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Contemporary Outcomes and Risk Profiles in Neonate and Infant Congenital Heart Surgery

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Abstract **Original Research Article**

Background: Congenital heart disease (CHD) is the most common global birth defect, affecting millions annually. Advances in neonatal cardiac surgery have improved survival, but challenges persist in reducing complications and optimizing long-term outcomes. ***Aim of the study:*** This study aims to identify the risk factors influencing survival outcomes following surgery for congenital heart diseases (CHD) in the neonates and infants **Methods:** This retrospective study analyzed 20 neonates and infants undergoing CHD surgery between March 2021 and August 2022 in the Department of Cardiac surgery, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh. Demographic, preoperative, and postoperative variables were assessed. Statistical analysis included logistic regression to identify mortality predictors. ***Result:*** The mean age of babies was 5.38±3.61 months, with a 65.0% male predominance. TAPVC (40.0%), TGA (35.0%), and PDA (25.0%) were the most common diagnoses. Postoperative mortality was 40.0%, with endotracheal (ET) tube blockage (OR: 0.058, p<0.001) and renal failure (OR: 0.037, p<0.001) identified as independent mortality predictors. The mean hospital stay was 9.17±1.36 days. ***Conclusion:*** Congenital heart surgery faces high mortality (40%), with ET tube blockage and acute kidney injury as key risk factors. Despite advancements, outcomes lag behind global benchmarks. Targeted quality improvement, enhanced perioperative & postoperative care, standardized protocols, and regional centers of excellence are crucial for improving survival and long-term outcomes.

Keywords: Congenital Heart Disease, Infant Surgery, TAPVC, TGA, PDA, Neonatal Outcomes, Risk Factors.

INTRODUCTION

Congenital heart disease (CHD) includes structural heart abnormalities present at birth, ranging from mild defects like ventricular and atrial septal defects to severe anomalies. CHD is the most common global birth defect, affecting millions annually, with a mean prevalence of 8.22 per 1,000 live births from 1970 to 2017. During this time, its prevalence increased by about 10% every five years due to advancements in early detection and diagnostic technologies [1]. Patent ductus arteriosus (PDA), where the ductus arteriosus fails to close after birth, leads to abnormal blood flow between the aorta and pulmonary artery. Common in premature infants (20–60% of cases), untreated PDA can cause pulmonary hypertension and heart failure [2,3]. Rare defects like total anomalous pulmonary venous connection (TAPVC), where pulmonary veins fail to connect to the left atrium, require prompt intervention to restore oxygenation and prevent complications like hypoxia and heart failure [4]. TAPVC accounts for approximately 2% of CHD cases and is associated with a high risk of mortality without timely intervention [5]. Similarly, transposition of the great arteries (TGA), a cyanotic CHD involving reversed main arteries, demands an arterial switch operation for survival and adequate oxygenation [6]. It represents about 5–7% of all CHD cases [7]. Congenital heart surgery is vital for correcting these types of structural defects, preventing heart failure progression, and improving survival and quality of life though advances in care still face challenges in reducing complications and enhancing long-term outcomes [8]. Outcome measures frequently used, such as ICU stay and hospital length, are less dependable in neonatal populations due to their variability and the requirement for large sample sizes. As a result, surrogate measures like vasoactive inotropic scores are often used instead [9]. More than 90% of children with critical or complex congenital heart disease (CHD) now survive into adulthood, representing a significant achievement in treatment outcomes. However, despite these advancements, long-term challenges such as developmental delays, neurodevelopmental disabilities, and acquired brain injuries have become major concerns [10]. These complications are often linked to factors originating in utero, along with the stress associated with surgical interventions and perioperative care [11]. Infants with complex CHD, including TGA and TAPVC, are at heightened risk for neurodevelopmental impairments due to prolonged exposure to hypoxemia, bypass-induced ischemia, and other perioperative factors. Moreover, neonates with PDA may face delayed recovery and chronic complications if left untreated, emphasizing the importance of early and targeted management [10]. Growth-restricted infants, especially those with birth weights below 2.5 kg, face poorer surgical outcomes due to limited reserves and compounded by intrauterine growth restriction and surgical stress, leading to delayed recovery and growth [12,13]. Early intervention improves outcomes, but institutional variability in high-risk surgery mortality (10–40%) remains a concern [14]. These disparities highlight the importance of quality improvement initiatives, including regionalized care and the creation of centers of excellence, to standardize outcomes and enhance access to high-quality care [15]. This study aims to identify the risk factors influencing survival outcomes following surgery for congenital heart diseases (CHD) in the neonates and infants.

METHODOLOGY & MATERIALS

This study involved a retrospective analysis of neonates and infants patients who underwent cardiac surgery at the Department of Cardiac Surgery in Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, Bangladesh. For over 1.5 years, from March 2021 to August 2022, 20 neonates and infants with confirmed congenital heart diseases were included in the study. Patients were selected based on predefined inclusion and exclusion criteria. Ethical approval was obtained from the institution's ethics committee, and before patient enrollment, a consent form was taken from every participant's guardian.

Inclusion Criteria

- Neonates and infants aged less than one year at the time of surgery.
- Neonates and infants with a confirmed diagnosis of congenital heart disease requiring surgical management.
- Patients undergoing congenital heart surgery.
- Patients with complete preoperative, intraoperative, and postoperative data available in medical records.

Exclusion Criteria

- Cases deemed inoperable by the cardiology team due to the complexity of malformations.
- Patients referred for nonsurgical management of congenital heart disease.
- Neonates and infants with severe non-cardiac comorbidities that contraindicated surgery.

Definitions

Operative mortality refers to death occurring before discharge during the same hospital admission. Acute kidney injury (AKI) was diagnosed when creatinine levels exceeded twice the upper normal limit, with a threshold of >1.5 mg/dL (normal range: 0.3–0.7 mg/dL). Chylous effusion was identified when triglyceride levels in chest tube drainage exceeded 1.25 mmol/L or when the patient required a medium-chain triglyceride formula. Bloodstream infection (sepsis) was confirmed through a positive postoperative blood culture.

Data Collection

Data were meticulously gathered from hospital records to provide a comprehensive evaluation of neonates and infants patients undergoing congenital heart surgery. The data were collected by trained medical professionals who were well-versed in neonates and infants cardiac care. They extracted detailed information from hospital medical records and cardiac surgery databases. Data were gathered on demographic, preoperative, and postoperative variables. Demographic variables included the patient's age at surgery, weight, gender, and gestational age. Preoperative data encompassed the use of preoperative mechanical ventilation. Postoperative variables focused on the length of intensive care unit (ICU) stay, hospital stay, and complications.

Data Analysis

Data analysis was analyzed using SPSS (version 26). Descriptive statistics were used to summarize the data. Continuous variables such as age and weight were presented as mean±standard deviation (SD). Categorical variables were expressed as frequencies and percentages. Univariate logistic regression analysis was performed to identify predictors, with odds ratios (OR) and 95% confidence intervals (CI) calculated for each variable. Statistical significance was defined as $p < 0.05$.

RESULT

The study included 20 participants with a mean age of 5.38±3.61 months, an average weight of 4.36±1.98 kg, and a mean gestational age of 37.84±2.35 weeks. Male participants comprised 65.0% of the study population, while females accounted for 35.0%. Regarding the Risk Adjustment for Congenital Heart Surgery (RACHS) categories, 35.0% of participants were classified under RACHS category 3, 25.0% in Category 2 and 20.0% in Category 1. Categories 4 and 5 represented 10.0% of the participants (Table 1). TAPVC was the most common condition among pediatric cardiac surgery types, observed in 40.0% of cases, followed by TGA in 35.0% and PDA in 25.0% (Table 2). Table 3 presented the postoperative outcomes, revealing a mortality rate of 40.0%. The most frequent complication was endotracheal (ET) tube blockage, occurring in 20.0% of cases, followed by sepsis in 15.0% and renal failure in 10.0%. Respiratory failure, brain injury, and complete heart block requiring a permanent pacemaker (PPM) were each reported in 5.0% of cases. The mean length of hospital stay was 9.17±1.36 days. The analysis of predictive mortality indicators in the study population identified several key factors. Endotracheal (ET) tube blockage demonstrated a strong association with mortality, with an odds ratio (OR) of 0.058 (95% CI: 0.014–0.256, p<0.001), indicating a significantly increased risk. Similarly, renal failure was a significant predictor, with an OR of 0.037 (95% CI: 0.009–0.177, p<0.001). In contrast, age and weight did not significantly correlate with mortality. The odds ratio for age was 0.962 (95% CI: 0.898–1.026, p=0.251), and for weight, it was 0.799 (95% CI: 0.327–1.69, p=0.534) (Table 4).

Table 1: Demographic profile of the study population (N=20).

Variables	Frequency (n)	Percentage (%)
	Mean±SD	
Age (months)	5.38±3.61	
Weight (kg)	4.36±1.98	
Gestational age (weeks)	37.84±2.35	
Gender		
Male	13	65.00
Female	7	35.00
RACHS-1		
1	4	20.00
2	5	25.00
3	7	35.00
4	2	10.00
5	2	10.00

RACHS: Risk Adjustment for Congenital Heart Surgery

Table 2: Distribution of pediatric cardiac surgery types (N=20).

Case Breakdown	Frequency (n)	Percentage (%)
TAPVC	8	40.00
TGA	7	35.00
PDA	5	25.00

PDA: Patent Ductus Arteriosus; TAPVC: Total Anomalous Pulmonary Venous Connection; TGA: Transposition of the Great Arteries.

Table 3: Postoperative parameters in the study population (N=20).

Variables	Frequency (n)	Percentage (%)
	Mean±SD	
ET tube blockage	4	20.00
Sepsis	3	15.00
Renal failure	2	10.00
Respiratory failure	1	5.00
Brain injury	1	5.00
Complete heart block required PPM	1	5.00
Length of hospital stay (days)	9.17±1.36	
Mortality	8	40.00

ET: Endotracheal.

Table 4: Predictive indicators of mortality (N=20).

Variables	OR (95% CI)	P value
Age (months)	0.962 (0.898-1.026)	0.251
Weight (kg)	0.799 (0.327-1.69)	0.534
ET tube blockage	0.058 (0.014-0.256)	<0.001
Renal failure	0.037 (0.009-0.177)	<0.001

DISCUSSION

The field of neonatal cardiac surgery has undergone significant evolution and standardization since the pioneering procedures of the 1970s, particularly for patients with transposition of the great arteries (TGA). These advancements have enabled surgeons to undertake complex repairs and palliative procedures for previously inoperable conditions, such as hypoplastic left heart syndrome (HLHS) [16]. Over time, the surgical management of even symptomatic neonates with tetralogy of Fallot has shifted from palliative shunts to definitive repairs performed during the neonatal period. Recent innovations in treatment approaches have further improved outcomes for these patients [17]. Selecting an ideal outcome measure for neonatal cardiac surgery remains a subject of debate due to the necessity for easy to estimate, reproducible, and independent metrics. While many researchers rely on conventional variables such as infection rates, lactate levels, and blood pressure, others have adopted surrogate measures like the low inotropic and vasoactive inotropic scores. Composite outcomes that integrate multiple parameters into a single measure have also been proposed [18,19]. In our study, we analyzed commonly reported outcome measures, including endotracheal (ET) tube blockage, sepsis, acute kidney injury (renal failure), respiratory failure, brain injury, and complete heart block requiring permanent pacemaker (PPM) implantation. Mortality continues to be a pivotal indicator of success in neonatal cardiac surgery programs and is strongly influenced by the volume–quality relationship [20]. Our data revealed an overall operative mortality rate of 40.00% for neonatal cardiac surgeries, a figure notably higher than those reported by leading international centers [21,22]. For comparison, the Society of Thoracic Surgeons (STS) database reports an operative mortality rate of 12.2%, while the European Association for Cardio-Thoracic Surgery (EACTS) database reports a rate of 13.3% [23]. However, comparing survival rates across institutions remains inherently challenging due to the complex interplay between surgical case volumes and mortality rates [24]. Using multivariable logistic regression analysis, we identified two independent risk factors for operative mortality: ET tube blockage [OR (95% CI): 0.058 (0.014–0.256), P < 0.001] and the incidence of AKI [OR (95% CI): 0.037 (0.009–0.177), P < 0.001]. Conversely, variables such as age at surgery, weight, and other postoperative complications did not emerge as independent predictors of mortality. These findings differ from earlier cohort studies that identified age, weight, and the Risk Adjustment for Congenital Heart Surgery (RACHS-1) score as independent predictors of mortality but align with more recent studies [25-28]. Our cohort's mean postoperative hospital length of stay (LOS) was 9.17±1.36 days. Patients with a history of prematurity, low birth weight, advanced age, or reduced body weight at the time of surgery were found to have prolonged LOS. Additionally, higher-complexity operations and surgeries requiring cardiopulmonary bypass (CPB) were associated with extended hospital stays. However, prolonged LOS was not significantly correlated with postoperative complications. These observations are consistent with findings reported in most existing literature [29-31].

The retrospective design inherently limits the ability to establish causal relationships. The small sample size of 20 neonates and infants reduces the statistical power of the analysis and limits the generalizability of the findings. The study was conducted at a single tertiary care center, which may not reflect the outcomes and practices of other institutions. The reliance on medical record data may have introduced biases or inconsistencies in data collection.

CONCLUSION

This study highlights significant challenges and outcomes in neonates and infants congenital heart surgery, with a high mortality rate of 40% and complications such as ET tube blockage and acute kidney injury emerging as independent predictors of mortality. Despite advancements in neonatal cardiac surgery, outcomes remain suboptimal compared to global benchmarks, underscoring the need for targeted quality improvement initiatives, enhanced perioperative & postoperative care and early intervention strategies. Establishing standardized protocols and regional centers of excellence may help improve survival and long-term outcomes in this vulnerable population.

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