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RESEARCH ARTICLE

Comparing Two Models of Pediatric Cardiac Care Establishment in a Developing Country

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ABSTRACT

Objectives: Multidisciplinary cardiac care is well known to lead to improved outcomes. In this study, two different organizational models (surgeon-led and team-based units) for pediatric cardiac intensive care unit (ICU) located in a developing country setting and their early postoperative outcomes for patients with pediatric congenital heart disease were compared.

Methods: A total of 246 infants and children who underwent surgery for congenital cardiac diseases were retrospectively analyzed. The correlations between the perioperative patient data of both models were analyzed and compared. The predictive factors for morbidity were calculated.

Results: No significant difference was observed in the Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery (STS-EACTS) mortality category and estimated mortality rate between groups. However, a statistically significant difference was observed in the STS-EACTS estimated postoperative length of stay and estimated major complication rate between groups. The extubation time and length of ICU stay varied significantly between groups.

Conclusion: Compared with the surgeon-led model, the team-based model resulted in superior postoperative patient outcomes in terms of morbidity, shorter extubation time, and ICU length of stay. Thus, in developing countries, higher morbidity rather than mortality may be anticipated when undertaking congenital heart surgery in non-neonatal age groups without a multidisciplinary team to support the surgeon. Therefore, higher major complications can be expected when congenital heart surgery programs have to be established despite the lack of experienced staffing.

Keywords: Cardiac intensive care, cardiac surgery, congenital heart diseases

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Introduction

With the rapidly growing specialty of pediatric cardiac intensive care, the demands of children with congenital heart disease (CHD) are being met.[1,2] Intensive care unit (ICU) workflow with multidisciplinary teams is well known to result in better outcomes.[2,3] At present, the collaboration between surgery and cardiac critical care has resulted in drastically improved results, with ICU mortality estimated in single-digit percentages.[4] For the perioperative management of these critically ill children, organized pediatric cardiac ICUs have become essential because of the growing difficulty of congenital heart repairs in the modern era and the special needs for managing children following cardiac surgery.[1] Furthermore, with the wider availability of accurate diagnostics and the improving potential for total anatomic repair, an increasing number of children are undergoing cardiac surgery for congenital heart disorders.[2] Consequently, there is a growing need for specialists to provide dedicated and high-quality intensive care to these critical patient groups.

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Attention has always been concentrated around the organizational structure and staffing of cardiac ICUs.[1] Previous studies have reported the positive impacts of intensive care with a cardiac team on clinical outcomes; nevertheless, data regarding this topic are limited.[1,5] Despite progress in the management of CHDs, there continue to be major discrepancies worldwide in the standard and availability of pediatric cardiac care.[6]

In many developed countries, pediatric cardiac intensive care has transformed into a separate field with specialized programs in practice.[2] On the other hand, in developing nations, pediatric cardiac surgery is an ongoing challenge, and current cardiac intensive care models cannot be implemented because of severe resource constraints that must be overcome. It is challenging to put into practice advanced methods to address the surgical needs of a substantial percentage of children with congenital heart defects while dealing with severe financial constraints and maintaining quality with the context of constant job turnover of equipped medical, nursing, and other paramedical personnel.[7] Thus, in these countries, resource limitations in terms of infrastructure, people, and materials require for numerous adjustments in intensive care programs.[5,6] Moreover, these developing countries are still in the early stages of developing pediatric cardiac critical care programs.[5] Pediatric cardiac critical care has not yet established itself as a unique field in developing nations with limited resources.[2]

In this study, we compared the experiences of one surgeon in two different organizational pediatric cardiac care models (i.e., a surgeon-led unit as opposed to a team-based multidisciplinary ICU). Our aim was to compare the early postoperative outcomes of children undergoing congenital heart surgery in a developing country and review the outcomes of both models.

Methods

A total of 246 infants and children who underwent operation for CHDs between June 2017–November 2019 and April 2021–November 2022 were retrospectively included and assigned to group 1 and 2, respectively. Group 1 comprised 123 patients operated in a regional non-referral hospital with a pediatric ICU led by the primary pediatric cardiac surgeon. Group 2 included 123 patients operated in a university hospital with a pediatric cardiac ICU led by a multidisciplinary cardiac team. Neonates were excluded from the cohort to preserve the homogeneity of the study since the number of neonates differed in both groups (55 neonates in group 1 and 7 neonates in group 2).

All patients were operated on by the same surgeon. Their preoperative, operative, and postoperative data up until discharge were evaluated. The Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery (STS-EACTS) mortality and morbidity scoring systems were used to evaluate patients.[8,9] The perioperative data and length of intensive care and hospital stay were reviewed. Besides the difference of staffing, the two centers were equivalent with regard to the availability of resources such as surgical equipment and medications.

In group 1, the pediatric cardiac ICU was managed by one cardiac surgeon, three practitioners, and nursing staff. The patients were admitted to a specialized ICU that was only for patients undergoing pediatric cardiac surgery. Postoperative care of patients was provided by the lead cardiac surgeon on call 24 h a day supported by an anesthesiologist and on-call cardiologists. Clinical decision-making was done on an individual basis by the surgeon.

In group 2, the multidisciplinary patient care team consisted of two pediatric intensive care specialists, two cardiac anesthesiologists, two pediatric cardiac surgeons, two pediatric cardiologists, nursing staff, and a respiratory physiotherapist. The patients were admitted to a pediatric ICU. The treatment plan was carried out under the supervision of the intensive care specialist, with mainly the support of pediatric cardiac surgery and cardiology.

Patient outcomes and perioperative data were retrospectively analyzed for the two time periods. The length of hospital and ICU stay, length of mechanical ventilation, mortality, and postoperative complications were analyzed. As defined by STS-EACTS, the following conditions were accepted as postoperative complications: acute postoperative renal insufficiency necessitating either temporary or permanent dialysis, postoperative atrioventricular block requiring a permanent pacemaker, postoperative neurologic impairment that persisted after discharge, need for mechanical circulatory support postoperatively, diaphragm paralysis/phrenic nerve damage, and unanticipated reoperation.[9]

Statistical Analysis

Statistical analyses were conducted using the MedCalc Statistical Software, version 12.7.7 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2013). The Shapiro–Wilk test was used to investigate the normality of continuous variables. For non-normally distributed variables, descriptive statistics were presented as median and interquartile range (1–3) values. Values with skewed distribution were analyzed using non-parametric statistical techniques. The Mann–Whitney U test was used to compare two groups with non-normal distributions. Pearson chi-square and Yate's continuity correction tests were used for comparison of categorical data. Logistic regression analysis was used for multivariate evaluation of perioperative factors affecting morbidity. A two-sided p-value less than 0.05 was considered statistically significant.

Table 1. Table of perioperative patient data and the univariate analysis

	Total (246pt)		Group 1e (123pt)		Group 2 (123pt)		p
	n	%	n	%	n	%	
Age (month)	14.3 (46.2–5)		10 (23–5)		28.2 (59.5–6.4)		<0.001
Age groups							
1–12 months	115	46.7	70[a]	56.9	45[b]	36.6	<0.001
12–36 months	57	23.2	33[a]	26.8	24[a]	19.5	
36–72 months	41	16.7	7[a]	5.7	34[b]	27.6	
72 months	33	13.4	13[a]	10.6	20[a]	16.3	
Sex							
Female	113	45.9	58[a]	47.2	55[a]	44.7	0.701
Male	133	54.1	65[a]	52.8	68[a]	55.3	
Weight	8 (13.7–5)		6.2 (9.5–4.8)		11 (16–6)		<0.001
Height	72 (96–58)		65 (78–56)		90 (108–65)		<0.001
Body surface area	0.39 (0.6–0.28)		0.33 (0.44–0.27)		0.52 (0.69–0.32)		<0.001
Cyanosis	118	48	49[a]	39.8	69[b]	56.1	0.011
Pulmonary hypertension	136	55.3	82[a]	66.7	54[b]	43.9	<0.001
Re-operation	70	28.5	11[a]	8.9	59[b]	48	<0.001
STS-EACTS-mortality category							0.864
Category 1	41	16.7	22[a]	17.9	19[a]	15.4	
Category 2	122	49.6	61[a]	49.6	61[a]	49.6	
Category 3	32	13	14[a]	11.4	18[a]	14.6	
Category 4	51	20.7	26[a]	21.1	25[a]	20.3	
STS-EACTS estimated mortality rate	3 (4.9–1.9)		2.6 (4.6–1.9)		3 (6.7–2.4)		0.164
STS-EACTS Estimated post-operative length of stay	11.7 (14.9–7.7)		8.3 (13.8–7.7)		12 (14.9–9.4)		0.001
STS-EACTS Estimated major complication rate	6.9 (12–3.4)		4.3 (9.9–3.4)		7.2 (12–6.3)		<0.001
Cross time	93 (135.2–57.7)		94 (135–64)		89 (136–50.5)		0.22
Bypass time	138 (190.5–98.2)		140 (198.5–100.7)		131 (183.2–89.5)		0388
Ultra-Fast-Track Extubation	83	33.7	14[a]	11.4	69[b]	56.1	<0.001
Complication rate	36	14.6	28[a]	22.8	8[b]	6.5	<0.001
Renal insufficiency	12	33.3	9	25	3	8.3	
AV block	5	13.8	3	8.3	2	5.5	
Neurologic impairment	1	2.7	1	2.7	0	0	
ECMO	17	47.2	14	38.8	3	8.3	
Diaphragm paralysis	1	2.7	1	2.7	0	0	
Mortality rate	15	6.1	10[a]	8.1	5[a]	4.1	0.287
ICU stay	2 (7–1)		5 (12–2)		1 (2–1)		<0.001
Hospital stay	12 (20–7)		14 (22–8)		10 (16–7)		0.007

[a,b]: Each superscript letter denotes a subset of groups whose column proportions do not differ significantly from each other at the 0.05 level. STS-EACTS: Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery; AV: Atrioventricular; ECMO: Extracorporeal membrane oxygenation; ICU: Intensive care unit

Results

Data relevant to procedures and perioperative patient information are summarized in Tables 1 and 2. Group 1 included patients who were managed postoperatively in a pediatric ICU led by a cardiac surgeon without a specialized intensivist. Group 2 comprised patients admitted to a specialized team-based pediatric cardiac ICU. A statistically significant difference was observed between the age of patients in both groups (p<0.001) (Table 1). On the other hand, the two patient groups were equally dispersed in terms of sex. The weight, height, and body surface areas between the two groups varied significantly (all p<0.001). Additionally, no difference was observed in terms of the cyanotic nature of the pathology between the two groups. With regard to the presence of pulmonary hypertension and reoperation status of patients, a significant variation was observed (all p<0.001).

Based on the STS-EACTS mortality scoring system, no significant difference was observed in the mortality catego-

Table 2. Table of the logistic regression analysis

Variables	Significance	Exp(B)	95% CI for Exp(B)
Body surface area	0.710	0.286	(0.000–209.003)
Age	0.843	0.996	(0.953–1.040)
Cyanosis	0.036	5.498	(1.119–27.009)
Redo	0.119	4.060	(0.697–23.642)
Pulmonary hypertension	0.451	1.871	(0.367–9.525)
STS-EACTS mortality category	0.470	0.637	(0.187–2.165)
STS-EACTS estimated mortality rate	0.756	1.062	(0.726–1.554)
STS-EACTS estimated post operative length of stay	0.120	0.782	(0.573–1.066)
STS-EACTS estimated major complication	0.301	1.138	(0.890–1.456)
Cross time	0.025	0.979	(0.960–0.997)
Bypass time	<0.001	1.033	(1.016–1.050)
ICU length of stay	0.109	1.053	(0.988–1.122)
Hospital length of stay	0.412	0.980	(0.935–1.028)
Surgeon-led ICU model	0.016	0.151	(0.032–0.706)

Exp(B): Odds ratio; CI: Confidence interval; STS-EACTS: Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery; CU: Intensive care unit

ry and estimated mortality rate between the two groups. On the other hand, the STS-EACTS estimated postoperative length of stay and estimated major complication rate were statistically significant between groups (p=0.001 and p<0.001, respectively).

Regarding operative data, no statistically significant difference was observed in the cross-clamp and bypass times between the two groups. Nonetheless, the ultra-fast-track extubation success differed significantly between them (p<0.001). Furthermore, a significant difference was observed with regard to the occurrence of postoperative complications between the two groups (p<0.001). Notably, no significant difference was found between the mortality rates of both groups. However, there was a significant difference between the ICU and hospital length of stay of both groups (p<0.001 and p=0.007, respectively).

Based on the results of logistic regression analysis, the cyanotic nature of the pathology, cross-clamp duration, bypass duration, and cardiac intensive care strategy were statistically significant predictors of morbidity (p=0.036, p=0.025, p<0.001, and p=0.016, respectively).

Discussion

The intensive care period forms a crucial component of the care of patients undergoing surgery for CHDs. Globally, three main postoperative cardiac ICU systems are used, with either surgeons, intensivists, or cardiologists providing the initiative regarding the plan of action in ICUs. In the early years of congenital heart surgery, pediatric cardiac surgeons were mainly responsible for the postoperative intensive care of patients.[2,5] However, in the past decades, further specialties, especially pediatric cardiac intensivists, have begun to play a bigger role in this field.[5] On the other hand, these practices differ widely between developing and developed countries.[7] Additionally, regional and institutional factors influence the strategy employed; thus, the standard of care among regions of a single country vary and are nonuniform. In developed countries, units with a multidisciplinary cardiac care team are widely established. Compared with high-income nations, pediatric cardiac intensive care centers are not generally available in low- and middle-income countries. In addition, resource constraints deem cardiac intensivists a luxury and make the surgeon responsible for postoperative care in ICUs.[7] This shortage is because of the lack of infrastructure, financial resources, and personnel resources required for a specialized pediatric cardiac intensive care program.[2,7,10] Our country, Türkiye, is still developing, yet hospitals vary according to the standard of care which they offer from developing to developed country levels. Hence, different strategies of pediatric cardiac intensive care are being implemented in different hospitals across the country. Notably, the main resource constraint in our country is the lack of experienced staffing and organizational outline for the establishment and management of pediatric cardiac programs in peripheral centers with frequent staff turnover that stand in the way of sustainable and efficient teamwork. In surgical programs of centralized hospitals for pediatric cardiac care, the strategies being applied are continually evolving. Moreover, in the case of pediatric cardiac surgery, there is a compulsory service system for all doctors where, to this day, they are assigned to a hospital in an unprogrammed manner. These hospitals have highly differing availability of resources and organizational model practices for pediatric cardiac care. This variation has been demonstrated in our study by the differing experiences with mortality and morbidity of one cardiac surgeon in two regions of the same country.

Mortality following cardiac surgery has been routinely used as a quantifiable indicator to assess the quality of pediatric cardiac surgical treatment. Surgical complexity, severity of CHD, and preexisting comorbidities all have a major impact on postoperative mortality.[10] In previous studies, the mortality rate of children following heart surgery was high in low- and middle-income countries, in contrast to the reported mortality rate of <5% in high-income countries when compared according to their pediatric cardiac care strategy.[10] In our study, the overall mortality in group 1 was two-fold higher than that in group 2. Nonetheless, it was statistically insignificant in infants and children. Moreover, the recorded mortality rate in group 1 was approximately three times the estimated mortality rate, which suggests a possible benefit of multidisciplinary teams in cardiac care.

Cyanotic CHD and longer cardiopulmonary bypass duration have been previously reported to be predictive variables for developing major complications postoperatively.[11] Our results were in agreement with this study. However, cross-clamp duration and staffing pattern were shown to be predictors of morbidity as well. Notably, our cohort included operations of higher surgical complexity with longer cross-clamp duration compared with those in the previous study, which might explain the association between cross-clamp duration and higher morbidity. In literature, prolonged cardiopulmonary bypass and aortic cross-clamp duration are significantly correlated with postoperative morbidity. Thus, to avoid morbidity, close monitoring for postoperative complications or transferring to centers with multidisciplinary teams might be considered for patients who are predicted to have prolonged cross-clamp and bypass durations in developing countries with staff constraints. On the other hand, the results of our multivariate analysis indicate that the intensive care strategy used and staffing have a more significant effect on patient morbidity compared with perioperative factors such as the cyanotic nature of the pathology and bypass duration. Thus, it may be deduced that a multidisciplinary-team-based approach for cardiac care effectively reduces postoperative complications.

Among the STS-EACTS postoperative complications, low cardiac output and arrythmia are the most common.[12] In our cohort, low cardiac output requiring extracorporeal membrane oxygenation support was the most common complication followed by the need for dialysis and arrythmias, which were more commonly seen in group 1. The possible explanation for this finding may be the younger age of patients in this group since morbidity is expected to increase as age decreases.[13] Moreover, in our practice in group 1, dialysis was used to support the overall hemodynamic status of the patient when needed, in addition to its application in kidney injury. The clinical interpretation of patients differs between surgeons and intensivists. In addition, the approach to hemodynamic instability varies, and an intensivist might approach with a different treatment plan. Furthermore, intensivists are specialists with additional training and experienced in non-cardiac organ failure and related treatments in addition to their experience with congenital and acquired heart diseases.[3] A previous study reported that the reduction in postoperative morbidity and mortality following congenital heart surgery in recent decades can be partially credited to the creation and advancement of pediatric cardiac intensive care specialists.[14] This difference in clinical judgement and choice of management plan of intensivists is one of the possible explanations for the difference in morbidity between the groups. In addition, this expertise might allow for an earlier recognition and treatment of postoperative complications, which may further explain the difference in morbidity recorded in this study.

Furthermore, the additional pressure on the surgeon caused by the lack of staffing and added responsibility of intensive care might be another factor contributing to the higher postoperative morbidity in group 1. Thus, it can be argued that when the surgeon has to claim responsibility of the ICU, the capacity for patient management in the ICU is lowered, and higher rates of complications and mortality from postoperative complications may be seen. Multidisciplinary units benefit not only the patients but also the surgeons.[15] In addition to performing the operation, being responsible for the entirety of postoperative care and being the on-call caretaker for 24 h make it exceedingly stressful for the surgeon.[7] Considering these factors, the advantages of a team-based cardiac care strategy for the surgeon include a simplification of everyday tasks, ease of capacity management, and the ability to share the load of postoperative care with colleagues.[15] As a result, creating a strong team with delegated tasks leads to superior outcomes.[2,7] The improvements in mortality and morbidity recorded in this study exemplify the advantages of team-based cardiac ICUs and specialized intensivists.

An ICU model incorporating intensivists has been previously shown to reduce the length of hospital stay.[1] In addition, previous studies have reported an association between reduced length of ICU stay and specialized pediatric cardiac ICU.[1,10,16,17] The results of our analysis indicate that a cardiac-team-led ICU have a statistically significant impact on ICU and hospital length of stay. This outcome may be caused by the increased occurrence of postoperative complications in the surgeon-led ICU, which may have resulted in prolonged length of hospital and ICU stay. The results of this study indicate that the presence of a multidisciplinary team significantly impacts the outcomes of congenital heart surgery. Thus, when undertaking cardiac surgery in developing countries with resource limitations, efforts should be made to support surgeons with a multidisciplinary team to share the ICU's responsibilities in order to improve patient outcome by reducing morbidity and cost burden on healthcare systems.

The main limitations of this study rooted from its retrospective nature. Data could not be collected prospectively because of the institutional differences between the two hospitals and the same lack of resources and staffing mentioned previously. The dataset includes a small number of patients that might not be sufficient to reach a clear consensus. Furthermore, the scoring system used in this study may not always accurately reflect the true surgical complexity of the cases. In addition, separating the impacts of surgical pitfalls from the impact of ICU care on patient outcomes is impractical and cannot be performed. When evaluating different strategies of pediatric cardiac critical care setting, the ideal independent outcome to measure would be a factor that represents the skill and quality of care delivered by the intensive care staff and is unaffected by treatment provided in advance to ICU admission. However, accurate parameters needed for such an evaluation have not yet been created. Thus, the patient outcomes in the two different ICU models cannot be attributed solely to the ICU setup, and outside factors have to be considered. Nevertheless, this particular limitation was minimized in this study by keeping the surgeon and surgical approach constant in both models. Therefore, the outcomes were made more comparable.

Conclusion

The introduction of a multidisciplinary pediatric cardiac intensive care model as opposed to a surgeon-led cardiac ICU model resulted in improved postoperative patient outcomes in terms of morbidity and shorter extubation time and ICU and hospital stay. Notably, higher morbidity rather than mortality may be expected while carrying out pediatric heart surgery on children in countries with human resource constraints. Lastly, more efforts should be made to achieve this team-based model for the postoperative care of this delicate patient group, especially in developing countries.

Disclosures

Ethics Committee Approval: The study was approved by The Koç University Committee on Human Research Ethics Committee (Date: 24/07/2023, No: 2023.244.IRB1.078).

Informed Consent: Written informed consent was obtained from all patients.

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