RESEARCH PAPER

# Early Outcomes of Neonatal Cardiac Surgery in India

**VIVEK V SHUKLA, PRASHANT BOBHATE, SMRUTIRANJAN MOHANTY, SURESH RAO, PREETHA JOSHI AND VINAY JOSHI**
*From Division of Pediatric Cardiac Surgery and Intensive Care, Kokilaben Dhirubhai Ambani Hospital, Mumbai, India.*

*Correspondence to: Dr Vivek Shukla, Department of Pediatrics, SUNY, Downstate Medical Center, Brooklyn, NY, USA-11203.*
*viveks3985@gmail.com*
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**Objective:** To assess outcomes and factors influencing outcomes in neonates requiring cardiac surgery in India. **Methods:** This study reports on review of hospital data from a tertiary care cardiac surgical institute from January-2009 to December-2015. **Results:** A total of 200 neonates were included; of them, 5% of the cases were antenatally diagnosed and most of them had unmonitored transport (111, 55.5%). The overall mortality rate was 13.5%, (*n*=27) and 178 (89%) underwent complete defect repair. There was a significant association of mortality with shock, the number of inotropes, intra-operative procedure, residual lesion, aortic cross-clamp and deep hypothermic circulatory arrest time (all *P*<0.05). Logistic regression analysis showed ventilation duration, cardiac-bypass time, shock, and residual cardiac lesion as independent predictors of mortality. **Conclusion:** Cardiac defects were found to have late detection and most transports were unmonitored. Complete surgical repair and shorter cardiac bypass time can potentially improve neonatal cardiac surgical outcomes.

**Key words:** *Congenital heart disease, Management, Outcome.*

Neonatal cardiac surgical care is a relatively evolving subspecialty with a lack of outcome data from developing countries [1,2]. Cardiac surgical care is associated with significant gaps in terms of the availability of the services and the need in developing countries [3-6]. Additionally, poor referral and transport networks, delayed diagnosis, scarce insurance coverage, high attrition rates and poor patient affordability contribute to suboptimal outcomes [1,2,5]. There is limited data regarding outcomes after neonatal cardiac surgery from developing countries [3-5]. The aim of the present study patient to study was outcomes, and factors influencing outcomes in neonates requiring cardiac surgery in India.

## METHODS

We conducted a retrospective review of data of all neonates (birth to 30 days of life) undergoing cardiac surgery at a tertiary level referral center situated in Western India. We report on data of all neonates, admitted to pediatric cardiac critical care unit of study institute from January 2009 to December 2015, pre-specified questionnaire was used for data collection based on electronic medical records which included demographic profile, cardiac defect characteristics, clinical presentation and hospital course, pre and post-operative risk factors, and early outcomes. Low cardiac output syndrome was defined based on existing literature as decrease in systemic perfusion transiently after cardiac surgery secondary to myocardial dysfunction [7]. Risk adjustment for congenital heart disease surgery (RACHS-1) score was used to categorize risk of individual surgeries [8]. Ethical approval with waiver of consent was obtained from institutional ethics committee.

*Accompanying Editorial: Pages 117-118.*

*Statistical analysis*: Mean (SD) and frequency (%) were used to depict baseline characteristics, demographic variables, short term morbidity, length of stay and mortality. Chi square test was used for categorical variables and independent sample t-test for continuous variables. Logistic regression with backward likelihood ratio method was done to find adjusted odds for independent predictors of mortality. The analysis was performed using STATA version 14.1.

## RESULTS

A total of 200 neonates (male to female ratio 3.6:1) requiring cardiac surgery were included in the study. Mortality was 13.5%. Transport was mostly unmonitored (private vehicles: 111, 55.5%) compared to monitored (transport ambulance: 89, 44.4%), but was not significantly associated with mortality (*P*>0.05). Only 10 (5%) cases were antenatally diagnosed.

Primary cardiac defects necessitating surgery included TGA (transposition of great arteries) (*n*=88) (D-TGA, 85), TAPVC (total anomalous pulmonary venous circulation) (*n*=24) (supra-cardiac TAPVC, 10; infra-diaphragmatic TAPVC 11; and mixed TAPVC, 3), aortic

malformations (*n*=22) (aortopulmonary window, 3; coarctation of aorta; 14; interrupted aortic arch, 5), valvular malformations (*n*=17) (tricuspid atresia, 1; aortic stenosis/atresia, 8; pulmonic atresia/stenosis, 8), septal defects (*n*=15) (ventricular septal defect with outflow obstruction, 14; atrioventricular canal defect, 1), hypoplastic left heart syndrome (*n*=13), double outlet left ventricle (*n*=9), tetralogy of Fallot (*n*=7) and patent ductus arteriosus (*n*=5). Outcomes as per underlying cardiac defect are described in ***Table* I**.

Risk factors/complications at admission included invasive ventilation requirement 80, shock in 53, clinical sepsis in 33, prematurity in 22, blood culture-proven sepsis in 16, active resuscitation required at birth (intubation or chest compression) in 15. Peri-operative and in-hospital complications included culture-proven sepsis in 47 (blood, 33; ETT aspirate, 3; and urine cultures, 11), re-exploration in 18, seizures in 12, and antiepileptic medication requirement at discharge in 9. Nineteen neonates were extubated after the surgery before admission to the ICU, whereas, 181 neonates needed post-operative invasive ventilation.

On univariate analysis, there was a significant association between mortality and shock, intra-operative procedure, residual lesion, number of inotropes needed and urgency of surgery (***Table* II**). There was no statistically significant association of mortality with unmonitored/monitored transport, birth weight, initial arterial lactate, and clinical sepsis. There was no statistically significant difference in time between diagnosis and surgery, age at diagnosis, and weight for both groups (***Table* III**). Neonates requiring cardiopulmonary bypass (CPB) support during surgery were 134 (67%), aortic cross-clamp (ACC) were 129 (64.5%), and deep hypothermic circulatory arrest (DHCA) were 134 (67%). CPB, ACC, and DHCA times in participants who died was more as compared to survivors. While CPB time was not significantly different, the ACC and DHCA time were significantly different among both subgroups (***Table* III**). median RACHS-1 score for the study participants was 4 (interquartile range 3-4). On univariate analysis, there was a significant association between RACHS-1 score and mortality (*P*<0.001).

**TABLE I Cardiac Defect and Outcome of Cardiac Surgery**

| *Cardiac defect* | *Mean RACHS 1 score* | Mortality *n* (%) |
|---|---|---|
| TOF (*n*=7) | 3.5 | 0 (0) |
| TGA (*n*=88) | 3.4 | 7 (7.9) |
| TAPVC (*n*=24) | 3.8 | 5 (20.8) |
| DORV (*n*=9) | 4 | 3 (33.3) |
| HLH (*n*=13) | 6 | 2 (15.3) |

*TOF: Tetralogy of fallot; TGA: Transposition of great arteries; TAPVC: Total anomalous pulmonary venous return; DORV: Double outlet right ventricle; HLH: Hypoplastic Left Heart; Surgeries performed: TOF: Septal and RVOT repair; TGA: Arterial switch operation; TAPVC: TAPVC repair and re-anastomosis of PV to LA; DORV: Intracardiac channel repair; HLH: Norwood procedure.*

Multivariable logistic regression done using mortality as outcome and neonatal variables and risk factors as independent variables, showed duration of ventilation [adjusted OR (95% CI) 2.19 (1.22,3.95), *P*=0.009], presence of residual lesion [adjusted OR (95% CI) 123.88 (9.43,1626.22), *P*=0.001], higher CPB time [adjusted OR (95% CI) 1.014, (1.005,1.024), *P*=0.003], and shock [adjusted OR (95% CI) 23.47 (1.95, 281.47), *P*=0.013] as independent predictors of mortality. This model had Nagelkerke R Square value of 0.67 with correct classification of 95.5%.

## DISCUSSION

This review of hospital records was done to study

**TABLE II Univariate Association Between Mortality and Categorical Variables (*N*=27)**

| *Variable* | *Category* | *Mortality, No. (%)* | *OR (95% CI)* | *P value* |
|---|---|---|---|---|
| *Inotropes | ≤2 (106) | 6 (5.6) | 4.79 (1.84, 12.47) | 0.001 |
| | >2 (94) | 21 (22.3) | | |
| Shock | Yes (102) | 19 (18.6) | 2.57 (1.07, 6.19) | 0.03 |
| | No (98) | 8 (7.2) | | |
| Intraoperative procedure | Complete repair (178) | 15 (8.4) | 13.04 (4.83, 35.16) | <0.0001 |
| | Staged repair (22) | 12 (54) | | |
| Urgency of surgery | Planned surgery (70) | 4 (5.7) | 3.55 (1.17, 10.71) | 0.025 |
| | Emergency surgery (130) | 23 (17.7) | | |
| Residual lesion | Yes (56) | 19 (33.9) | 8.73 (3.54 - 21.52) | <0.001 |
| | No (144) | 8 (5.6) | | |

**Number of inotropic medications required.*

**What This Study Adds?**

- Presence of shock, duration of ventilation, residual lesions, and cardiac bypass time were the variables independently associated with mortality in neonates undergoing cardiac surgery.

**TABLE III Association of Various Patient and Surgical Factors with Mortality (*N*=200)**

| *Variables* | *Mortality, mean (SD)* | |
|---|---|---|
| | *No (173)* | *Yes (27)* |
| Weight, kg | 2.7 (0.52) | 2.8 (0.51) |
| *RACHS score | 3.5 (0.9) | 4.6 (1.07) |
| Age, d | 7.5 (7.66) | 6.2 (6.38) |
| Time between diagnosis and surgery, d | 5.8 (5.13) | 4.6 (5.38) |
| *ICU stay, d | 9.7 (6.34) | 4.7 (4.38) |
| *Hospital stay, d | 14.9 (6.63) | 4.5 (4.38) |
| CPB time, min | 202.7 (75.19) | 344.5 (361.41) |
| #DHCA time, min | 26.4 (20.41) | 61.9 (20.43) |
| ‡ACC time, min | 95.7 (43.94) | 150.4 (70.28) |
| Ventilation, d | 3.4 (2.19) | 6.2 (5.95) |
| Cardiac support, d | 3.9 (2.97) | 5.8 (5.81) |

*RACHS: Risk adjustment for congenital heart disease surgery; ACC: aortic cross-clamp; DHCA: deep hypothermic circulatory arrest; CPB: cardiopulmonary bypass; *P<0.001; #P=0.001; ‡P=0.01.*

outcomes and factors influencing outcomes in neonates requiring cardiac surgery in India. The variables that were found to be associated with mortality by multivariable logistic regression analysis were shock, duration of ventilation, residual lesion, and cardiopulmonary bypass time. We found that with every additional ventilation day, odds of mortality increased by 2.19 times and with every additional minute of cardiac bypass time, odds of mortality increased by 1.014. Neonates who died were having shorter duration of ICU and total hospital stay, which is possibly related to more unstable clinical status of those neonates.

Limitations of present study include retrospective study design and inherent possibility of selection bias. Additionally, as this was a single center study the generalizability of the results of the present study need to be explored further. Laboratory testing was delayed after admission in many cases to period after clinical stabilization, this precluded estimating admission illness severity scoring, which involves baseline laboratory tests. This also explains why mortality was related to presence of shock but not to initial lactate. The current study focuses only on short term outcomes, longer follow-up with neurodevelopmental and co-morbidities outcome would have been more informative.

Mortality rate (13.5%) seen in this study is higher than that reported in similar studies from developed countries (6-10%) [9,10], likely due to easier availability of cardiac surgical services and better diagnostic and referral services. Delayed diagnosis of congenital heart malformations [6] has been shown to impact outcomes adversely. However, in our study, we did not find a correlation between age at diagnosis and death, possibly due to death before hospitalization of those with critical cardiac defects. Mortality in cases undergoing complete repair was significantly lower than those who had residual lesion/staged repair. Similar reports of better outcomes with complete repair are seen in studies from developed [11-13] and developing countries [6]. Based on such data there is growing emphasis on performing early corrective operations in neonatal period [13,14].

The findings of this study are based on participants enrolled over a relatively long study period that would hopefully improve scope of generalizability of results. Early diagnosis, monitored transport, and corrective surgery with efforts to minimize aortic cross clamp time and deep hypothermic arrest time would likely reduce mortality burden. As intensive care is related to significant out-of-pocket expenses likely resulting in delayed diagnosis, poor healthcare seeking and worse patient outcomes [15], cardiac surgical care should be subsidized by the state for familiesunable to afford it. Larger scale studies from multiple centers from developing/underdeveloped countries with long-term outcome data would provide additional insight regarding this subject.

*Contributors*: VS: conceptualized and planned the study, drafted the proposal and manuscript, planned and conducted data collection, revised the manuscript; PB: planned the study design, conducted data collection, analyzed the data, and modified the manuscript for important intellectual points; SM,SR: planned the study design, modified the manuscript for important intellectual points; PJ: planned the study design, oversaw data collection, modified the manuscript for important intellectual points; VJ: conceptualized and devised the study, oversaw data collection, supervised the progress of the study, analyzed the data, provided important intellectual inputs to the manuscript.

He will be the guarantor for the study. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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