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ORIGINAL ARTICLE

The RACHS-1 risk category can be a predictor of perioperative recovery in Asian pediatric cardiac surgery patients

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Abstract
Purpose The Risk Adjustment for Congenital Heart Surgery (RACHS-1) classification was originally designed to facilitate the prediction of in-hospital mortality for pediatric cardiac surgery patients. However, there have been few reports on clinical outcomes predicted by the RACHS-1 category, especially in an Asian population. The aim of this study was to determine whether RACHS-1 classification can predict patient outcomes.
Methods A total of 580 pediatric cardiac surgery procedures performed from January 2005 to December 2009 were retrospectively classified into the six RACHS-1 categories. The association between RACHS-1 category and clinical outcomes, including length of catecholamine requirement, mechanical ventilation time, intensive care unit stay, and in-hospital mortality, were examined.
Results The frequencies of RACHS-1 categories in the study population were: category 1, 10.7 %; category 2, 36.7 %; category 3, 42.8 %; category 4, 6.6 %; category 5, 0.0 %; category 6, 3.3 %. There was a significant linear correlation between RACHS-1 category and in-hospital mortality ($r = 0.96$, $p < 0.001$). Kaplan–Meier analysis demonstrated that length of catecholamine infusion, mechanical ventilation time, and ICU stay were significantly different ($p < 0.05$) in the different RACHS-1 categories, except for those between category 4 and 6 ($p = 0.09$).
Conclusions Based on the results of our analysis, we conclude that the RACHS-1 stratification system can predict in-hospital mortality and patient outcomes in patients undergoing pediatric cardiac surgery.

Keywords RACHS-1 · In-hospital mortality · ICU stay · Mechanical ventilation time · Catecholamine requirement

Introduction

Establishing a tool that can effectively predicting mortality and morbidity for pediatric congenital cardiac surgery patients is clinically practical. The Risk Adjustment for Congenital Heart Surgery (RACHS-1) classification system was originally designed to predict in-hospital mortality due to pediatric cardiac surgery in patients under 18 years of age [1]. The RACHS-1 system divides patients into six categories according to operation procedures. Many reports on the RACHS-1 classification system and its correlation with in-hospital mortality have been published on U.S. and European populations [1–3]. However, no study has yet documented its correlation with in-hospital mortality in an Asian population. Moreover, few studies have documented correlations between the RACHS-1 category system and clinical outcomes other than in-hospital mortality, such as length of ICU stay [2–4]. Accordingly, the goal of this study was to determine whether the RACHS-1 stratification system can also be used to predict clinical outcomes relevant to patient recovery other than in-hospital mortality.

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Materials and methods

Patients and variables

This study was approved by the Review Board for Human Experiments at the Kyoto Prefectural University of Medicine (Kyoto, Japan). Patient data were obtained from anesthetic records and a database at the pediatric intensive care unit (ICU). Between January 2005 and December 2009, 689 congenital heart surgeries in patients under 18 years of age were performed. Of these surgeries, the following procedures and patients were excluded from our analysis: re-thoracotomies and closing chests ($n = 24$), pacemaker implantations or revisions ($n = 6$), patent ductus arteriosus in under 30-day-old neonates with an isolated cardiac defect ($n = 72$), and presence of major non-cardiac anomalies ($n = 7$). The final analysis was therefore performed on 580 procedures in 562 patients. These procedures were performed by four surgeons. Anesthetic records and patient information, including gender, age, weight, operation procedure, RACHS-1 category, in-hospital mortality, length of catecholamine requirement, mechanical ventilation time, and ICU stay, were recorded.

Length of ICU stay was defined as the duration in hours from ICU admission until ICU discharge/transfer criteria were met, as published previously [5]. If a patient remained in the ICU to receive other treatments (e.g., combined abdominal malformation or airway problem) unrelated to the surgery after ICU admission, two-thirds of that period was attributed to surgery-associated ICU stay, as previously described [2]. Prolonged stay in the pediatric ICU was required for seven patients, among whom five (2 in RACHS-1 category 2, 2 in category 3, and 1 in category 4) had airway problems associated with tracheomalacia; the two remaining patients (1 in category 2 and 1 in category 3) had abdominal problems associated with malrotation of the intestine. Intensive care was needed by these seven patients. The association between the RACHS-1 category and clinical outcomes, including length of catecholamine requirement, mechanical ventilation time, ICU stay, and in-hospital mortality, was examined.

Statistical analysis

Data were analyzed using StatFlex statistical software (Artech Co. Ltd., Osaka, Japan). The relationship between the RACHS-1 category and in-hospital mortality were analyzed by Pearson's correlation coefficient test. Relationships between the RACHS-1 category and the other clinical outcomes (length of catecholamine requirement, mechanical ventilation, ICU stay) were analyzed by the Kaplan–Meier method and log-rank test. Data are reported as mean ± standard deviation (SD); $p < 0.05$ was considered to be statistically significant.

Results

The RACHS-1 categories of our patient population were determined. The frequencies of the different classifications were: category 1, 10.7 %; category 2, 36.7 %; category 3, 42.8 %; category 4, 6.6 %; category 5, 0.0 %; category 6, 3.3 %. Only one patient was assigned to category 5, but this patient was ultimately excluded from the analysis due to the presence of major non-cardiac anomalies (Table 1; Fig. 1). The percentages of surgery performed by each of the four surgeons were 81.7, 13.3, 3.8, and 1.2 %, respectively.

Total in-hospital mortality in our study was 2.1 %. In-hospital mortality for each category was: category 1, 0.0 %; category 2, 0.5 %; category 3, 2.4 %; category 4, 7.6 %; category 5, 0.0 %; and category 6, 10.0 %. There was a strong linear regression between RACHS-1 category and in-hospital mortality by Pearson's correlation coefficient test ($r = 0.96$, $p < 0.01$; Fig. 2).

According to Kaplan–Meier analysis and log rank tests on the length of ICU stay in hours (Fig. 3a), mechanical ventilation time in hours (Fig. 3b), and the duration of catecholamine infusion in days (Fig. 3c), there were statistically significant differences among the RACHS-1 categories ($p < 0.05$) for these parameters, except for between category 4 and category 6 ($p = 0.09$).

Discussion

The findings of our study show that the RACHS-1 stratification system can strongly predict in-hospital mortality in patients undergoing pediatric cardiac surgery. This result therefore is in accordance with those of previous studies showing that RACHS-1 category can reflect in-hospital mortality [2, 3]. Further, we demonstrated that the RACHS-1 stratification system can predict other clinical outcomes associated with patient recovery.

The RACHS-1 stratification system was first reported by Jenkins et al. [1] for predicting mortality in patients under 18 years of age who were undergoing pediatric cardiac surgery, who demonstrated that there is a strong correlation between in-hospital mortality and each category. They also reported that application of the RACHS-1 category is useful for comparison of mortality rates in the same category between each institution [6]. However, some reports have pointed out several limitations of the RACHS-1 category system. One of these limitations is that cardiac anomalies which require complicated procedures with

Table 1 Patient characteristics

Patient characteristics	RACHS-1 category					
	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6
Numbers of patients	62 (100 %)	213 (100 %)	248 (100 %)	38 (100 %)	0	19 (100 %)
Age (years)						
<1	13 (20.9 %)	108 (50.7 %)	133 (53.6 %)	22 (57.9 %)		18 (94.7 %)
1–5	20 (32.3 %)	82 (38.5 %)	85 (34.2 %)	11 (28.9 %)		1 (5.3 %)
6–12	19 (30.6 %)	12 (5.6 %)	10 (4.0 %)	5 (13.2 %)		
13–17	10 (16.2 %)	11 (5.2 %)	20 (8.2 %)	0 %		
Gender						
Male	28 (45.1 %)	129 (60.6 %)	133 (53.6 %)	19 (50 %)		8 (42.1 %)
Female	34 (54.9 %)	84 (39.4 %)	115 (46.4 %)	19 (50 %)		11 (57.9 %)
Weight (kg), mean (SD)	19.5 (17.4)	10.5 (10.2)	10.0 (12.5)	8.0 (6.5)		4.4 (1.77)
Most common procedures	ASD ($n = 43$)	VSD ($n = 102$)	TCPC ($n = 58$)	ASO ($n = 12$)		Norwood ($n = 10$)
	PDA >30 days ($n = 9$)	AVSD ($n = 49$)	PAB ($n = 43$)	Rastelli ($n = 8$)		D–K–S ($n = 9$)
	Coarctation repair >30 days ($n = 8$)	TOF ($n = 41$) Glenn ($n = 31$)	MBTS ($n = 38$)	Unifocalization ($n = 7$)		

RACHS-1 Risk Adjustment for Congenital Heart Surgery classification system, *ASD* Atrial septal defect, *PDA* patent ductus arteriosus, *VSD* ventricular septal defect, *AVSD* atrial-ventricular septal defect, *TOF* tetralogy of Fallot, *PAB* pulmonary artery banding, *MBTS* modified Blalock–Taussig shunt, *ASO* arterial switch operation, *D–K–S* Damus–Kaye–Stanse

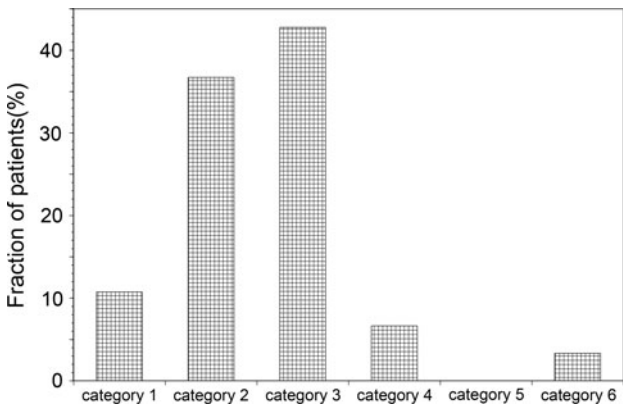

Fig. 1 Distribution of patients according to the Risk Adjustment for Congenital Heart Surgery (RACHS-1) classification system in the Kyoto Prefecture University of Medicine (KPUM) from January 2005 to December 2009. *Number above bar* Fraction of patients in that category. There was only one operation classified into category 5, but that patient was excluded from the analysis due to the presence of a major non-cardiac anomaly

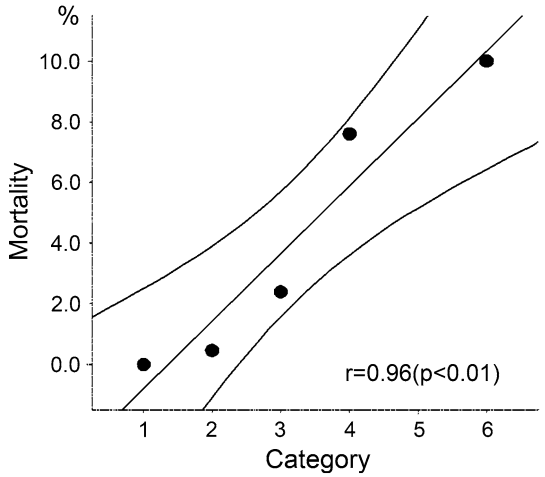

Fig. 2 Mortality rates for each category. Increasing category number paralleled a rise in mortality. There was a strong linear correlation between category and mortality ($r = 0.96$, $p < 0.01$). The *bottom of the graph* summarizes mortality for each category with the 95 % confidence interval

multiple steps or with non-cardiac anomalies were excluded from the analyses. Another limitation is that there were no predictive clinical applications of the RACHS-1 category system outside of patient mortality. Our findings may encourage the application of the RACHS-1 system for predicting patient recovery.

Our Kaplan–Meier analysis and log-rank tests revealed that there was a significant difference in clinical outcomes among the RACHS-1 categories, except for categories 4 and 6, which showed a longer catecholamine requirement, mechanical ventilation time, and length of ICU stay with the higher stage of the RACHS-1 category patient. A possible explanation for the lack of a significant difference in clinical outcomes between categories 4 and 6 is that the number of patients in categories 4 and 6 in our study was small. This potential limitation is inherent to the RACHS-1 category system, as the number of cases in a category tends to diminish with increasing category number.

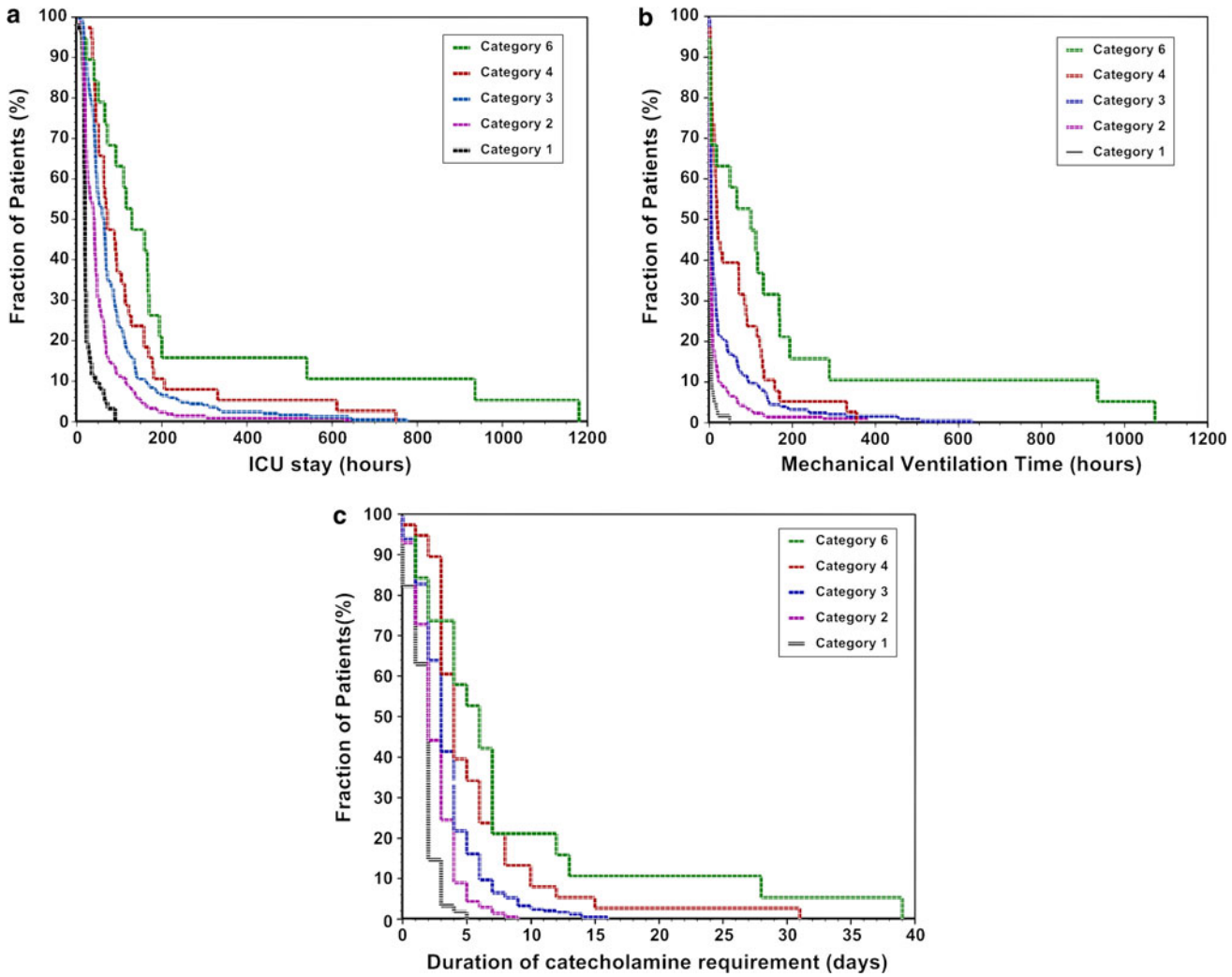

Fig. 3 Kaplan–Meier curves for each category concerning length of intensive care unit (*ICU*) stay, mechanical ventilation time (*MVT*), and the duration of catecholamine requirement. There were statistically significant differences ($p < 0.05$) between all categories for these parameters except for category 4 and category 6 ($p = 0.09$). **a** ICU stay, **b** duration of mechanical ventilation time, **c** duration of catecholamine requirement

The Aristotle Score, which is composed of two factors (Basic score and Comprehensive score), could compensate for the deficits of the RACHS-1 classification system [7]. Previous studies have shown that the RACHS-1 category system is a better predictor of in-hospital mortality and duration of ICU stay than the Aristotle Basic Score [8, 9]. On the contrary, the Aristotle Comprehensive Score might be more useful for the prediction of congenital heart surgery outcomes than the RACHS-1 category system [10, 11]. However, the Aristotle Comprehensive Score is difficult to use in clinical settings due to its complexity.

One possible explanation for the lower rate of in-hospital mortality in our study population as opposed to results reported in previous studies might be derived from the fact that more than 80 % of the procedures in the present study were performed by the same surgeon and that in-hospital mortality of pediatric cardiac surgery patients mainly depends on the surgeon's skill.

A limitation of our study is that the RACHS-1 risk category was applied to the Japanese population of a single institute. However, our findings revealed that the RACHS-1 risk category is as applicable to the Asian population as it is to Western populations. Further studies are needed to verify the applicability of RACHS-1 to larger Asian populations.

In conclusion, our results suggest that the RACHS-1 stratification system can be used to predict in-hospital mortality also in a pediatric Japanese population. Moreover, we found that the RACHS-1 stratification system can also predict other clinical outcomes, including length of catecholamine requirement, mechanical ventilation time, and ICU stay.

Conflict of interest No conflicts of interest declared.

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