ORIGINAL ARTICLE

# Open-heart surgery in preterm infants: A single-center experience

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## ABSTRACT

**Background** : **Open-heart surgery is challenging in preterm neonates and infants, and its feasibility in low-resource settings has not been defined. We describe our institutional experience with open-heart surgeries performed on consecutive preterm infants.**

**Materials, Methods and Results** : **This was a single-center retrospective cohort from a tertiary hospital in Southern India and included consecutive preterm neonates (<37 weeks) admitted for open-heart surgery. This report is limited to babies who were <3 months at the surgery. The salient features of the 15 preterm included twin gestation: 7 (46.7%); median gestational age at birth: 35 weeks (28–36 weeks); median corrected gestational age at surgery: 37 weeks (33–40 weeks); birth weight: 1.75 kg (1.0–2.6 kg); weight at surgery: 1.8 kg (1.2–2.9 kg); and small for gestational age: 12 (80%). The heart defects included transposition of the great arteries (7), total anomalous pulmonary venous return (3), large ventricular septal defect (VSD) (1), and VSD with coarctation of the aorta (4). Eleven (73%) were mechanically ventilated preoperatively and five had preoperative sepsis. The mean cardiopulmonary bypass time was 169.7 ± 61.5 min, and cross-clamp time was 99.7 ± 43.8 min. There was no inhospital mortality; one baby expired during follow-up at 1 month. Postoperative mechanical ventilation duration was 126.50 h (84.25–231.50 h), and intensive care unit stay was 13.5 days (9–20.8). The total hospital stay was 39 days (11–95 days). Two children (13.3%) had postoperative sepsis.**

**Conclusion** : **Through collaborative multidisciplinary management, excellent outcomes are feasible in low-resource environments for selected preterm neonates undergoing corrective open-heart operations.**

**Keywords** : Congenital heart surgery, low resource environments, preterm

## INTRODUCTION

An estimated 15 million infants are born preterm globally with a substantial majority in low- and middle-income countries (LMICs).[1] Premature neonates have a more than 2-fold higher risk of congenital

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heart disease (CHD).[2] Preterm infants present several unique challenges to surgical management of CHD and prematurity is consistently acknowledged as a risk factor for mortality in infants undergoing congenital heart surgery.[2-4]

Successful heart operations for preterm neonates require a high level of expertise and cohesion among caregivers that include neonatologists, pediatric cardiologists, pediatric heart surgeons, pediatric cardiac intensivists, perfusion technologists, and nurses.[5,6] In addition to human resources, there is a need for sophisticated care systems and advanced infrastructure.[5,7] In low-resource environments of LMICs, it is often challenging to organize these human and material resources. Additional challenges in LMICs include the high background prevalence of maternal undernutrition and nosocomial infections.[7,8] Perhaps, as a result, there is very little that has been published on preterm heart surgeries from low-resource environments.[9]

We sought to describe our institutional experience with open-heart surgeries performed on consecutive preterm neonates. Since these babies required a relatively long period for preoperative stabilization, we included all babies who were 3 months or younger at the time of surgery.

## METHODS

### Definitions

Prematurity was defined as babies born <37 weeks of gestation.[1,10] Small-for-gestational-age (SGA) newborns were described as those below the 10$^{th}$ percentile for the gestational age.[11]

This single-center retrospective cohort study was carried out in a referral tertiary hospital in Southern India. Ours is one of seven hospitals that cater to a referral population of 35 million in the State of Kerala. The center serves a population of approximately 30 million in the state of Kerala and neighboring regions. A detailed description of the study setting, care organization structure in the unit, and the International Quality Improvement Collaborative for CHD (IQIC; https://iqic.chboston.org/) have been published previously.[12] The Institutional Ethics Committee approved the study and waived the need for consent. Preoperatively, all babies were either stabilized before surgery in the neonatal intensive care unit (NICU) itself or the NICU team participated in the stabilization process in the pediatric cardiac intensive care unit (ICU). The pediatric cardiac team along with the neonatologists jointly cared for all babies postoperatively.

### Participants and variables

We included all consecutive preterm babies admitted in the neonatal period (<28 days) for open-heart surgery for critical CHD. Since there was often a need to keep them in the NICU for a variable period before surgery, we included babies even if they were operated on beyond the neonatal period. We chose an arbitrary cutoff of 3 months of age at the time of cardiac surgery. The study period was between January 2015 and December 2020.

Preoperative variables, including baseline demographics, antenatal and birth history, preoperative condition, diagnosis, and the RACHS classification, were studied. Operative variables analyzed included cardiopulmonary bypass time and aortic cross-clamp time. Postoperative variables included ventilation duration, length of ICU and hospital stay, the occurrence of postoperative bloodstream sepsis, and any other complications in the postoperative period.

The babies were all followed up in the pediatric cardiac clinic as well as in the neonatology clinic at 1 month and every 6 months thereafter. Neurodevelopmental outcomes were assessed using the Alberta Infant Motor Scale Score Sheets, which is a norm-referenced, standardized, observational, and performance-based measure and is easy to perform.[12,13]

### Statistics

The data were analyzed with the help of the Statistical Package for Social Sciences (SPSS) Version 20.0 for Windows (IBM Corporation, ARMONK, NY, USA). Quantitative data are presented as the mean with a 95% confidence interval and standard deviation or the median and interquartile range (IQR) (25$^{th}$–75$^{th}$ percentile).

## RESULTS

Initially, 36 babies were identified, who were preterm at birth and operated on later. However, only 15 babies were admitted at <30 days of age and operated in the same admission, whereas 21 babies were discharged after the initial admission and operated at a later date, and thus were excluded. Consequentially, a total of 15 babies formed the study population. Outcome measures of the eligible study population were tabulated and then analyzed cumulatively.

Six babies (40%) were diagnosed prenatally and seven were born as twins (46.7%). The median gestational age at birth was 35 weeks with an IQR of 28–36 weeks. The median corrected gestational age at surgery was 37 weeks (IQR – 33–40 weeks). A majority of the babies were male, 13 (86.7%). The median birth weight was 1.75 kg (IQR – 1.0–2.6 kg) and the majority were small for their gestational age – 12 (80%). The median weight at surgery was 1.87 kg (1.2–2.9 kg).

The preoperative conditions are summarized in Table 1. Eight babies (53%) were managed preoperatively in the NICU by the neonatologists, and all the babies received care postoperatively in the NICU after a variable period of stay in the pediatric cardiac ICU. The median duration of stay in the ICU was 13.5 days (9–20.8). The individual diagnosis as well as the RACHS category and the mean age and weight at birth and surgery are shown in Table 2.

The mean bypass time for all the patients was 169.7 ± 61.5 min. The average cross-clamp time was 99.71 ± 43.8 min. Three babies had delayed sternal closure.

### Inhospital outcomes

There was no inhospital mortality. The most common complication was arrhythmia seen in 3 (20%) of these babies. Junctional ectopic tachycardia (JET) was the most common arrhythmia seen. Sepsis was the second-most prevalent complication contributing to increased length of stay. It was observed in two babies of the study population. Other complications noted [Table 3] were diaphragm paresis, surgical site infection, pneumothorax, and chylothorax noted in one baby each. None of the babies had an atrioventricular block or required extracorporeal membrane oxygenator support.

One baby required reoperation for restenosis of the pulmonary vein on follow-up, following an intracardiac total anomalous pulmonary venous connection (TAPVC) repair. This baby was discharged after the first surgery at 2½ months of age, with a weight of 1.43 kg at discharge, and was readmitted with severe pulmonary vein restenosis requiring reoperation at 3 months of age. The child did not survive the reoperation. One baby with a diagnosis of Down syndrome developed subglottic stenosis and underwent an anterior cricoid split.

One baby with a birth weight of 1.75 kg and gestation of 33 weeks, with a diagnosis of d-transposition of the great arteries with an intact ventricular septum, required a diaphragmatic plication for diaphragmatic paresis postarterial switch operation. This baby was diagnosed antenatally and was one of the twins and weighed 1.8 kg at surgery [Figure 1]. The corrected gestational age of the baby was 36 weeks at the time of surgery. This baby developed sepsis, hyperbilirubinemia, and hypoglycemia in the preoperative period and required inotropes and mechanical ventilation before surgery. Postoperatively, complications included sepsis and supraventricular tachycardia (JET). This baby was managed in the NICU preoperatively and postoperatively till discharge and discharged with a weight of 2.3 kg. Additional reinterventions included sternal wire removal and vacuum dressing for mediastinitis in one patient.

The median ventilation duration postsurgery was 126 h with a wide range (24–444 h), and the median ICU stay was 324 h with a wide range: 72–696 h. The median postsurgical stay was 21.5 days (range: 10–60), and the median total hospital stay was 39 days (range: 11–95).

Freedom from reintervention was seen in 11 babies constituting 73.3% of the population.

### Follow-up outcomes

One baby died during readmission 2 months after surgery following reoperation for restenosis of obstructed TAPVC.

The mean weight at birth was 1.75 ± 0.42 kg; mean weight at admission was 1.81 ± 0.44 kg; mean weight at surgery was 1.87 ± 0.40 kg; mean weight at discharge was 1.96 ± 0.38 kg; mean weight at 1-month follow-up was 3.06 ± 0.77 kg; mean weight at 6-month follow-up was 5.70 ± 1.55 kg; mean weight at 1-year follow-up was 8.00 ± 1.91 kg; and mean weight at 2-year follow-up was 9.92 ± 0.67 kg [Figure 2]. Neurodevelopmental milestones were delayed in two babies with poor performance on the Alberta Infant Motor Scale.

## DISCUSSION

Prematurity is a well-recognized risk factor for poor outcomes following cardiac surgery.[14,15] There are

**Table 1: Preoperative variables**

| Variable | *n*/median | Percentage/IQR |
|---|---|---|
| Antenatal diagnosis | 6 | 40 |
| One of the twins | 7 | 46.7 |
| Gestational age (weeks) at birth | 35 | 28–36 |
| Gestational age (weeks) at surgery | 37 | 33–40 |
| Birth weight (kg) | 1.75 | 1.0–2.6 |
| Weight at surgery (kg) | 1.87 | 1.2–2.9 |
| SGA | 12 | 80 |
| Preoperative mechanical ventilation | 11 | 73.3 |
| Preoperative inotropic use | 8 | 53.3 |
| Preoperative sepsis | 5 | 33.3 |
| Retinopathy of prematurity | 5 | 33.3 |
| Jaundice | 4 | 26.7 |
| RDS: Babies requiring surfactant | 2 | 13.3 |
| Abnormal neurosonogram | 4 | 26.7 |

IQR: Interquartile range, RDS: Respiratory distress syndrome, SGA: Small for gestational age

**Table 2: Case distribution, age, and weight of individual categories**

| Diagnosis | Age at surgery (days) | Weight at surgery (kg) |
|---|---|---|
| Transposition of the great arteries – intact ventricular septum (*n*=5) | 15.20±6.8 | 2.07±0.5 |
| Transposition of the great arteries – VSD (*n*=2) | 13.5±2.1 | 1.83±0.18 |
| Total anomalous pulmonary venous return (*n*=3) | 13.3±12.7 | 1.73±0.3 |
| VSD (*n*=1) | 56 | 1.69±0.69 |
| VSD with coarctation (*n*=4) | 14±8.1 | 1.83±0.23 |
| Total | Median - 15 (2–68) | 1.87±0.40 |

VSD: Ventricular septal defect

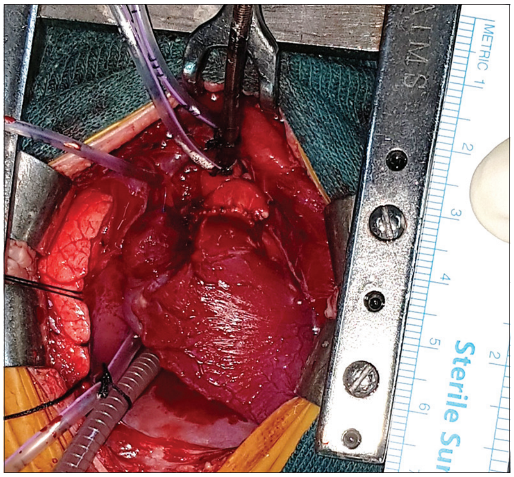


**Figure 1: The heart of a preterm child weighing 1.8 kg. This is the postoperative picture of an arterial switch operation done for the transposition of the great arteries**

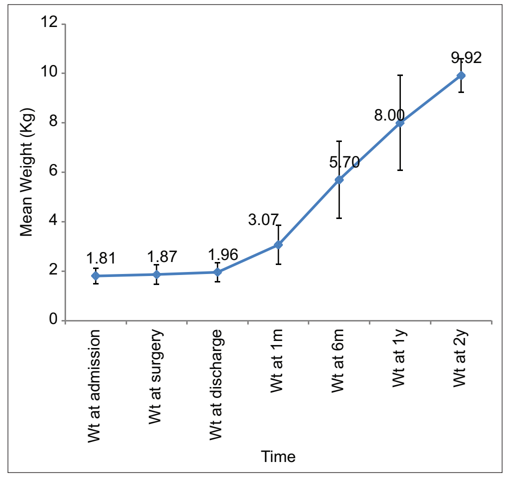


**Figure 2: The weight gain trends for the patients during follow-up**

**Table 3: Postoperative complications**

| Inhospital mortality | Zero, *n* (%) |
|---|---|
| Arrhythmias | 3 (20) |
| Sepsis | 2 (13.3) |
| Diaphragm palsy | 1 (6.7) |
| Surgical site infection | 1 (6.7) |
| Chylothorax | 1 (6.7) |
| Pneumothorax | 1 (6.7) |
| Late reoperations | 1 (6.7) |
| Late mortality | 1 (6.7) |

limited data on the impact of gestation on the outcome of corrective heart surgeries. Tanner *et al.* reported that preterm infants have more than twice as many cardiovascular malformations as do infants born at term and that one of six infants with cardiovascular malformations is born preterm.[16]

Our study is the first from a low-resource environment to focus on a homogeneous population of preterm neonates who underwent open-heart surgery. The median gestational age at birth (35 weeks; range 28–36 weeks) and the median corrected gestational age at surgery (37 weeks; range 33–40 weeks) compare well with studies from the West.[14]

Williams and Cohen analyzed perioperative management of low-birth-weight infants for open-heart surgery and stated that premature infants or SGA have an increased risk of morbidity and mortality. The risk is even greater for those who are premature and SGA, presumably because an unfavorable *in utero* environment further compromises the patient's immature organs. Williams and Cohen suggest collaborative multidisciplinary efforts for achieving successful outcomes.[17] Our babies received intense preoperative and postoperative stabilization – half of them in the NICU preoperatively – and all of them in the NICU postoperatively as described above. As is already known, in infants of gestational age of under 37 weeks, with a birth weight of under 2500 g, particularly in high-risk infants under 1500 g, who require congenital heart surgery, achieving hemodynamic stability and maintaining this stability during and after the intensive care period, and treating and directing accompanying diagnoses are important milestones for cardiac surgery.[17] Active engagement of the NICU team in pre- and postoperative care brings about a significant difference in the care of preterm babies before and after surgery and helps achieve these milestones. We recommend coordinated multidisciplinary teamwork involving neonatologists as well to meet the unique challenges this subset of patients brings along.

We also recommend the formation of a dedicated neonatal cardiac program offering care to neonates or young infants with CHD from birth to discharge. A dedicated medical and nursing team should staff this program and include members from neonatal intensive care, pediatric cardiology, pediatric cardiac anesthesia, and pediatric cardiac surgery. With this goal in mind, there is a need to train these personnel aggressively and thoroughly and equip them with advanced skills in the management of newborn infants with CHD. The role of dedicated neonatal cardiac intensive care nurses and neonatal nurse practitioners, neonatal respiratory therapists, neonatal nutritionists, and feeding specialists cannot be emphasized enough. They are an important fulcrum for the success of this venture.

Lechner *et al.* from Austria reported an early mortality rate of 13% in the low-birth-weight group.[14] Alkan-Bozkaya *et al.*, in another study, carried out in the USA, reported four early postoperative deaths in a study cohort of 33 preterm/low-birth-weight babies.[15] There was no inhospital mortality in our cohort. One baby expired on follow-up at 1-month postsurgery. It must be acknowledged here that our study did not include the highest risk categories like Stage I palliation for hypoplastic left heart syndrome.

There has been considerable debate regarding the timing of surgery in these babies. Lately, early primary repair is often preferred.[18-22] However, since low birth weight is a well-recognized risk factor for mortality, some centers prefer to wait till adequate weight gain is achieved. This is commonly observed in LMICs where there are many challenges for operating on these tiny babies. However, while waiting for weight gain over the weeks, these infants are at greater risk of pulmonary infection, gastrointestinal ischemia, anemia, hypoxic-ischemic encephalopathy, and myocardial dysplasia. Delaying repair of congenital heart defects in low-birth-weight infants does not confer any benefit and is associated with higher preoperative morbidity.[17,22] In our cohort, the median age at surgery was 15 days (2–68). As expected, the age at surgery was higher in those babies with a diagnosis of perimembranous ventricular septal defect compared to the rest.

A major concern when performing open-heart surgery in low-weight, premature infants is morbidity, of which neurological outcome is an important contributor. Neurodevelopmental milestones were delayed in two of our babies with poor performance on the Alberta Infant Motor Scale. Reddy *et al*. reported age at surgery to be an important factor for morbidity in low-weight infants.[22] Lechner *et al*., on comparing patients with and without neurological delay, found a statistically significant difference in length of mechanical ventilation, hospital stay, and length of stay in the ICU, which may indicate that patients with neurological damage experience a delayed postoperative recovery.[14] The fact that some possible risk factors influencing neurological morbidity need to be understood more clearly is an indication that there is a need for more advanced, broader, multicenter studies of groups that are more homogeneous in terms of risk factors and cardiac pathology.

Few studies have examined the role that SGA status plays in postoperative outcomes for low-birth-weight infants with CHD. Wei *et al.* on a comparison of SGA and non-SGA infants of similar weights showed no significant differences in postoperative morbidities. SGA and non-SGA infants did not differ in terms of survival to discharge or immediate postoperative outcomes.[23] In our cohort, we had a majority who were SGA –12 (80%). Hypoglycemia and hyperbilirubinemia, which are known complications of SGA and intrauterine growth restriction were seen in about a quarter of babies –3 (20%) and 4 (26.7%), respectively.

### Study limitations

Because of the limited number of cases and the retrospective nature of the study, the study has a few limitations. However, our study group represents a difficult and relatively rare type of patient subset, with scant published data, especially from LMICs.

## CONCLUSIONS

Open-heart surgery in preterm children with good outcomes is feasible in low-resource environments. Although low birth weight and gestational age of <37 weeks at surgery remain a risk factor for early mortality, a dedicated neonatal cardiac program can yield excellent outcomes. There is a requirement for a cohesive multidisciplinary team effort, including neonatologists, cardiac anesthetists, pediatric cardiologists, pediatric cardiac surgeons, and well-trained, dedicated neonatal nursing staff. Perioperative care is significantly improved by the inclusion of neonatologists in the team. Even the long-term issues of these fragile infants are well taken care of by incorporating inputs from them. In short, managing preterm infants with CHD can be well described by the old adage “It takes a village to raise a child.” Morbidity, however, continues to remain significant in these babies as a consequence of a host of issues. Further long-term prospective investigations are necessary to evaluate neurodevelopmental outcomes.

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### Conflicts of interest

There are no conflicts of interest.

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