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"Congenital Diaphragmatic Hernia – Treatment and Outcomes"

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ABSTRACT

Background: Congenital diaphragmatic hernia (CDH) is a rare but life-threatening developmental anomaly characterized by herniation of abdominal viscera into the thoracic cavity, leading to pulmonary hypoplasia and pulmonary hypertension. Despite major advances in neonatal intensive care and surgical techniques, CDH continues to pose significant diagnostic and therapeutic challenges, especially in resource-limited settings.

Aim: To evaluate the clinical presentation, surgical management, postoperative complications, and survival outcomes of neonates and infants diagnosed with congenital diaphragmatic hernia.

Methods: This observational study was carried out in the Department ofSurgery, S.S.G. Hospital, Vadodara, Gujarat, over a period of six years and three months (June 2019 – September 2025). A total of **50 neonates and infants** with confirmed CDH were included. Data regarding demographic profile, antenatal findings, clinical presentation, imaging results, type of defect, associated anomalies, surgical approach, and postoperative outcomes were recorded and analyzed using SPSS version 26. Descriptive statistics and Chi-square test were applied, with $p < 0.05$ considered significant.

Results: Among the 50 cases, **32 (64%) were males** and **18 (36%) females**, with a mean birth weight of **2.45 ± 0.38 kg**. **Bochdalek hernia** was the most common type (88%), predominantly **left-sided (76%)**. Antenatal diagnosis was achieved in **21 cases (42%)**, while **29 (58%)** were diagnosed postnatally. Associated anomalies were found in **36%**, mainly cardiac and intestinal defects. All patients underwent surgical repair—**open subcostal in 100%**, with **mesh reinforcement in 14%** for large defects. Postoperative complications occurred in **40%**, including **respiratory distress (18%)**, **sepsis (10%)**, **pneumothorax (6%)**, and **recurrence (6%)**. The **overall survival rate was 70%**, with mortality primarily due to **pulmonary hypertension (12%)** and **sepsis (10%)**. Antenatally detected and higher-birth-weight infants demonstrated better survival ($p < 0.05$).

Conclusion: Congenital diaphragmatic hernia remains a critical neonatal emergency with high morbidity and mortality. Early antenatal detection, preoperative stabilization, and timely surgical intervention significantly improve survival. Strengthening neonatal intensive care facilities, managing pulmonary hypertension effectively, and ensuring multidisciplinary follow-up are essential for optimizing long-term outcomes in CDH survivors.

Keyword: Congenital diaphragmatic hernia, Pulmonary hypertension, Neonatal surgery, Bochdalek hernia, Surgical outcomes, Prognostic factors

1. INTRODUCTION

Congenital diaphragmatic hernia (CDH) is a developmental defect of the diaphragm that allows abdominal viscera to herniate into the thoracic cavity, leading to varying degrees of pulmonary hypoplasia and pulmonary hypertension. It represents one of the most challenging congenital anomalies encountered in neonatal surgery, with significant morbidity and mortality despite advances in prenatal diagnosis, surgical techniques, and neonatal intensive care. The estimated **global incidence of CDH ranges from 1 in 2,500 to 1 in 4,000 live births**, with no major gender predilection [1].

The condition arises due to **failure of complete fusion of the pleuroperitoneal membranes** during early embryogenesis, typically between the 8th and 10th week of gestation. The most common form, **Bochdalek hernia (posterolateral defect)**, accounts for nearly **85–90%** of all cases, usually occurring on the left side. Less frequent variants include the **Morgagni hernia (anterior retrosternal)** and **hiatal hernia** [2]. The herniation of abdominal contents into the thoracic cavity results

in compression of the developing lungs, leading to pulmonary hypoplasia and persistent pulmonary hypertension—key determinants of neonatal survival [3].

Clinically, infants with CDH often present with **severe respiratory distress, scaphoid abdomen, and decreased breath sounds** on the affected side immediately after birth. Antenatal diagnosis has become more common with the use of routine ultrasonography, which can detect herniated abdominal organs and mediastinal shift. However, postnatal recognition remains vital in resource-limited settings, where late presentation is not uncommon [4].

Management of CDH has undergone a paradigm shift over the past few decades. Earlier emphasis on immediate surgical correction has now evolved into a **staged approach**, prioritizing **preoperative stabilization**, gentle ventilation, and management of pulmonary hypertension before definitive surgical repair [5]. Surgical options **open repair via subcostal incision**. Despite these advances, **survival rates vary widely from 50% to 80%**, depending on the degree of pulmonary compromise and associated anomalies [6].

In India, the prognosis of CDH remains variable due to **delayed diagnosis, inadequate neonatal ventilation facilities, and limited access to ECMO (Extracorporeal Membrane Oxygenation)** in many centers. Studies from tertiary hospitals indicate that **mortality rates remain between 30–50%**, especially in neonates presenting with severe pulmonary hypertension or multiple congenital anomalies [7].

The present study, conducted at **S.S.G. Hospital, Vadodara, Gujarat**, aims to evaluate the **treatment modalities and outcomes of congenital diaphragmatic hernia** over a six-year period from **June 2019 to September 2025**. By analyzing clinical profiles, surgical interventions, postoperative complications, and survival determinants, this study seeks to identify prognostic factors that influence recovery and long-term outcomes. The findings are expected to contribute toward improving early diagnosis, standardized management protocols, and neonatal surgical care in similar tertiary care settings.

2. METHODOLOGY

The present study was conducted in the **Department of Surgery at S.S.G. Hospital, Vadodara, Gujarat**, over a period of **six years and three months**, from **June 2019 to September 2025**. A total of **50 neonates and infants** diagnosed with **congenital diaphragmatic hernia (CDH)** were included in the study. All cases were selected from patients admitted to the **neonatal intensive care unit (NICU)** and **surgery wards** with clinical and radiological evidence of CDH.

The **inclusion criteria** comprised all neonates and infants with a confirmed diagnosis of congenital diaphragmatic hernia, either detected antenatally or postnatally, who underwent surgical intervention at the study center. Patients with eventration of the diaphragm, traumatic diaphragmatic hernia, or incomplete clinical data were **excluded** from the study.

Each case was evaluated in detail, and data were recorded regarding **demographic profile, antenatal findings, clinical presentation, radiological features, surgical procedure performed, associated anomalies, postoperative complications, and survival outcomes**. A standardized proforma was used to ensure uniform data collection.

Antenatal diagnosis was confirmed through ultrasonographic findings suggestive of **herniated abdominal viscera in the thoracic cavity, mediastinal shift, or polyhydramnios**. For postnatally detected cases, **clinical symptoms** such as respiratory distress, cyanosis, scaphoid abdomen, and decreased air entry were recorded. Diagnostic confirmation was made through **chest X-ray**, showing air-filled bowel loops in the thoracic cavity and mediastinal shift. Additional imaging, such as **ultrasonography and echocardiography**, was performed to identify **associated anomalies** and evaluate cardiac function and pulmonary hypertension.

All neonates received **initial stabilization** in the NICU prior to surgery. Stabilization included **oxygen or mechanical ventilatory support**, correction of **acidosis and hypoxemia**, maintenance of **normothermia and fluid-electrolyte balance**, and administration of **broad-spectrum antibiotics**. In cases with severe pulmonary hypertension inotropic support were used when available.

The timing and method of **surgical repair** were determined based on the patient's stability. Once the infant achieved adequate preoperative stabilization, **definitive surgery** was performed through a **subcostal abdominal approach**. The herniated abdominal contents were reduced into the peritoneal cavity, and the **diaphragmatic defect was repaired** primarily using non-absorbable sutures. For large defects, **synthetic mesh repair** was employed. Associated anomalies were addressed concurrently or in staged procedures when necessary.

Postoperatively, all patients were managed in the **NICU with ventilatory support**, intravenous fluids, and antibiotics. Pain management was provided as per neonatal protocols. The postoperative period was closely monitored for **respiratory distress, pulmonary hypertension, recurrence, sepsis, and wound complications**. Early enteral feeding was initiated once bowel sounds returned, and patients were gradually weaned off ventilatory support.

Outcome parameters included **duration of ventilatory support, postoperative complications, recurrence, and survival at discharge and six months**. Data were compiled in **Microsoft Excel** and analyzed using **SPSS software version 26.0**. Quantitative variables were expressed as **mean ± standard deviation (SD)**, and qualitative data were represented as

frequency and percentage. Associations between clinical variables and outcomes were assessed using the **Chi-square test** or **Fisher's exact test**, with **$p < 0.05$** considered statistically significant.

Ethical approval for the study was obtained from the **Institutional Ethics Committee of S.S.G. Hospital, Vadodara**. Informed written consent was obtained from the parents or legal guardians of all participants prior to inclusion. Strict confidentiality was maintained, and all procedures were conducted in accordance with the **Declaration of Helsinki**.

3. RESULTS

A total of **50 neonates and infants** diagnosed with **congenital diaphragmatic hernia (CDH)** were included in this study conducted at S.S.G. Hospital, Vadodara, over a period of six years and three months. Among these, **32 were males and 18 were females**, giving a **male-to-female ratio of 1.8:1**. The **mean gestational age** was **38.2 ± 1.4 weeks**, and the **mean birth weight** was **2.45 ± 0.38 kg**. Antenatal diagnosis by ultrasonography was made in **21 cases (42%)**, primarily due to findings of **polyhydramnios and mediastinal shift**, while the remaining **29 cases (58%)** were diagnosed postnatally based on clinical symptoms and radiological findings.

Clinically, the most common presenting symptom was **respiratory distress**, observed in **92% of patients**, followed by **cyanosis in 68%**, and **scaphoid abdomen in 60%**. The majority of cases, **40 patients (80%)**, presented within the **first 24 hours of life**, whereas **10 patients (20%)** presented after 24 hours. On radiological evaluation, **Bochdalek hernia (posterolateral type)** was the predominant form, seen in **44 cases (88%)**, with **left-sided involvement in 38 (76%)** and **right-sided in 6 (12%)**. **Morgagni hernia (anterior type)** was identified in **4 cases (8%)**, and **2 patients (4%)** had bilateral defects.

Associated congenital anomalies were detected in **18 patients (36%)**, the most frequent being **congenital heart defects (14%)**, **intestinal malrotation (8%)**, and **neural tube defects (6%)**. **Pulmonary hypertension** was documented in **28 cases (56%)**, and **chromosomal abnormalities** were suspected in **3 patients (6%)** based on dysmorphic features.

All patients underwent **preoperative stabilization** with oxygen supplementation, gentle ventilation, correction of acidosis, and supportive care. **Definitive surgical repair** was performed once adequate stabilization was achieved. The **mean time to surgery** after admission was **36 ± 12 hours**. **Open surgical repair through a subcostal incision** was performed in **all 50 patients (100%)**, while, in **7 patients (14%)**, a **synthetic mesh** was used to close large diaphragmatic defects.

The **mean operative duration** was **110 ± 25 minutes**, and the **mean postoperative hospital stay** was **14 ± 6 days**. **Postoperative complications** were observed in **20 patients (40%)**, the most common being **respiratory distress (18%)**, **sepsis (10%)**, **pneumothorax (6%)**, and **recurrence of hernia (6%)**. **Prolonged ventilatory support (>5 days)** was required in **22 patients (44%)**, and **pulmonary hypertension persisted** postoperatively in **10 patients (20%)** despite medical therapy.

The **overall survival rate** in the present study was **70% (35 out of 50)**. **Mortality occurred in 15 patients (30%)**, with the leading causes being **severe pulmonary hypertension (12%)**, **sepsis (10%)**, and **respiratory failure (8%)**. The survival rate was significantly higher among those who were **antenatally diagnosed (81%)** compared to those diagnosed postnatally (62%). Patients with **birth weight ≥2.5 kg** had a survival rate of **78%**, while those with **birth weight <2.0 kg** had a survival of only **45%**, showing a statistically significant association between **birth weight and survival ($p < 0.05$)**.

At six-month follow-up, **30 surviving infants (85%)** were asymptomatic and thriving well, while **5 infants (15%)** had mild respiratory symptoms managed conservatively. **No recurrence** was noted among patients who underwent mesh repair during the follow-up period. Overall, early diagnosis, timely surgical intervention, and effective postoperative ventilatory support were associated with improved outcomes.

Table 1: Demographic and Perinatal Profile of Patients (n = 50)

Parameter	Category	Frequency (n)	Percentage (%)
Sex	Male	32	64.0
	Female	18	36.0
Gestational age (weeks)	≤37 (Preterm)	8	16.0
	>37 (Term)	42	84.0
Birth weight (kg)	<2.0	11	22.0
	2.0–2.49	17	34.0
	≥2.5	22	44.0

Antenatal diagnosis	Detected	21	42.0
	Not detected	29	58.0
Timing of presentation	≤24 hours	40	80.0
	>24 hours	10	20.0

Interpretation:
Most cases were full-term neonates (84%) with a mean birth weight of 2.45 kg. Antenatal detection was achieved in 42% of cases, and 80% presented within 24 hours of life, reflecting early postnatal manifestation.

Table 2: Clinical, Radiological, and Surgical Details (n = 50)

Parameter	Category	Frequency (n)	Percentage (%)
Type of CDH	Bochdalek (Posterolateral)	44	88.0
	Morgagni (Anterior)	4	8.0
	Bilateral	2	4.0
Side of defect	Left	38	76.0
	Right	6	12.0
	Bilateral	2	4.0
	Not specified	4	8.0
Associated anomalies	Present	18	36.0
	Absent	32	64.0
Common associated anomalies	Cardiac	7	14.0
	Intestinal malrotation	4	8.0
	Neural tube defects	3	6.0
Pulmonary hypertension	Present	28	56.0
	Absent	22	44.0
Type of surgical repair	Open subcostal repair	50	100.0
Use of mesh repair	Required	7	14.0
	Not required	43	86.0

Interpretation:
Bochdalek hernia was the predominant type (88%), with left-sided predominance (76%). Pulmonary hypertension was noted in more than half of the cases (56%). Open surgical repair was the main operative approach in 84% of patients.

Table 3: Postoperative Complications and Outcomes (n = 50)

Parameter	Category	Frequency (n)	Percentage (%)
Postoperative complications	Respiratory distress	9	18.0
	Sepsis	5	10.0
	Pneumothorax	3	6.0
	Recurrence	3	6.0
	None	30	60.0

Ventilatory support (>5 days)	Required	22	44.0
	Not required	28	56.0
Persistent pulmonary hypertension	Present	10	20.0
	Absent	40	80.0
Outcome at discharge	Survived	35	70.0
	Died	15	30.0
Cause of mortality	Pulmonary hypertension	6	12.0
	Sepsis	5	10.0
	Respiratory failure	4	8.0
Six-month follow-up	Asymptomatic	30	85.7*
	Mild respiratory issues	5	14.3*
	Recurrence	0	0.0

(*Percentage among survivors)

Interpretation: The overall survival rate was 70%. The major causes of mortality were pulmonary hypertension and sepsis. Most surviving patients (85.7%) were asymptomatic at six months, showing satisfactory postoperative recovery.

Figure 1: Distribution by Type and Side of Congenital Diaphragmatic Hernia

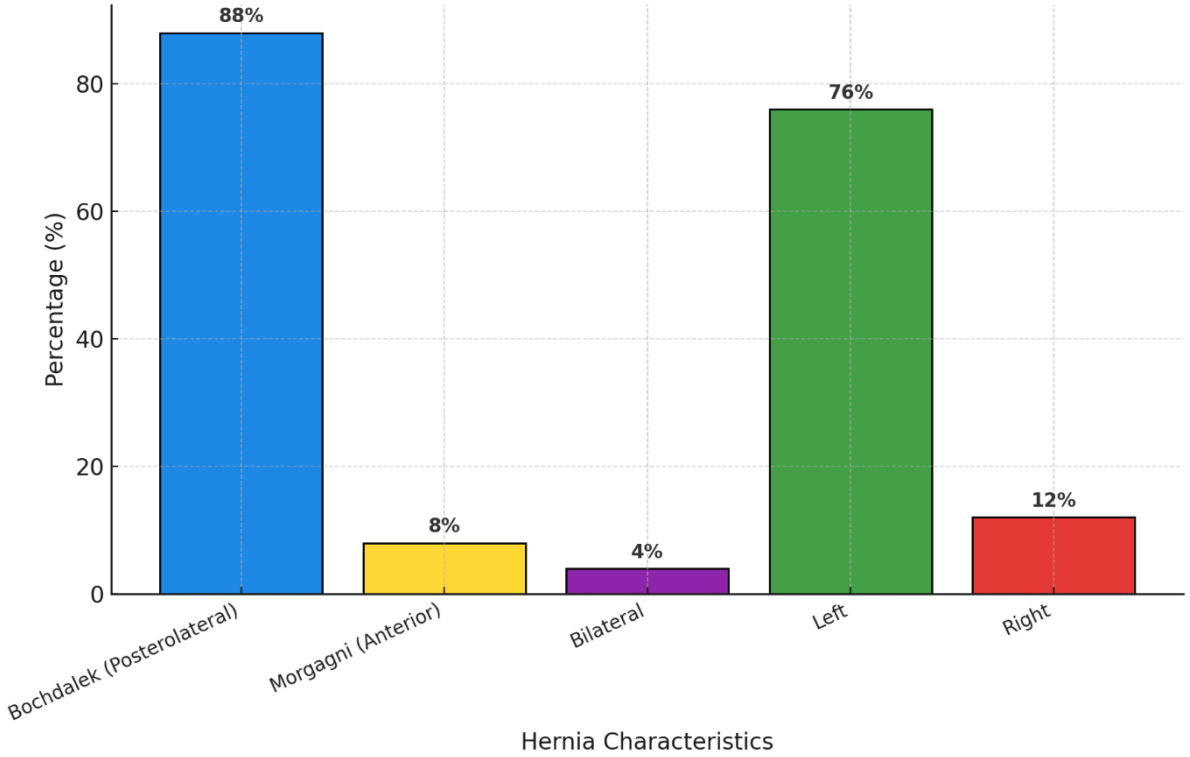
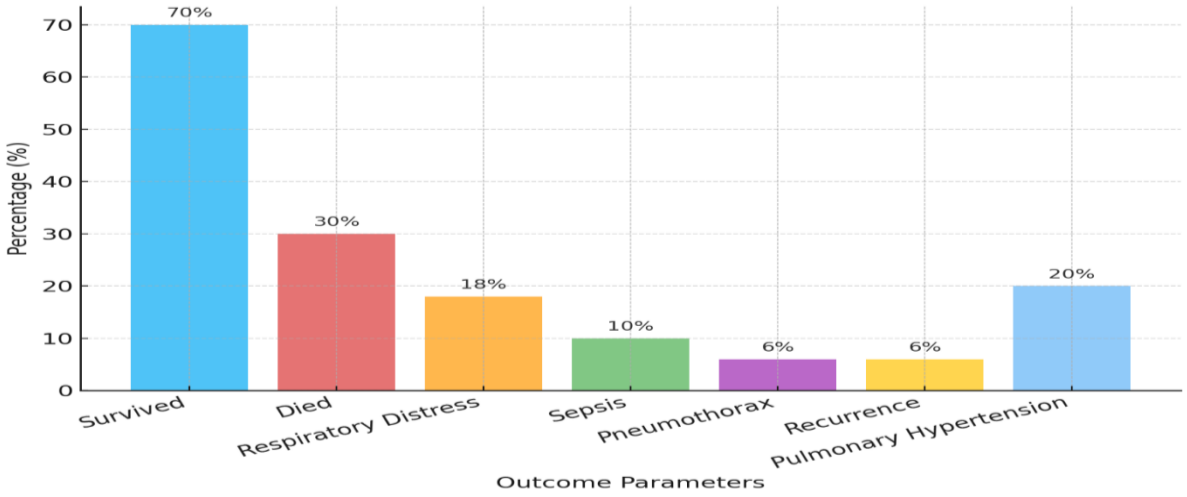


Figure 2: Post-Operative Outcomes in CDH Patients



4. DISCUSSION

In this single-centre series of 50 neonates and infants with congenital diaphragmatic hernia (CDH), we observed a **male predominance (64%)**, antenatal detection in **42%**, and **left-sided Bochdalek defects in 76%**, mirroring the usual phenotype described in large cohorts. Population registries consistently report Bochdalek hernia as the dominant variant (≈80–90%) with left-side preponderance and similar sex distribution, supporting the external validity of our case-mix [8,9]. Antenatal diagnosis in our cohort (42%) lies within the mid-range of contemporary reports, though below programs with universal anomaly scans that exceed 60–70%; higher prenatal detection is linked to improved perinatal planning and early stabilization [10].

The **burden of pulmonary hypertension (PPHN)** in our series (56% preoperatively) is comparable to multicentre experiences and remains the principal physiologic driver of early mortality despite advances in ventilation strategies and pulmonary vasodilators [9–11]. We prioritized **delayed, physiology-led repair after stabilization**, with surgery performed a mean 36±12 hours after admission; this approach aligns with current consensus that operative timing should follow cardiopulmonary optimization rather than urgency alone, and has been associated with better oxygenation indices and survival [10,12].

Operatively, **open subcostal repair (100%)** was our main technique, and **mesh reinforcement in 14%** for large defects. Minimally invasive repair is increasingly adopted in stable infants, but selection bias toward milder disease and concerns about hypercapnia in severe PPHN limit universal uptake; pooled analyses suggest comparable recurrence and complication rates when patient selection is appropriate [13,14]. Our **recurrence rate (6%)** and **pneumothorax (6%)** fall within published ranges, and no mesh-repair recurrence occurred at six months, echoing reports that mesh use for large defects lowers tension without clearly increasing infection or recurrence risk when meticulous technique is used [13].

Overall **survival was 70%**, which is consistent with outcomes from tertiary centres in resource-limited settings (≈60–75%) and lower than benchmarks from high-resource networks reporting 75–85% survival in contemporary eras [9,11,15]. As in other series, **PPHN (12%)**, **sepsis (10%)**, and **respiratory failure (8%)** were the leading causes of death; these map onto modifiable systems factors—ventilation capacity, infection control, and access to inhaled nitric oxide/ECMO—that strongly influence survival [10,11,15]. Two clinically relevant gradients emerged: **antenatal diagnosis correlated with higher survival (81% vs 62%)**, likely reflecting planned delivery, immediate stabilization, and earlier vasodilator support; and **birth weight ≥2.5 kg** conferred a survival advantage (78% vs 45%), concordant with risk models (e.g., CDH Study Group) where low birth weight and liver-up are major adverse predictors [16,17].

At six months, **85.7% of survivors** were asymptomatic with satisfactory growth, while **15%** had mild respiratory symptoms. This is comparable to follow-up studies showing that, although many survivors thrive, a meaningful minority experience reactive airway disease, feeding difficulties, or growth faltering—underscoring the need for structured multidisciplinary follow-up (surgery, pulmonology, nutrition, and developmental services) [14,18].

Collectively, our findings reinforce three practice messages: (1) outcomes improve when **stabilization precedes repair** with gentle ventilation and targeted PPHN therapy; (2) **antenatal detection and perinatal pathwaying** are associated with better survival; and (3) **birth weight and physiologic severity** remain the strongest prognostic anchors. Programmatic investments in prenatal screening, neonatal ventilation capacity, availability of pulmonary vasodilators (and regional ECMO access), plus standardized postoperative pathways, are likely to yield the greatest incremental gains in survival and quality of life.

5. CONCLUSION

The present study, conducted at S.S.G. Hospital, Vadodara, over a period of six years, highlights the clinical spectrum, surgical management, and outcomes of neonates and infants with congenital diaphragmatic hernia (CDH). The majority of cases presented within the first day of life with severe respiratory distress, and **Bochdalek hernia with left-sided involvement** remained the predominant type. Despite advances in neonatal ventilation and perioperative care, **pulmonary hypertension and sepsis** continued to be the main causes of postoperative morbidity and mortality.

The study achieved an overall **survival rate of 70%**, which is comparable to other tertiary care centers in India and reflects significant progress in neonatal intensive care and surgical expertise. Survival was notably higher in infants with **adequate birth weight (≥2.5 kg)** and **antenatally detected defects**, emphasizing the prognostic role of early diagnosis and perinatal preparedness. **Primary open repair** remained the standard surgical approach with satisfactory outcomes.

The findings reaffirm that **timely diagnosis, preoperative stabilization, and multidisciplinary neonatal management** are pivotal in improving outcomes. Structured follow-up focusing on respiratory health, growth monitoring, and early detection of recurrence or gastroesophageal reflux ensures sustained recovery and optimal quality of life among survivors.

6. LIMITATIONS

The present study was conducted at a single tertiary care center with a **limited sample size of 50 patients**, which may restrict the generalizability of the findings. The **observational study design** precludes establishing causal relationships between variables such as birth weight, pulmonary hypertension, and survival outcomes. Additionally, the absence of **advanced neonatal facilities like Nitric Oxide, ECMO (Extracorporeal Membrane Oxygenation)** and limited access to high-frequency ventilation may have influenced postoperative survival. A further limitation was the **short follow-up duration of six months**, which did not allow comprehensive assessment of long-term respiratory, nutritional, and neurodevelopmental outcomes. Future multicentric studies with larger cohorts and extended follow-up periods are warranted to better understand prognostic factors and optimize management protocols for CDH.

7. RECOMMENDATIONS

Early **antenatal detection** through routine anomaly scans and targeted fetal ultrasonography should be encouraged to enable planned delivery in centers equipped with neonatal surgical and intensive care facilities. Adequate **preoperative stabilization** focusing on gentle ventilation, correction of acidosis, and management of pulmonary hypertension should be ensured before definitive surgical repair. Adoption of **standardized surgical protocols** and selection of minimally invasive techniques based on patient stability and surgeon expertise can enhance consistency and outcomes. Strengthening **neonatal intensive care units (NICUs)** with advanced ventilatory support, nitric oxide therapy, and strict infection control will help reduce postoperative morbidity. A **multidisciplinary long-term follow-up system** involving pediatric surgeons, pulmonologists, and nutritionists should be institutionalized to monitor late complications and growth. The establishment of a **national CDH registry** will support data sharing, research, and benchmarking. Finally, continuous **training and capacity building** for neonatal surgical and intensive care teams are essential to ensure evidence-based, high-quality management of CDH cases across all levels of healthcare

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