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Original article

A comparative study of the risk stratification models for pediatric cardiac surgery

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A B S T R A C T

Objective: The objective of the study was to compare Risk Assessment for Congenital Heart Surgery (RACHS-1), Aristotle Basic Complexity (ABC) and Society of Thoracic Surgeons – European Association for Cardiothoracic Surgery (STS-EACTS) complexity scoring models for predicting outcome after surgery for congenital heart disease.

Methods: This retrospective study included children <18 years. Procedures were categorized based on RACHS-1, ABC and STS-EACTS system. Outcome indicators were prolonged length of ICU stay (upper 25th percentile) and hospital mortality. The stratification models were tested for calibration using Hosmer Lemeshow modification of chi-square test and for discrimination using Receiver Operating Characteristic (ROC) curve. Area under the curve (AUC) of individual ROC curves was compared using z-statistics.

Results: The study included 920 patients. All 3 models showed good fit for both prolonged ICU stay and mortality on calibration. STS-EACTS outclassed RACHS-1 and ABC models with AUC of 0.759 for prolonged PLOS and 0.870 for hospital mortality. AUC of ROC curve for STS-EACTS was significantly higher than RACHS-1 model for both prolonged PLOS (p – 0.046) and hospital mortality (p – 0.015). No significant difference was observed between the AUC of ROC curves of other models.

Conclusion: Risk stratification for pediatric heart surgery is a useful tool to predict the outcome. STS-EACTS risk stratification model has the best discriminative power.

1. Introduction

Analysis of outcomes after congenital cardiac surgery is a complex problem and requires a reliable and reproducible process. With the advent of many surgical techniques for congenital heart disease the complexity stratification tool has become extremely useful for the analysis of outcome [1,2]. Though complexity stratification may not be the only factor determining outcome it remains an important tool for mortality and morbidity assessment post cardiac surgery.

The Risk Adjustment for Congenital Heart Surgery (RACHS-1) method was developed by the Children's Hospital Boston team and allocated 207 surgical procedures into 6 different categories having similar risk for hospital mortality [3]. Later in 1999 Lacour Gayet and a committee of experts created a tool for stratification of complexity called as Aristotle Basic Complexity (ABC) scores [4]. The score was developed by a group of 50 surgeons from 23 countries who postulated the complexity of a procedure as sum of 3 factors: potential for operative mortality; potential for operative morbidity and technical difficulty of the surgery. Each surgical procedure received a score ranging from 0.5 to 15 and was divided into categories according to the score: Level 1 (1.5–5.9); Level 2 (6.0–7.9); Level 3 (8.0–9.9) and Level 4 (10.0–15.0). This was followed by Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery (STS-EACTS) mortality score, published in 2008 which was developed primarily using the real database from 77,294 patients (33,360 patients from the EACTS and 43,934 patients from the STS between 2002 and 2007 [5]. Using Bayesian statistics that fit the data for small denominators, mortality rates were calculated for each procedure. Each procedure

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received a score ranging from 0.1 to 5.0, based on the estimated mortality and the procedures were grouped into 5 categories.

The objective of the current study was to compare the RACHS-1, ABC and STS-EACTS complexity scoring models for predicting the length of PICU stay and hospital mortality after surgery for congenital heart disease.

2. Material and methods

This retrospective study was conducted in 65-bedded cardiac PICU of a tertiary care cardiac hospital. Patient ≤18 years of age undergoing cardiac surgery for congenital heart disease on cardio-pulmonary bypass between June and November 2015 were enrolled in the study. Data were collected from the case records and PICU charts of the patients that included demographic parameter, operative diagnosis, and the procedure performed. Perioperative data including cardio-pulmonary bypass (CPB) time and Aortic cross clamp (AXC) time were also recorded.

Patients were allocated to risk categories according to the RACHS-1 system. ABC scores and STS-EACTS scores were calculated, and patients were allotted to risk categories based on standard charts. Operations involving two or more procedures done concurrently were categorized for the procedure with the higher risk category. Primary outcome indicator in the study was PICU length of stay (PLOS) and hospital mortality. For further analysis PLOS was dichotomized as upper (worst) 25th percentile versus lower (best) 75th percentile.

Statistical analysis was performed using SPSS software. Continuous data were expressed as mean ± SD and categorical data as absolute number and percentage. The analysis was done for overall performance including the extent to which the model accurately predicts the dependent variable, which indicates the goodness of fit (calibration) and ability to separate subjects who experienced the outcome event, from the others (discrimination). Discriminative power of scoring systems was assessed using area under the curve (AUC) of receiver operating characteristic curves (ROC), and z-statistics was applied to compare AUC of individual ROC curves. Calibration was measured using Hosmer-Lemeshow modification of chi-square test. $P < 0.05$ was considered as significant.

3. Results

The study included 920 patients with a mean age of 46.2 ± 48.2 months. The baseline characteristics of the study population are shown in Table 1. Commonest procedure performed was Ventricular septal defect closure and Intra-cardiac repair of Tetralogy of Fallot. None of the procedure was classified in category 5 and 6 of RACHS-1 model or category 5 of STS-EACTS scoring model. Median PLOS of the study population was 60 h and the cut-off for prolonged PLOS was calculated as 87 h (upper 25th percentile). Patients with prolonged PLOS were of younger age and had longer CPB and AXC time. Overall hospital mortality of the cohort was 3.04% (n-28).

The distribution of scores over the entire cohort is shown in Table 2. An increase in the percentage of patients requiring prolonged PLOS and increasing mortality was noted with the increase in complexity grade of the procedures. When modeled for multivariate logistic regression analysis, the RACHS-1 (χ^2 – 12.54; p – 0.129), ABC (χ^2 – 6.302; p – 0.613) and STS-EACTS (χ^2 – 9.096; p – 0.334) models showed good fit for prolonged PLOS on calibration. To predict hospital mortality the multivariate logistic regression analysis also showed good fit for RACHS-1 (χ^2 – 7.85; p – 0.449), ABC (χ^2 – 6.37; p – 0.606) and STS-EACTS (χ^2 – 7.85; p – 0.837) models on calibration.

The AUC of the ROC curves for the scores to predict prolonged PLOS (Fig. 1) and hospital mortality is shown in Table 3. STS-EACTS outclassed RACHS-1 and ABC model with AUC of 0.759 for prolonged PLOS and 0.870 for hospital mortality. RACHS-1 model was found to have the worst predictive value for both prolonged PLOS (0.701) and hospital mortality (0.766). As depicted in Table 4 statistically significant difference was found between the AUC of ROC curves of STS-EACTS and RACHS-1 model for both prolonged PLOS (p – 0.046) and hospital mortality (p – 0.015). No significant difference was observed between the AUC of ROC curves of other complexity scoring models.

4. Discussion

In the present cohort, STS-EACTS model was found to be the best predictor of both PLOS and hospital mortality followed by ABC which performed better than the RACHS-1 model. AUC of ROC curve for STS-EACTS model was found to be significantly larger than that of RACHS-1; however no significant difference was found with ABC model. Although all 3 complexity scoring models have been validated to predict the mortality and outcome post cardiac surgery no clear superiority of one over another exists. When applied to the STS database both ABC and RACHS-1 were found to be slightly different with ABC method allows classification of more operations, whereas the RACHS-1 system discriminates better at the higher end of complexity [6]. STS-EACTS model is in fact considered superior to the earlier two models due to the fact that they stratify the mortality according to real data for each surgical procedure based on the STS-EACTS multicenter database [5]. The earlier models were developed by the panel of experts based on the clinical judgment and experience and were highly subjective.

The Al-Radi et al. compared the predictive value of the RACHS-1 and ABC model for the hospital mortality outcome and found RACHS-1 to be better than the ABC scoring model [7]. In a study done by Joshi et al. ABC model was found to be better than RACHS-1 with net reclassification improvement of 43% from RACHS 1 to ABC [8]. O'Brien et al. with the introduction of STS-EACTS model compared the new model with its predecessors and found the discriminatory capacity of STS-EACTS to be higher than the RACHS-1 and ABC [9]. Cavalcanti et al. compared the RACHS-1, ABC and STS-EACTS model and found no significant difference in predicting mortality [10]. Another study by Vasdev et al. found the ability to predict mortality of the RACHS-1 similar to that of the STS-EACS with both better compared to the ABC score [11].

Although the complexity stratification of procedures are common and has been validated important limitations exists. Each

Table 1
Baseline characteristics and intra-operative variables.

Variables	Total (n-920)	PLOS lower 75th percentile (n-692)	PLOS upper 25th percentile (n-228)	p value
Age (months)	46.2 ± 48.2	25.5 ± 41.4	52.9 ± 48.4	0.000
Sex (male/female)	522/398	384/308	138/90	0.183
Weight for age < −3SD	370	280	90	0.792
CPB time (minutes)	83.7 ± 48.9	72.9 ± 34.8	116.5 ± 67.5	0.000
AXC time (minutes)	50.3 ± 36.4	42.9 ± 26.9	72.7 ± 49.8	0.000
Palliative surgery	58	38	20	0.077

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