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Surgical Interventions in Infants Born Preterm with Congenital Heart Defects: An Analysis of the Kids' Inpatient Database

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Objective To evaluate short-term outcomes in infants born preterm with congenital heart defects (CHDs) and the factors associated with surgery, survival, and length of hospitalization in this population.

Study design We analyzed data from infants born preterm (gestational age <37 weeks) enrolled in the multicenter Kids' Inpatient Database of the Healthcare Cost and Utilization Project who were admitted to the hospital within 30 days after birth. Infants with atrial septal defects were excluded.

Results Of 1 429 762 enrolled infants born preterm, 27 434 (2.0%) with CHDs were included. Overall survival to discharge was 90.5%; 74.0% among infants with critical CHDs and 45.7% among infants with hypoplastic left heart syndrome. Cardiac surgeries were performed in 12.2% of all infants born preterm. Rates of surgical intervention for infants with critical CHDs were lower for very low birth weight (≤1.5 kg) vs larger infants >1.5 kg (27% vs 44%), and only 6.3% of infants born with very low birth weight underwent surgeries in Risk-adjustment for Congenital Heart Surgery categories 4 or greater. Greater birth weight, left-sided lesions, care at children's hospitals, and absence of trisomies were associated with a greater likelihood of surgery. Birth weight <2 kg, nonwhite race, trisomy syndromes, prematurity-related morbidities, and Risk-adjustment for Congenital Heart Surgery category 4 or greater were independent predictors of mortality. Birth weight <2 kg, Risk-adjustment for Congenital Heart Surgery category, morbidities, and sidedness of lesion predicted length of stay.

Conclusions The high survival rates of infants born preterm with CHDs suggests that a cautiously optimistic approach to surgery may be warranted in all but the most immature infants with the greatest-risk conditions. *(J Pediatr 2017;■■:■■-■■).*

The reported prevalence of congenital heart defects (CHDs) in 2005 was 7.2 per 1000 live births across 16 European countries.[1,2] Despite progress in management, CHDs remain an important cause of infant mortality.[3-7] Short-term outcomes of infants born very preterm with CHDs, who have only been offered intensive care in recent decades, have not been studied extensively. Single-center studies report increased mortality and postoperative length of stay (LOS) among infants with CHDs born at 34-38 weeks' gestational age (GA).[8-10] In one multicenter study of 110 infants with CHDs born extremely preterm (birth weights 401-1000 g), mortality was greater but prematurity-related morbidities were similar to the 13 887 infants without birth defects.[11]

The decision of whether to offer corrective surgery to infants born preterm with CHDs is variable and based on scant data.[9,12] Body weight is reported to be associated with mortality rates after cardiac surgery; in 1 study, 24.7% of 93 infants born preterm with CHDs weighing 1500-2000 g and 17.3% of 315 infants weighing >2000 g died. The authors noted that, until 2003, open-heart surgery was not performed on neonates weighing <1500 g.[13]

Data on interventions, outcomes, and associated risk factors in contemporary cohorts of infants born preterm with CHDs are important for parental counseling and medical decision-making. We used a large, multicenter database to describe rates of mortality, morbidities, and cardiac surgeries during the initial hospitalization in infants born preterm with CHDs, categorized

BPD	Bronchopulmonary dysplasia
CHD	Congenital heart defects
GA	Gestational age
HLHS	Hypoplastic left heart syndrome
ICD-9 CM	*International Classification of Disease, Ninth Revision, Clinical Modification*
IVH	Intraventricular hemorrhage
KID	Kids' Inpatient Database
LOS	Length of stay
NEC	Necrotizing enterocolitis
RACHS-1	Risk-Adjustment for Congenital Heart Surgery
TAPVC	Total anomalous pulmonary venous connection
TGA	Transposition of great arteries
TOF	Tetralogy of Fallot
VLBW	Very low birth weight

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as very low birth weight (VLBW) (birth weights ≤1500 g) and larger infants born preterm. We also investigated factors associated with cardiac surgeries, mortality, and LOS in these infants.

Methods

We analyzed data collected as part of the administrative Kids' Inpatient Database (KID). The Healthcare Cost and Utilization Project, administered by the Agency for Healthcare Research and Quality, produces the National Inpatient Sample and its pediatrics-only version, KID.[14] This all-payer database annually collects information from hospital administrative discharge (ie, billing) records from about 4000 hospitals across 44 states in the US of various levels (primary to tertiary), settings (university academic, general), and types of insurance (public, private). About 100 data elements (*International Classification of Disease, Ninth Revision, Clinical Modification* [ICD-9-CM] diagnoses, Current Procedural Terminology procedures, demographic and hospital characteristics, discharge status, LOS, severity, and comorbidity measures) for each hospital stay are included from the discharge abstract. KID data are available every 3 years between 1997 and 2012 and include a random sample of 10% of uncomplicated in-hospital births and 80% of other pediatric discharge codes from participating institutions. The KID allows calculation of national estimates with sampling error by using discharge weight, cluster (hospital), and stratum (region) variables in the analyses, in which the basic unit is a patient discharge, rather than an individual patient.

Our study included infants born preterm (<37 weeks' GA; coded by ICD-9-CM 7650x, 7651x, and 765.20 through 765.28) with CHDs (ICD-9-CM codes, **Table I**; available at www.jpeds.com), enrolled in the KID sample in 2003, 2006, 2009, and 2012 who were inborn or transferred from other hospitals within 30 days of birth. Data were abstracted for the period between admission and discharge, transfer, or death. Stillbirths (ICD-9-CM V32, V35, or V36) and isolated atrial septal defect or patent ductus arteriosus were excluded. To minimize duplication, infants with a final disposition coded as transfer were excluded from surgical intervention, survival, and LOS analyses.

Perioperative risk categories were defined by Risk-Adjustment for Congenital Heart Surgery (RACHS-1) scores, with 1 being the lowest and 6 being the highest risk categories, by use of the ICD-9-CM codes for cardiac surgeries (**Table II**; available at www.jpeds.com).[15] If multiple surgeries were performed, we included the highest RACHS-1 category surgery and, if multiple surgeries in the same category were performed, the earlier procedure was included.[16-18] Infants with any of the 20 critical CHDs who underwent isolated patent ductus arteriosus ligation as the sole procedure during hospitalization were not categorized by RACHS-1 but were included for outcomes.

Statistical Analyses

Baseline characteristics (birth weight distribution, care at children's hospitals, and prevalence of critical CHDs) and outcomes data (mortality, cardiac surgeries, and LOS) from the 4 included years were compared (**Table III**; available at www.jpeds.com) by use of the χ^2 linear-by-linear association for categorical variables and 1-way ANOVA for continuous variables; alpha was set at 0.01 (Bonferroni correction) for statistical significance. Because of the small numbers for RACHS-1 categories 5 and 6 procedures and comparable mortality outcomes and baseline characteristics in the 4 years, we combined data for these analyses.[14,19] Categorical data were reported as weighted frequencies and proportions, continuous variables as means and SDs when normally distributed, and as medians and IQRs otherwise. Demographic, clinical, and hospital characteristics and prematurity associated comorbidity indicators (intraventricular hemorrhage [IVH], bronchopulmonary dysplasia [BPD], and necrotizing enterocolitis [NEC]) were assessed as independent predictors of cardiac surgeries and mortality with the use of adjusted logistic regression models. Variables with a *P* value of .1 on univariate analysis were selected as candidates for the final model and were assessed for collinearity and interaction. ORs with 95% CIs were calculated for each predictor. LOS determinants were modeled with adjusted gamma regression.

Survival by birth weight and RACHS-1 categories were displayed as Cox-proportional hazard curves with hazard ratios and 95% CIs. Data were analyzed with SAS software, version 9.4 (SAS Institute, Cary, North Carolina) and all tests were 2-tailed.

Results

For baseline characteristics (**Table IV**) and frequency distribution of CHDs, a total of 27 434 neonates were included, which yielded a prevalence of 19.2 cases per 1000 preterm admissions (**Table V**; available at www.jpeds.com). After 4732 transferred infants were excluded to avoid potential duplication, the prevalence decreased to 15.9 per 1000 admissions. Infants who did not have a documented birth weight (n = 1763; 8%) and who were transferred out (n = 4732) were excluded from outcome (mortality, surgical intervention, and LOS) analyses by birth weight categories, leaving 20 939 subjects. The weighted frequency of ventricular septal defect, the most common acyanotic CHD, was 15 614 (56.9%), tetralogy of Fallot (TOF), the most common cyanotic CHD, was 1817 (6.6%), and hypoplastic left heart syndrome (HLHS) was 780 (2.8%) (**Table VI**; available at www.jpeds.com).

Characteristics of the preterm CHD cohort reveal that infants of VLBW <1500 g comprised 25.6% of the cohort and infants with GA ≤30 weeks made up 19.1% (**Table IV**). Rates of morbidities were relatively low, including 7.8% of infants with any IVH, 2.1% with NEC, and 6.5% with BPD. Stage 2 or 3 NEC occurred in 1.4% of infants of VLBW and 0.4% of the >1500-g group. Infants who did not have birth weights were comparable with the included 20 939 subjects in baseline characteristics, rates of prematurity-related morbidities, mortality, and surgeries for critical CHDs. However, they had significantly greater rates of critical CHD and total cardiac surgeries (**Table VII**; available at www.jpeds.com).

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