Original Article

Nepalese Heart Journal 2023; Vol 20(2), 27-31

Predicting Surgical Mortality After Congenital Heart Surgeries Using Risk Adjustment in Congenital Heart Surgery-1 (RACHS-1) Risk Scoring System: A Retrospective Analysis in A Single Tertiary Center

Smriti Mahaju Bajracharya[1], Dikshya Joshi[2], Sidhartha Pradhan[3]

[1] Deaprtment of Cardiac Anesthesia and critical care, Shahid Gangalal National Heart Centre, Bansbari, Kathmandu, Nepal
[2] Department of cardiac thoracic and vascular surgery, Bir Hospital, Kanti-Path, Kathmandu
[3] Department of Cardiac Surgery, Shahid Gangalal National Heart Centre, Bansbari, Kathmandu, Nepal

Corresponding Author: Smriti Mahaju Bajracharya
Deaprtment of Cardiac Anesthesia and critical care, Shahid Gangalal National Heart Centre, P. Box. No:11360, Bansbari, Kathmandu, Nepal
Email: smriti.mahaju@gmail.com
ORCID ID NO: 0000 0001 7103 3609

Cite this article as: Bajracharya SM, Joshi D, Pradhan S. Predicting Surgical Mortality After Congenital Heart Surgeries Using Risk Adjustment in Congenital Heart Surgery-1 (RACHS-1) Risk Scoring System: A Retrospective Analysis in A Single Tertiary Center. Nepalese Heart J 2023; Vol 20(2), 27-31

Submission date: September 21, 2023
Accepted date: October 15, 2023

Abstract

Objective: The main objective of our study was to analyze the in-hospital mortality in children who underwent surgery for congenital heart defects in a single tertiary cardiac center in Nepal using RACHS-1 risk score during 6 year period.

Methods: After approval from institutional board review, retrospective data analysis were performed from June 2013 to June 2019 at Shahid Gangalal National Heart Centre. Patients younger than 14 years, who underwent cardiac surgery for congenital heart defects, were enrolled. Data from patient records regarding the age, gender, weight, diagnosis, procedures performed, cardio-pulmonary bypass (CPB) time and aortic cross-clamp (AoX) were obtained. The operations were classified according to the six RACHS-1 categories and patients were allotted to RACHS-1 categories retrospectively by matching the procedure of each patient with a risk category.

Results: Two thousand four hundred and seventeen patients underwent surgeries for congenital heart diseases who were classified according to the RACHS-1 score. Among the patients, 56.1 % were male and 20.1 % were younger than one year of age. The mortality was 1.5%,13.3%, 21.7% and 73.4% for category 1, 2, 3 and 4 respectively. The overall ability of the RACHS-1 classification to predict in-hospital mortality Area under the ROC curve was 0.736 with 95% confidence interval (CI) of 0.709-0.763.

Conclusion: The RACHS-1 classification is applicable to our pediatric populations which was a useful and easily applicable tool, requiring only very few data for mortality risk in our hospital although there are other factors that have an impact on the mortality.

Key words: Congenital heart surgeries, mortality, RACHS-1 classification

DOI: https://doi.org/10.3126/nhj.v20i2.59449

Introduction

Congenital heart diseases(CHD) constitute a significant proportion of congenital anomalies, accounting for an overall incidence of approximately 28% among major congenital anomalies[1] and approximately 1.35 million infants with congenital heart defects.[1] In Nepal, the estimated prevalence of congenital heart disease is approximately 1.3 per 1000 schoolchildren.[2] The complex nature of congenital heart disease leads to a diverse range of outcomes for children who undergo surgical interventions, whether for corrective or palliative purposes. While some children experience significant improvements in their heart function and quality of life after surgery, others may face complications or require additional interventions.

As the number of life-saving surgeries for congenital heart defects continues to increase, it becomes increasingly important to thoroughly evaluate the outcomes of these procedures. However, developing a risk-stratification scoring system that can be universally applied poses a significant challenge. Various methodologies have been utilized to predict outcomes while accounting for the complexities involved in pediatric cardiac surgery. Understanding the prevalence of congenital heart defects globally and in specific regions, like Nepal, helps inform healthcare strategies and resource allocation.

In January 2002, a seminal article titled 'Consensus-based method for risk adjustment for surgery for congenital heart disease' was published in The Journal of Thoracic and Cardiovascular Surgery.[3] A collaborative effort by experts from Children's Hospital Boston yielded a risk classification system for surgical interventions addressing cardiac defects, delineating six distinct mortality risk

categories, each with an associated expected mortality rate.

The main objective of our study was to analyze the in-hospital mortality in children who underwent surgery for congenital heart defects in a single tertiary cardiac center in Nepal using RACHS-1 risk score during 6 year period.

Materials and Methods

Patients and Variables

This retrospective observational study was conducted at the Shahid Gangalal National Heart Center(SGNHC), a tertiary cardiac referral facility. After approval by the Institutional Review Committee, obviating the need for patient consent, the data were collected from June 2013 to June 2019. The data were retrieved manually from hospital's record book (from anesthesia records, perfusionists' records, operation theatre records and Intensive care units records). The study population comprised of patients admitted to the Department of Cardiac Surgery. This comprehensive cohort consisted of patients aged 14 years or younger who underwent cardiac surgery for congenital heart disease. The exclusion criteria included secondary thorax closures, pacemaker implantations, and re-sternotomies or re-explorations.

A total of 2417 patients were identified. Perioperative variables such as age, sex, weight, diagnosis, and pertinent procedural details, including cardiopulmonary bypass (CPB) time and aortic cross-clamp (AoX) time, were meticulously extracted from patient records. The primary outcome of this study was the all-cause in-hospital mortality. A retrospective allocation to the Risk Adjustment in Congenital Heart Surgery-1 (RACHS-1) categories for each case was performed according to the classification scheme proposed by Jenkins et al.[3] Patients who underwent more than one procedure during the same hospitalization were considered complex and were scored for procedures with higher complexity.

Statistical Analysis

Data were analyzed using Statistical Package for Social Science (SPSS) statistical software, version 23. Descriptive statistics were calculated for continuous variables using mean values accompanied by the respective standard deviations (SD). Categorical variables were described in terms of proportions.

Data considered to be normal were analyzed for continuous variables using Student's t-test. The Chi-square test was used for categorical analysis, and the discriminative power of the scoring system was assessed using the area under the curve(AUC) of the receiver operating curves(ROC). Differences were considered statistically significant at $p < 0.05$.

Results

During the study period, 2147 who underwent cardiac surgeries were scored according to the RACHS-1 category. Of the 2147 patients in our study, 353(14.3%) patient died. 1060(43.9%) were female, 487 (20.1 %) were aged less than 1 year, and 2142(88.7%) underwent surgery with cardiopulmonary bypass. The demographic characteristics and intraoperative variables are summarized in Table 1. We also found that majority of patients who died belonged to category of greater complexity along with lower weight and age, prolonged CPB and ACX time. (TABLE 1)

Table 1. Demographic characteristics and intra-operative variables

Variable	Total (n=2417) (%)	Survivor (n=2064) %	Non-survivors (n=353) %	P
Age <1 year	487(20.1%)	311(12.9%)	176(7.3%)	0.00
1-5 years	883(36.5%)	756(31.3%)	127(5.3%)	
5-10 years	575(23.8%)	540(22.3%)	35(1.4%)	
>10 to under 14 years of age	472(19.5%)	457(18.9%)	15(0.6%)	
Weight (in kgs)	16.39+/-11.42	17.76+/-11.45	8.41+/-7.28	<0.0001
Gender Male Female	 1357(56.1%) 1060(43.9%)	 1138(47.1%) 926(38.3%)	 219(9.1%) 134(5.5%)	0.16
CPB time(mins) Without CPB	274(11.3%)	241(10%)	33(1.4%)	0.20
With CPB	2142(88.7%)	1822(75.4%)	320(13.2%)	
CPB time(mins)	93.46+/-63	81.38+/-48.7	162+/-86.6	<0.0001
ACX time(mins)	60.34+/-42.04	53.57+/-35.40	100.29+/-54.2	<0.0001

Table 2. shows the distribution of hospital mortality according to RACHS-1 categories. The observed mortality rates exhibited significant heterogeneity across various RACHS-1 categories. In particular, the mortality rate in category 2 was 13.3%, which further increased to 73.4% in category 4. We found that the more complex the surgery, the higher the mortality rate(p=0.0001). The all-cause in-hospital mortality rate was 14.6 %.

Table 2: Distribution of hospital mortality according to the RACHS-1 categories.

RACHS-1 category	Rate (%) N=2417	Observed mortality (14.6%)	Predicted Mortality %	PCCC Rate (%)
Category 1	616(25.5%)	9(1.5%)	0.4	964(22.0%)
Category 2	1145(47.4%)	152(13.3%)	3.8	1453(33.1%)
Category 3	561(23.2%)	122(21.7%)	9.5	1523(34.7%)
Category 4	94(3.9%)	69(73.4%)	19.4	276(6.3%)
Category 5	1(0%)	1(100%)	-	4(0.1%)
Category 6	0	0	47.0	168(3.8%)
Total	2417	353		

To find how likely patients are to die in the hospital based on their category of RACHS-1, we used a statistical measure called the area under the ROC curve . The AUC for RACHS-1 was 0.736 with 95% confidence interval (CI) of 0.709-0.763 [Figure 1] meaning they were good at predicting hospital mortality.

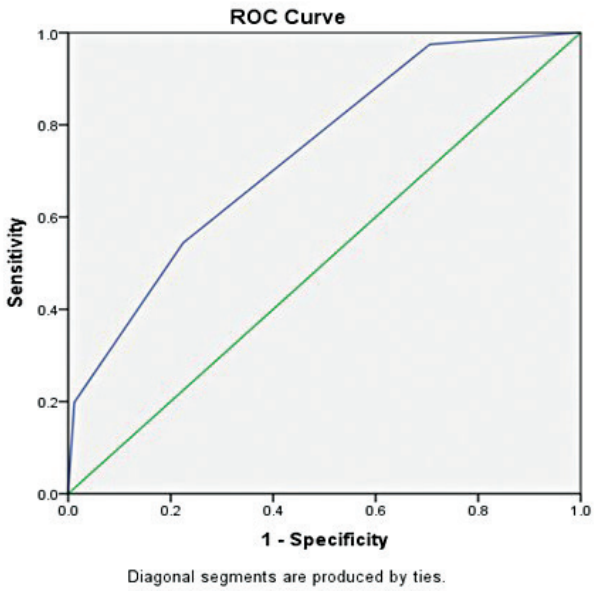

Figure 1- Receiver operating curves analysis of Risk-adjusted congenital heart surgery scoring(ROC Curve)

Discussion

Our findings suggest that the RACHS-1 classification system is a useful tool for predicting in-hospital mortality within our patient population. Our study has shown that the RACHS-1 system can be applied to our pediatric patient population and offers a practical method of assessing surgical risk. The increasing prevalence of congenital heart surgeries emphasizes the necessity of effective risk stratification. This not only aids in assessing outcomes but also ensures the delivery of optimal treatment. There is paucity of studies regarding operative or in-hospital mortality in congenital heart disease within our specific context. The RACHS-1 scoring system has been widely used in studies evaluating differences in mortality among groups of patients, and our study adds to the growing body of evidence[3-6] supporting its usefulness in predicting in-hospital mortality.

In our study, we found an overall mortality rate of 14.6%, which aligns with the findings of previous research.[4,5] However, it is noteworthy that our observed mortality rate is higher than that reported in studies conducted in developed nations.[6-9] The prevalence of category 2 cases in the RACHS-1 system, accounting for nearly 50% of cases in our cohort, differs starkly from international studies such as the Pediatric Cardiac Care Consortium (PCCC) (33%)[3], German (35%)[10] 20, Danish (37%)[8] 10, and Brazilian (33.9%)[5] studies. This divergence is primarily driven by a higher incidence of specific conditions like Ventricular Septal defects and Tetralogy of Fallot in our population.

Furthermore, our study demonstrated a significant disparity in mortality rates across different RACHS-1 categories. Specifically, we observed a mortality rate of 73.4% in our cohort compared to 19.4% in the PCCC cohort.[3] This stark difference in mortality rates highlights the challenges faced by pediatric surgical teams in resource-constrained settings, such as developing countries like ours. A study review conducted by Jacobs et al.[11] further supports our findings, indicating that higher complexity surgeries tend to be associated with higher mortality rates. These findings emphasize the importance of effective risk stratification and tailored interventions in such settings.

Majority of congenital heart diseases are observed in developing countries in Asia and Africa, compared to developed nations.[12] This inequality highlights the necessity of focusing on these less developed regions to alleviate the global burden of congenital heart disease (CHD). It is worth noting that over 80% of CHD-related deaths occur in children under the age of 5.[12] Limited access to healthcare resources and treatment options, which are available to only 7% of the population due to resource constraints, significantly contributes to increased morbidity and mortality rates.[13] Patients in these regions often experience delayed diagnoses and face challenges in accessing specialized tertiary healthcare centers for essential surgical interventions. This prolonged waiting period can worsen the progression of their medical conditions, underscoring the urgent need for improved healthcare infrastructure and timely interventions. Thus, it is crucial to prioritize the development of reliable screening methods in future research.

Our study emphasizes the significance of age as a predictor of mortality, consistent with previous research that has also shown higher risk in different age groups.[1,14,15] However, it is crucial to note that delayed surgery does not necessarily result in safer outcomes, as certain conditions such as Transposition of Great Arteries require early intervention. Therefore, our findings indicate that children who require bypass surgeries at a very young age are at a higher risk of death compared to older children.

Our study revealed that weight is an important predictor of in-hospital mortality, consistent with previous research.[4,16,17] Specifically, lower weight was significantly associated with increased mortality rates. Additionally, we found that prolonged cardiopulmonary bypass (CPB) and aortic cross-clamp (ACX) times were significant predictors of mortality, which is consistent with the findings of Kang et al.[18] These results suggest that longer bypass times may indicate more complex surgeries, which could increase the risk of mortality. Therefore, early intervention and careful management of these factors may be important in mitigating the risk of mortality in patients with congenital heart disease.

Although the RACHS-1 scoring system has been found to distinguish mortality differences among groups in large North American populations [3,11] and in our study as well, it is important to recognize that no predictive models can achieve 100% accuracy and it has certain limitations. Its simplicity and minimal data requirements are counterbalanced by a moderate precision in individualized predictions. However, the RACHS-1 scoring system fails to address several critical issues, such as age at operation, malnutrition, late diagnosis due to limited access to specialized care, and concomitant clinical conditions[19], which are common factors present in our population and significantly impact outcomes. Therefore, in addition to RACHS-1, it is important to consider these factors in predicting mortality. Our study reveals that younger age, lower weight, and certain clinical factors emerged as significant predictors of mortality, highlighting the importance of incorporating these factors into predictive models.

It is crucial to recognize the limitations of our study, which was conducted at a single center and relied on retrospective data. The inherent limitations include the possibility of inaccurately recorded or missing data due to the absence of a digitized data entry system. However, it is worth noting that the data collection and entry processes were consistently managed by the same three experienced anesthesiologists and surgeons throughout the entire study duration.

Future research could further investigate additional factors that have the potential to significantly impact surgical outcomes and integrate them into the existing risk stratification system. Our study provided valuable insights into the factors influencing the outcomes of pediatric heart surgeries in developing countries, highlighting important considerations for assessing and enhancing risk management. By incorporating comprehensive patient and surgical data, these models could be further refined to enhance their predictive capabilities and provide more accurate prognostic information. Future research should focus on establishing national heart surgery database to allow for the comprehensive assessment of outcomes in our settings.

Conclusion

The RACHS-1 classification is applicable to our pediatric populations which is a useful and easily applicable tool, requiring only very few data for mortality risk in our hospital although there are other factors that have an impact on the mortality.Given that the majority of births occur in these countries, where access to treatment is limited, addressing these challenges is of utmost importance.

Acknowledgements

Department of Cardiac Anesthesia and Critical Care and Department of Cardiac Surgery, Shahid Gangalal National Heart Centre, Mr. Sudip Dahal

References

1. Van der Linde D, Konings EE, Slager MA, Witsenburg M, Helbing WA, Takkenberg JJ, et al. Birth prevalence of congenital heart disease worldwide: a systematic review and meta-analysis. J Am Coll Cardiol. 2011;58(21):2241-7.
2. KC MB, Sharma D, Shresth MP et al, Prevalence of rheumatic and congenital heart disease in school children of Kathmandu valley in Nepal, Indian Heart Journal, 2003; Nov-Dec:55(6):615-8.
3. Jenkins KJ, Gavreau K, Newburger JW, Spray TL, Moller JH, Iezzoni L. Consensus-based method for risk adjustment for surgery for congenital heart disease. J Thorac Cardiovasc Surg 2002; 123:110–8.
4. Cavalcanti PE, Sá MP, Santos CA, Esmeraldo IM, Chaves ML, Lins RF, Lima Rde C. Stratification of complexity in congenital heart surgery: comparative study of the Risk Adjustment for Congenital Heart Surgery (RACHS-1) method, Aristotle basic score and Society of Thoracic Surgeons-European Association for Cardio- Thoracic Surgery (STS-EACTS) mortality score. Rev Bras Cir Cardiovasc. 2015 Mar-Apr;30(2):148-58. doi: 10.5935/1678-9741.20150001. PMID: 26107445; PMCID: PMC4462959.
5. Cavalcante CT, de Souza NMG, Pinto VC Júnior, Branco KM, Pompeu RG, Teles AC, Cavalcante RC, de Andrade GV. Analysis of Surgical Mortality for Congenital Heart Defects Using RACHS-1 Risk Score in a Brazilian Single Center. Braz J Cardiovasc Surg. 2016 May-Jun;31(3):219-225. doi: 10.5935/1678-9741.20160022. PMID: 27737404; PMCID: PMC5062711.DOI: 10.5935/1678-9741.20160022
6. Joshi SS, Anthony G, Manasa D, Ashwini T, Jagadeesh AM, Borde DP, et al. Predicting mortality after congenital heart surgeries: Evaluation of the Aristotle and Risk Adjustement in Congenital Heart surgery-1 risk prediction scoring systems: A retrospective single center analysis of 1150 patients. Ann Card Anaesth 2014; 17:266-70.
7. Lacour-Gayet F, Clarke D, Jacobs J, Comas J, Daebritz S, Daenen W, et al. The Aristotle score: A complexity-adjusted method to evaluate surgical results. Eur J Cardiothorac Surg 2004;25:911-24.
8. Larsen SH, Pedersen J, Jacobsen J, Johnsen SP, Hansen OK, Hjortdal V. The RACHS-1 risk categories reflect mortality and length of stay in a Danish population of children operated for congenital heart disease. Eur J Cardiothorac Surg 2005;28:877-81.
9. Hewitson J, Brink J, Zilla P. The challenge of pediatric cardiac services in the developing world. Semin Thorac Cardiovasc Surg 2002;14:340-5.
10. Boethig D, Jenkins KJ, Hecker H, Thies WR, Breymann T. The RACHS-1 risk categories reflect mortality and length of hospital stay in a large German pediatric cardiac surgery population. Eur J Cardiothorac Surg 2004;26:12-7.

11. Jacobs JP, Jacobs ML, Lacour-Gayet FG, Jenkins KJ, Gauvreau K, Bacha E, et al. Stratification of complexity improves the utility and accuracy nof outcomes analysis in a Multi-Institutional Congenital Heart Surgeryn Database: application of the Risk Adjustment in Congenital Heart Surgery (RACHS-1) and Aristotle Systems in the Society of Thoracic Surgeons (STS) Congenital Heart Surgery Database. Pediatr Cardiol. 2009;30(8):1117-30.

12. Wu W, He J, Shao X. Incidence and mortality trend of congenital heart disease at the global, regional, and national level, 1990-2017. Medicine (Baltimore). 2020 Jun 5;99(23):e20593. doi: 10.1097/MD.0000000000020593. PMID: 32502030; PMCID: PMC7306355

13. Jenkins KJ, Castañeda AR, Cherian KM, Couser CA, Dale EK, Gauvreau K, et al. Reducing mortality and infections after congenital heart surgery in the developing world. Pediatrics. 2014;134(5):e1422-30.

14. Stark J, Gallivan S, Lovegrove J, Hamilton JR, Monro JL, Pollock JC, Watterson KG. Mortality rates after surgery for congenital heart defects in children and surgeons' performance. Lancet 2000; 355(9208):1004–77.

15. Stark JF, Gallivan S, Davis K, Hamilton JR, Monro JL, Pollock JC, Watterson KG. Assessment of mortality rates for congenital heart defects and surgeons' performance. Ann Thorac Surg 2001;72(1): 169–74.

16. Nina RVAH, Gama MEA, Santos AM, Nina VJS, Figueiredo Neto JA, Mendes VGG, et al. O escore de risco ajustado para cirurgia em cardiopatias congênitas (RACHS-1) pode ser aplicado em nosso meio? Rev Bras Cir Cardiovasc. 2007;22(4):425-31.

17. Mattos SS, Neves JR, Costa MC, Hatem TP, Luna CF. An index for evaluating results in paediatric cardiac intensive care. Cardiol Young. 2006;16(4):369-77.

18. Kang N, Cole T, Tsang V, Elliott M, De Leval M. Risk stratification in paediatric open-heart surgery. Eur J Cardiothorac Surg 2004; 26:3—11.

19. Nair SG. Pediatric cardiac program in India: Changing perspectives. Ann Card Anaesth 2011;14:79-81.