative time and increase the post-operative complications.<sup>[13]</sup>

Meanwhile, the thoracoscopic repair was found to be associated with shorter ventilation time, earlier return to full enteral feeds, shorter hospital stay, improved cosmesis and decreased cost compared to the open repair.<sup>[14-16]</sup> However, the high recurrent rate remains a concern after thoracoscopic repair.<sup>[17]</sup> In this

**Table 1: Pre-operative data (continuous variables are presented as median (25<sup>th</sup>- 75<sup>th</sup> percentiles) and categorical variables as number and percent)**

	Open repair (n=30)	Thoracoscopic repair (n=11)	P
Male	19 (63.33)	7 (63.64)	0.986
Gestational age (weeks)	38 (36- 39)	38 (37- 39)	0.917
Weight (kg)	2.9 (2.5- 3.2)	2.9 (2.7- 3)	0.779
Age at surgery (days)	4 (3- 5)	3 (3- 3)	0.004
Left side hernia	28 (93.33)	10 (90.91)	>0.99
High flow oscillating ventilation	15 (50)	3 (27.27)	0.291
Nitrous oxide inhalation	11 (36.67)	2 (18.18)	0.231

**Table 2: Operative and post-operative data (continuous variables are presented as median (25<sup>th</sup>- 5<sup>th</sup> percentiles) and categorical variables as number and percent)**

	Open repair (n=30)	Thoracoscopic repair (n=11)	P
Type of repair, n (%)			
Primary	28 (93.33)	11 (100)	>0.99
Patch	2 (6.67)	0	
Duration of surgery (min)	91 (84- 99)	174 (153- 186)	<0.001
Hospital stay (days)	12.5 (10- 19)	10 (9- 13)	0.081
Duration of mechanical ventilation (days)	6 (3- 12)	3 (2- 5)	0.007
Chest complications, n (%)			
Pneumothorax	1 (3.33)	0	>0.99
Pleural effusion	1 (3.33)	0	
Mortality	2 (6.67)	0	>0.99
Recurrence	0	1 (9.09)	0.268

study, we found that neonates who had thoracoscopic repair had shorter ventilation time and earlier reestablishment of enteral feeding compared to the open approach; however, hospital stay was not significantly different between groups despite lower in thoracoscopic repair.

We did not find a high recurrence rate in our study, which can be attributed to the small patients' numbers and the exclusion of severely ill patients and patients with large defects. In a meta-analysis, the recurrence rate was three-fold higher in the thoracoscopic repair compared to the open technique.<sup>[5]</sup> We had one patient with a recurrent hernia and was managed via open laparotomy.

In a study by Weaver and associates,<sup>[18]</sup> the recurrence rate was 8.4% after the thoracoscopic repair. The risk factors for recurrence were repair on HFOV, and herniation of the spleen. Risk factors found in other studies were persistent pulmonary hypertension and prolonged post-operative ventilation.<sup>[19]</sup>

The large defect is a technical challenge for proper thoracoscopic repair, and some authors consider it a contraindication to the minimally invasive repair.<sup>[20]</sup> In our series, one patient was converted to an open approach due to the need for a patch repair.

**Table 3: Risk factors of prolonged mechanical ventilation and hospital stay**

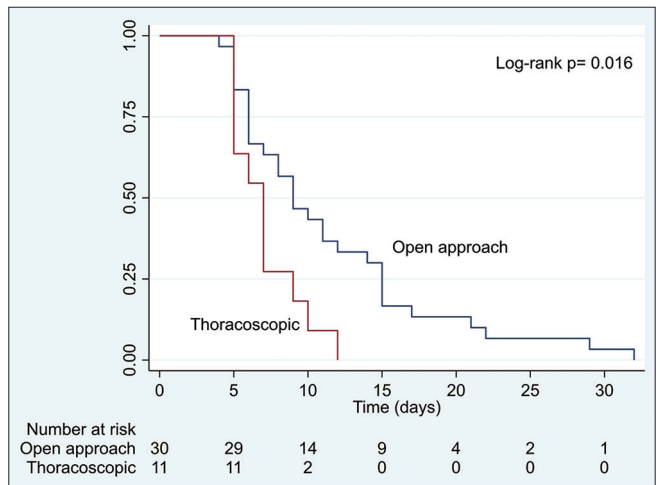
	Coefficient	P	95% CI
Duration of mechanical ventilation			
Age at surgery	-0.067	0.309	-0.195- 0.062
Female	0.109	0.511	-0.217- 0.436
Nitrous oxide inhalation	0.730	0.006	0.208- 1.251
HFOV	0.470	0.070	-0.038- 0.978
Thoracoscopic repair	-0.627	0.004	-1.054- -0.199
Hospital stay			
Age at surgery	-0.030	0.448	-0.107- 0.047
Female	0.143	0.164	-0.058- 0.343
Nitrous oxide inhalation	0.510	0.002	0.181- 0.839
Thoracoscopic repair	-0.240	0.059	-0.489- 0.009
HFOV	0.270	0.092	-0.044- 0.584

HFOV: High-frequency oscillating ventilation, CI: Confidence interval

**Table 4: Factors affecting the reestablishment of enteral feeding**

	HR	P	95% CI
Age at surgery	1.326	0.014	1.059- 1.660
Thoracoscopy	3.557	0.004	1.485- 8.524

CI: Confidence interval, HR: Hazard ratio



**Figure 3: Kaplan Meier curve for time to feeding**

We did not report a significant difference between both groups regarding gender distribution and the pre-operative HFOV and NO inhalation, while patients who had thoracoscopic repair were significantly younger.

The left-sided hernia was the most common form in this study, which is comparable to what was reported by others.<sup>[21]</sup> Patients with right-sided CDH were found to have lower survival and a higher need for extracorporeal life support.<sup>[22]</sup>

We reported significantly longer operative time in patients who had a thoracoscopic repair. The definition of operative time varies in different studies, and we defined it as the time

from skin incision to skin closure. The thoracoscopic repair is technically demanding, and there is a learning curve. The operative time could decrease over time; however, we could not assess the learning curve due to the small number of patients, and the use of this technique is other diseases. Long operative time in neonates can lead to hypothermia and acidosis. Therefore, it is advised to assess the surgical risk of the patients and operate on patients with low operative risk. In addition, surgeons should achieve satisfactory thoracoscopic training in older- and lower-risk patients before operating on the neonates.

Consequently, strict selection criteria should be applied to choose stable neonates who can tolerate the stress of the operation and the expected compromise of the post-operative pulmonary function.<sup>[23]</sup>

There was considerable heterogeneity in the length of post-operative hospital stay after CDH repair in neonates.<sup>[24-26]</sup> Several factors could affect the length of stay other than the approach itself. In this study, length of stay was reduced in the thoracoscopic repair but did not reach a significant level. Pre-operative nitrous oxide inhalation was associated with prolonged hospital stay; this can be considered a proxy to the severity of pulmonary hypertension.

The conversion to open repair varies widely in the literature, and several factors affect this, including surgeons' experience and the size of the defect. Two patients had a conversion in our series; one patient with a large defect requiring patch repair, and the second patient had severe pulmonary hypertension and could not tolerate the procedure.

We believe that proper patients selection for thoracoscopic repair improves the outcome of the repair. An open repair is still a valid option, especially in critically ill patients.

### Study limitations

The study is a retrospective analysis with a possible selection and referral biases. The choice of the patients was not consistent in both groups, and several unmeasured variables may have affected the outcomes and not included in the analysis. It is a single-centre study, and generalisation of the results may not be feasible. However, all patients had repair using a similar protocol for open and thoracoscopic techniques.

### CONCLUSIONS

The thoracoscopic approach is safe and effective for the reconstruction of the CDH. It is associated with shorter mechanical ventilation and rapid return to enteral feeding. Proper patient selection is essential to achieve good outcomes.

### Financial support and sponsorship

Nil.

### Conflicts of interest

There are no conflicts of interest.

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