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ORIGINAL ARTICLE

Congenital diaphragmatic hernia: outcome review of 2,173 surgical repairs in US infants

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Abstract Congenital diaphragmatic hernia (CDH) remains one of the most challenging conditions to treat within the pediatric surgical and medical communities. In spite of modern treatment modalities, including extracorporeal membrane oxygenation (ECMO) and improved ventilatory support, mortality remains high. The present study analyzes a US database containing information from nearly 93 million discharges in the US. Infants with congenital diaphragmatic hernia who underwent surgical repair were identified by ICD-9 procedure code and inclusion criteria including an age at admission of less than 1 year. Variables of gender, race, age, geographic region, co-existing diagnoses and procedures, hospital type, hospital charges adjusted to 2006 dollars, length of stay, and inpatient mortality were collected. A total of 89% of patients were either treated initially or rapidly transferred to urban teaching hospitals for definitive treatment of CDH. The inpatient mortality rate was 10.4% with a median length of stay of 20 days (interquartile range of 9–40 days). The median inflation-adjusted total hospital charge was $116,210. Respiratory distress was the most common co-existing condition (68.8%) followed by esophageal reflux (27.8%). The most common concomitant procedures performed were ECMO (17.8%) and fundoplication (17.6%). This study, which represents the largest characterization of US infants who have undergone CDH repair using data from a nationally representative non-voluntary database, demonstrates that surgical repair is associated with significant mortality and morbidity.

Keywords Agency for Healthcare Research and Quality (AHRQ) · Healthcare Cost and Utilization Project (HCUP) · Kids' inpatient database (KID) · National inpatient sample (NIS) · Congenital diaphragmatic hernia (CDH)

Abbreviations

AHRQ	Agency for Healthcare Research and Quality
HCUP	Healthcare Cost and Utilization Project
KID	Kids' inpatient database
NIS	National inpatient sample

Introduction

Congenital diaphragmatic hernia (CDH) is a complex congenital anomaly that consists of incomplete formation of the diaphragm coupled with some degree of pulmonary hypoplasia [1, 2]. Known as the costliest non-cardiac birth defect [3], the incidence of CDH varies between 1:2,000 and 1:4,000 live births [4] with an estimated 30% spontaneous abortion rate. The etiology of CDH has been linked to both genetic [5, 6] and environmental factors [7] but remains poorly understood. Treatment modalities for CDH have evolved in the recent years with the most significant development being the delay of surgical repair until the

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patient is hemodynamically stable [2, 8–10]. Other important treatment hallmarks include avoidance of barotrauma with lung protective ventilator strategies and the selective use of extracorporeal membrane oxygenation (ECMO) [11]. Taken together along with other advances in neonatal critical care, the mortality of CDH has fallen from greater than 50% in the 1970s to between 5 and 30% in recent studies [10, 12–14].

The best outcome studies to date for CDH have relied primarily on single-institution experiences [15–19] or network-based data [20–24]. The present study aimed to provide national outcomes data for the first time for infants who underwent surgical repair for this rare congenital condition.

Materials and methods

Databases

An analysis was performed using 6 years of the national inpatient sample (NIS) database (1998, 1999, 2001, 2002, 2004, and 2005) and 3 years of the kids inpatient database (KID) (1997, 2000, and 2003). Both databases are produced as part of the Healthcare Cost and Utilization Project (HCUP) of the Agency for Healthcare Research and Quality. The NIS is an all-payer database that annually contains information from up to 8 million inpatient discharges from approximately 1,000 hospitals across the US. Hospitals are sampled to represent a 20% stratified sample of all community hospitals. The definition of a community hospital follows that of the American Hospital Association (AHA): non-federal (e.g., not military, Veterans Administration, or Indian Health Service), short-term general and other specialty hospitals, including obstetrics–gynecology, ear–nose–throat, short-term rehabilitation, orthopedic, and pediatric. Excluded are long-term care hospitals, psychiatric hospitals, alcoholism/chemical dependence treatment facilities, and hospital units within institutions (such as prisons). The number of states for which NIS data is available has increased from 8 states in 1988 to 37 states in 2003. The KID contains a sample of pediatric (age 20 years or less) discharges from all community, non-rehabilitation hospitals in states which participate in the HCUP. Unlike the NIS, which samples at the hospital level, the KID samples patient discharges which are then weighted to obtain normal estimates. The sampling algorithm involves systematic random sampling to select 10% of uncomplicated in-hospital births and 80% of complicated in-hospital births as well as other selected pediatric cases. The KID contains information from up to 36 states. Information collected on patients in both databases includes age in days at admission, gender, race, diagnosis and procedure information, mortality, length of stay and total hospital charges. Since the KID was available only for 3 years (1997, 2000, 2003), we used the KID for every year it was available and captured additional pediatric data for the remaining years from the NIS.

Patient selection

Inclusion criteria for the analysis were an International Classification of Disease (ICD)-9 procedure code of 53.75 (repair of diaphragm, abdominal approach) and an age at admission of less than 1 year.

Data management and analysis

A descriptive analysis was performed using variables of gender, race, inpatient mortality, geographic region (Northeast, Midwest, South, West) and type of hospital (urban teaching, urban non-teaching and rural). Summary statistics for length of stay and inflation-adjusted total hospital charges were calculated. The prevalence of certain co-existing diagnoses and procedures was determined using ICD-9 codes.

Results

Demographic data

Demographic data are summarized in Table 1. A total of 2,173 patients were identified from the search of the NIS and KID databases, with 1,242 patients admitted at age <30 days, and 438 patients with age ≥30 days. The detailed distribution of patient age on admission is reported

Table 1 Patient demographic data

Characteristic	Total (n = 2,173)	<30 days (n = 1242)	≥30 days (n = 438)
Gender			
Male	1,296 (59.6)	752 (60.6)	253 (57.8)
Female	866 (39.8)	490 (39.5)	185 (42.2)
Race[a]			
White	918 (54.1)	482 (38.8)	196 (44.8)
Black	148 (8.7)	75 (6.0)	28 (6.4)
Hispanic	409 (24.1)	216 (17.4)	75 (17.1)
Other	219 (10.1)	133 (10.7)	33 (7.5)
Age (day) on admission[b]			
Median (IQR)	0 (0–40)	0 (0–0)	185 (105–272)

IQR Interquartile range

[a] 22% of the states did not collect information on race

[b] 22.7% of data on age in days missing

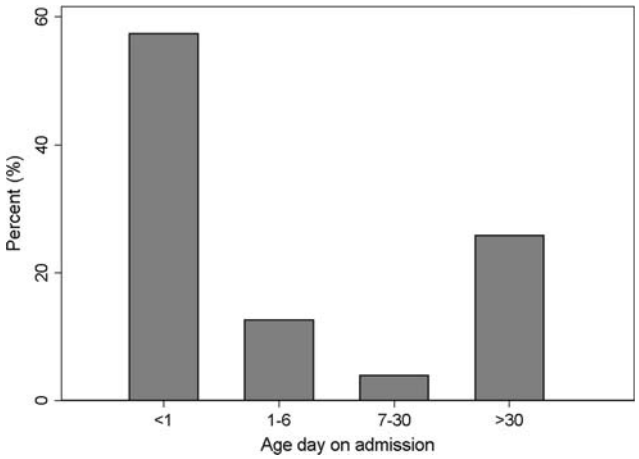

Fig. 1 Distribution of patients by age on admission, in days

on Fig. 1. Male gender was more common within the study group with 1,296 (59.6%) males and 866 (39.8%) females. The racial makeup was 54.1% white, 24.1% Hispanic, 8.7% Black and 3.6% Asian or Pacific Islander. A total of 158 patients were classified as "other" including Hawaiian and Native American. Race data were not available for 22% of participants because not all hospitals and states report this information to HCUP. The median age at admission was 0 days (interquartile range 0–40). The data on age in days were not available for 22.7% of the patients. There are minor demographic differences between the age <30 days group versus the age ≥30 days.

Hospitalization characteristics and inpatient mortality

Most of the individuals were hospitalized in the South and West (31.3 and 35.3%, respectively) with 16.1% in the Midwest and 17.2% in the Northeast (Table 2). The majority of infants were either born in or quickly transferred to urban teaching hospitals (89.0%). Few patients were treated at rural centers. Overall inpatient mortality was 10.4%. The median length of stay was 20 days (interquartile range of 9–40 days). The median inflation-adjusted total hospital charge in 2006 dollars was $116,210. Additionally, the patients admitted with age <30 days were significantly sicker than patients admitted with age ≥30 days, in terms of mortality, length of stay, and total hospital charges.

Co-existing diagnoses

The prevalence of co-existing conditions and congenital abnormalities among the infants was determined, and the results are displayed in Table 3. Overall, respiratory problems were the most common (74.1%) with respiratory distress (68.8%), pulmonary hypoplasia (17.8%), pleural effusion (9.2%) and pneumothorax (5.0%) being most frequently encountered. Gastrointestinal anomalies were found in 27.8% of the infants with esophageal reflux (22.1%) and intestinal fixation anomaly (6.8%) being the most common. Cardiovascular anomalies were found in 26.5% with the most common being patent ductus arteriosus (17.0%), secundum atrial septal defect (11.7%), and ventricular septal defect (5.3%). Other common co-existing diagnoses were infection (28.9%), acidosis (9.0%), and neonatal jaundice (8.9%). Undescended testis (2.6%) and Down's syndrome (1.4%) were among the rare co-existing diagnoses. The younger (age <30 days) patients have significantly more respiratory, cardiovascular, and miscellaneous co-existing diagnoses, with the only exception being less gastrointestinal tract diagnoses.

Table 2 Hospitalization characteristics

Characteristic	Total (n = 2,173)	<30 days (n = 1,242)	≥30 days (n = 438)
Geographic region			
Northwest	374 (17.2)	227 (18.3)	60 (13.7)
Midwest	351 (16.1)	261 (21.0)	88 (20.1)
South	680 (31.3)	218 (17.6)	73 (16.7)
West	768 (35.3)	536 (43.2)	217 (49.5)
Type of hospital			
Urban teaching	1,936 (89.0)	1129 (90.9)	389 (88.8)
Urban, non-teaching	200 (9.2)	89 (7.2)	40 (9.1)
Rural	10 (0.4)	<10 (<0.8)	<10 (<2.9)
In-hospital mortality	225 (10.4)	160 (12.9)	<10 (<2.9)
Length of stay			
Median (IQR)	20 (9–40)	26 (15–45)	6 (3–10)
Total hospital charges ($)[a]			
Median (IQR)	116,210 (42,666–281,361)	173,014 (81,271–338,946)	25,554 (15,425–50,426)
Mean	203,739	246,929	53,980

IQR Interquartile range

[a] Adjusted to 2006 dollars

Table 3 Co-existing diagnoses

Diagnosis	Total (n = 2,173)	<30 days (n = 1,242)	≥30 days (n = 438)
Respiratory	1,612 (74.1)	1,123 (90.4)	134 (30.6)
Respiratory distress	1,495 (68.8)	1,084 (87.3)	87 (19.9)
Pulmonary hypoplasia	387 (17.8)	288 (23.2)	19 (4.3)
Pleural effusion	201 (9.2)	140 (11.3)	13 (3.0)
Pneumothorax	110 (5.0)	70 (5.6)	15 (3.4)
Pulmonary collapse	105 (4.8)	38 (3.1)	31 (7.1)
Primary pulmonary hypertension	93 (4.3)	69 (5.6)	<10 (<2.9)
Laryngotracheal anomaly	44 (2.0)	17 (1.4)	18 (4.1)
Cardiovascular	575 (26.5)	394 (31.7)	38 (8.7)
Patent ductus arteriosus	370 (17.0)	278 (22.4)	10 (2.3)
Secundum atrial septal defect	254 (11.7)	157 (12.6)	22 (5.0)
Ventricular septal defect	116 (5.3)	70 (5.6)	15 (3.4)
Congenital heart anomaly	73 (3.3)	57 (4.6)	<10 (<2.9)
Coarctation of the aorta	27 (1.2)	19 (1.5)	0 (0.0)
Gastrointestinal tract	604 (27.8)	294 (23.7)	176 (40.2)
Esophageal reflux	480 (22.1)	210 (16.9)	158 (36.1)
Intestinal fixation anomaly	149 (6.8)	97 (7.8)	26 (5.9)
Miscellaneous			
Infection	627 (28.9)	460 (37.0)	19 (4.3)
Fetal/neonatal jaundice	193 (8.9)	155 (12.5)	0 (0.0)
Acidosis	194 (9.0)	142 (11.4)	13 (3.0)
Hypotension	176 (8.0)	134 (10.8)	<10 (<2.9)
Dehydration	146 (6.7)	116 (9.3)	<10 (<2.9)
Thrombocytopenia	104 (4.8)	84 (6.8)	<10 (<2.9)
Undescended testis	58 (2.6)	51 (4.1)	<10 (<2.9)
Down's syndrome	30 (1.4)	<10 (<0.8)	19 (4.3)

Table 4 Co-existing procedures

Procedure	Total (n = 2,173)	<30 days (n = 1,242)	≥30 days (n = 438)
ECMO	386 (17.8)	264 (21.3)	<10 (<2.9)
Esophageal fundoplication	382 (17.6)	114 (9.2)	168 (38.4)
Appendectomy	333 (15.3)	221 (17.8)	52 (11.9)
Gastrostomy	283 (13.0)	119 (9.6)	86 (19.6)
Circumcision	181 (8.3)	135 (10.9)	<10 (<2.9)
Bronchoscopy	110 (5.0)	67 (5.4)	19 (4.3)
Spinal tap	64 (2.9)	41 (3.3)	<10 (<2.9)
Thoracentesis	51 (2.3)	39 (3.1)	<10 (<2.9)
Tracheostomy	47 (2.1)	28 (2.3)	<10 (<2.9)
Umbilical hernia repair	38 (1.7)	18 (1.4)	14 (3.2)
Pyloroplasty	31 (1.4)	<10 (<0.8)	16 (3.7)
Pyloromyotomy	31 (1.4)	15 (1.2)	<10 (<2.9)

Co-existing procedures

The prevalence of co-existing procedures was high among CDH patients, with 1,937 invasive procedures performed (Table 4). Overall, ECMO and esophageal fundoplication were the most common (17.8 and 17.6%, respectively). Other common co-existing procedures were appendectomy (15.3%), gastrostomy (13.0%) and circumcision (8.3%). Among the rare co-existing procedures were umbilical hernia repair (1.7%), pyloroplasty (1.4%) and pyloromyotomy (1.4%).

Discussion

The purpose of this study was to help profile national outcomes for US patients who have undergone surgical repair of CDH. This study is one of the largest to present surgical outcomes for this disease in that it represents involuntary sampling of patients from 37 states. Our study demonstrated an inpatient survival rate of 90% for infants who underwent surgical repair of CDH, which seems appropriate as only infants who were deemed to be surgical candidates for the surgical repair were considered within this analysis. Due to a higher rate of coding errors associated with diagnosis codes (e.g. 756.6 for a diagnosis of CDH), we elected to focus on our inclusion criteria on procedure codes (e.g. for the surgical procedure of the CDH repair 53.75) as reported for billing. The national inpatient survival rate after surgery as reported at approximately 90% for the period of this study (1998–2005) is consistent with the overall improvement of outcomes in the modern era of treatment which has included the deferral of surgery until respiratory and hemodynamic stabilization, avoidance of barotrauma preoperatively, selective use of ECMO, and the existence of high-volume centers with established treatment protocols [2, 9, 10, 12, 13]. This is consistent with survival rates for live-born infants with the disease which have been reported to be as high as 87–96%, although sample sizes in such studies are small [10, 25, 26]. When considering the broader population of infants antenatally and postnatally diagnosed with CDH, there is indeed documented higher perinatal and postnatal mortality [14, 27, 28], which are more consistent with the full burden of the disease. Colvin and colleagues [28] discuss the notion that 30–50% of CDH cases in Western Australia are spontaneously or electively aborted. Thus, for families of an infant who survives long enough to attempt surgical repair, these outcomes data may offer some assurance of improved chances of survival.

The complexity of CDH treatment is underscored by the data in the present analysis detailing length of hospital stay (median 20 days) and the high cost of initial treatment ($116,210). Robbins and colleagues [3] identified CDH as the costliest non-cardiac congenital anomaly. This is due to a combination of the cost of the initial resuscitation and the cost of the frequently required secondary procedures. These data do not, however, include the costs involved in subsequent treatment of comorbidities, rehabilitation, nutritional support, and pharmaceutical costs. For example, up to 90% of patients born with CDH have clinically significant reflux and dysmotility [29]. The present study demonstrated that only 17% of patients underwent esophagogastric fundoplication during the initial hospitalization, suggesting that patients may require a second hospitalization for definitive treatment of such co-morbidities.

Our study has several limitations. The NIS and the KID do not contain enough detailed clinical information to provide insight into specifics of surgical repair (i.e. use of prosthetic material), neonatal and ventilatory strategies, etc. Thus, data represent an average outcome. We are also limited by errors in coding in large databases, but these should be random and thus should not bias the results significantly. Data from the present study should be interpreted in light of these limitations.

This study is the first to utilize both the NIS and KID databases in conjunction to analyze the outcomes of patients undergoing CDH repair. Further analysis should focus on separating the CDH population into subsets, with the aim being to understand the outcomes of this disease on a population-based scale for different subsets of CDH patients.

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