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Unplanned Return to Cardiac Intensive Care Unit of Children After Congenital Heart Surgery: Incidence, Outcomes, and Risk Factors

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ABSTRACT

Objective: Factors leading to an unplanned return to the cardiac intensive care unit (CICU) in children after congenital heart disease and their impact on mortality have not been well characterized. We sought to determine the incidence and outcomes of unplanned return to the CICU. A secondary objective was to identify risk factors.

Methods: Retrospective analysis of the registration data collected by our unit. The study subjects included postoperative patients with congenital heart disease who survived to initial transfer out of the CICU. Patients who unexpectedly returned to the CICU due to an acute change in clinical status were defined as unplanned returns. Demographic, preoperative, intraoperative, and postoperative variables were assessed. Univariate comparisons were performed between the return group and non-return group, and multivariate regression analysis was performed to identify potential risk factors for unplanned return to the CICU.

Results: Of the 531 children who met the inclusion criteria, 29 were unplanned returns to the CICU. Respiratory symptoms (41.4%) and cardiac symptoms (44.8%) were the most common reasons for returning to the CICU. Patients with unplanned returns had a higher mortality rate (13.8% vs. 0.56%, $P < 0.01$). In multivariate analysis, unplanned CICU admission was associated with chromosomal abnormalities ($P < 0.01$), longer ventilator duration ($P < 0.01$), and more prolonged cardiopulmonary bypass ($P < 0.01$) was associated with a return to independence.

Conclusions: Unplanned return to the CICU during the same hospital stay was uncommon but associated with higher mortality. Chromosomal abnormalities, longer ventilator use duration, and prolonged CPB were significant risk factors for the entire cohort. We hope to minimize the impact of unplanned return after congenital heart disease surgery by changing the process of transferring these high-risk postoperative patients out of the CICU and early postoperative care.

INTRODUCTION

In recent years, the survival rate of critically ill patients with congenital heart disease in many tertiary hospitals has improved. Children with congenital heart disease after surgery are unstable in breathing and circulation. Vasoactive drugs and life support equipment need to be monitored in the CICU to reduce congenital heart disease operations' mortality and morbidity rate. After the condition improves, patients will be transferred from the CICU to the general ward. We note that there have been reports of readmissions to the CICU as high as 8% [Lal 2020; Smischney 2020]. The main reasons for patient return to the CICU include asphyxia, ventricular fibrillation, hypoxemia, severe pulmonary infection, cardiac tamponade, and critical pulmonary hypertension [Li 2019]. Our clinical work shows that after recovery and transfer from the cardiac intensive care unit, approximately 5.5 % of patients need to be re-entered for further treatment during the same hospital stay, due to changes in their condition. Compared with patients admitted to the CICU for the first time, patients who re-entered the CICU were more challenging to treat and had higher morbidity and mortality [Magruder 2015]. Returning to the CICU often results in prolonged hospitalization, waste of medical resources, reduced quality of medical care, and even medical disputes. The primary objective of this study was to determine the incidence and outcomes of unplanned returns to the CICU. The secondary goal was to identify risk factors for unexpected returns. The broader goal was to determine if there were controllable factors that could be addressed to improve outcomes for patients with an unplanned return to the CICU.

METHODS

Patients: The study population consisted of 531 children with congenital heart disease who were hospitalized in the heart center of Fujian Children's Hospital from January 2020

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to April 2022. A total of 29 children were transferred from the CICU to the general ward and returned to the CICU again after the children were stabilized after surgery. Inclusion criteria for children returning to the CICU: (1) After congenital heart surgery, the patients were transferred from the CICU to the ward after their condition was stable, and they returned to the CICU due to changes in acute conditions; (2) Returned to the CICU for the first time. Exclusion criteria: (1) Patients who were transferred to CICU for monitoring due to disease factors before surgery; (2) Returned to CICU multiple times; (3) Patients who were directly discharged home from the CICU.

Data collection method: Retrospective statistical analysis of the general data of 29 children, including preoperative, intraoperative, and postoperative data, disease types of children returning to CICU, time of returning to CICU, etiological diagnosis of returning to CICU, and return to CICU subsequent return. For included patients, data were extracted using our unit's congenital heart database, including demographic data and data on CICU care events and details of cardiac surgery. Further details of the patient's hospitalization process, including test results and cardiac anatomy details, are available from the electronic medical record.

Our center is equipped with a 26-bed cardiac intensive care unit and a 45-bed general ward. Most patients in the CICU are transferred to the general ward when their condition is stabilized. The CICU and general ward are separate teams of different doctors and front-line caregivers. Verbal handovers from the CICU doctor to the general ward doctor and the CICU nurse to the general ward nurse need to be completed before the patient is transferred out of the CICU. The patient cannot be transferred out of the CICU without the review of the attending physician of the CICU. From a cardiorespiratory standpoint, patients must be stable to be eligible for transfer to a general ward. General ward staff can initiate a high-flow nasal cannula, continuous positive airway pressure, and vasoactive drugs such as epinephrine and dopamine, and the patient is then transferred back to the general ward. Arterial blood pressure monitoring, central venous pressure monitoring, and temporary pacing were not performed in the general ward. Procedures requiring sedation are not performed in general wards. The general ward routinely is staffed with a cardiac surgeon and nurse every day.

For transfer times, nighttime transfers are defined as transfers between 8 p.m. and 6 a.m. Weekend transfers are defined as transfers between 8 p.m. Friday and 6 a.m. Monday. For the experience level, doctors with less than 5 years of clinical practice were defined as junior doctors, doctors with 5-10 years of clinical practice were defined as intermediate doctors, and doctors with more than 10 years of clinical practice were defined as senior doctors. The number of caregivers for the child can be divided into 1, 2, and more than 3 people.

Statistical analysis: SPSS25.0 (IBM Crop., Armonk, NY) statistical software was used to analyze the data; the count data was represented by n/%, the chi-square test was used, and the measurement data was represented by x±s, and the t-test was used. Tests that do not conform to the normal distribution select nonparametric tests for statistical analysis. To identify potential predictors of unplanned return to the CICU after congenital heart surgery, we performed the univariate analysis of the listed candidate predictors using Fisher's exact test. We constructed a generalized estimating equation Poisson regression model for multivariate analysis that included variables with a significant $\alpha = 0.10$ in univariate analysis. Interaction terms were tested, and models were evaluated for potential collinearity. We determined the multivariate model's hazard ratio (RR) and 95% confidence interval (CI). For multivariate models, statistical significance was considered at $\alpha = 0.05$.

RESULTS

From January 2020 to April 2022, 531 patients were transferred out of the CICU during the study period. Of the total number, 126 transfer-outs were excluded because of death during the initial CICU stay, direct discharge home, or the need for planned readmission after a procedure during the same stay. Patients discharged home directly were either high-risk patients who were inoperable or relatively simple and stable children, such as those after ductal ligation. Nineteen patients were removed from the hospital and required separate and irregular re-transfer to the CICU. The control group included 357 discharged patients who did not need to be re-entered into the CICU; 29 patients were unplanned to return to the CICU as the study group.

Table 1 shows the types of diseases returned to the CICU and return time after being transferred out of the CICU. (Table 1) In this study, 531 children with congenital heart disease were moved out of CICU after the operation, and 29 cases returned to the CICU unplanned, with a return rate of 5.50%. There were 4 cases of VSD, 1 case of ASD, 3 cases of PS, 4 cases of TOF, 9 cases of TAPVC, 2 cases of TGA, 4 cases of PA, and 2 cases of COA/IAA. The time of returning to CICU was 8 cases who returned within 24 hours after being transferred out of CICU, 6 cases returned within 25-48 hours, 4 cases returned within 2-3 days, 7 cases returned within 3-7 days, and 7 cases returned within 7 days. Four cases returned after 7 days.

The categorization of reasons for return to the CICU included respiratory system causes (41.4%), circulatory system (44.8%), neurological causes (3.5%), and other causes (10.5%). Among them, respiratory system and circulatory system were dominant.

Table 3 compares the differences between the two groups of patients. (Table 3) Mortality was used in this study as an indicator of post-return outcomes. Mortality significantly was higher in these patients than those who did not require a return. The overall mortality rate for patients with unplanned returns was 13.8%. The mortality rate for patients who did not require CICU re-entry was 0.56% ($P < 0.01$). In multivariate tests, chromosomal abnormalities ($P < 0.01$), duration of ventilator use ($P < 0.01$), and time of cardiopulmonary bypass ($P < 0.01$) were independently associated with the unplanned return. There was an association between body weight and risk of readmission ($P < 0.05$). In the unplanned return group, 6.8% (2/29) were transferred out of the CICU after 8 p.m., and 10% (3/29) were transferred out over the weekend. This

study assessed that evening hours were more likely to have unplanned return to the CICU ($P < 0.05$).

To further analyze risk factors, we considered the influence of human factors. We reviewed the staffing of physicians and level of parental care for all patients in the returning and non-returning groups. Different surgeons performed all cardiac surgeries during this period, and unplanned returns were not related to the surgeon. The CICU physician was responsible for all the children, and after statistical analysis, the unplanned return was not associated with the experience level of the CICU physician. Interestingly, we found that fewer family members caring for the child were more likely to have an unplanned return ($P < 0.05$). (Table 4)

Table 1. Disease diagnosis and duration classification of children returning to the CICU

Classification	Number of cases (n)
Disease classification	
Ventricular septal defect	4 (13.8%)
Atrial septal defect	1 (3.4%)
Pulmonary valve stenosis	3 (10.3%)
Complete pulmonary venous drainage	9 (31.0%)
Tetrology of Fallot	4 (13.8%)
Transposition of the great arteries	2 (6.9%)
Pulmonary valve atresia	4 (13.4%)
Aortic disease	2 (6.9%)
Duration classification	
Return within 24 hours	8 (27.6%)
25-48 hours return	6 (20.7%)
2-3 days return	4 (13.8%)
3-7 days return	7 (24.1%)
Return after 7 days	4 (13.8%)

DISCUSSION

Transfer of children after congenital heart disease out of the CICU appears to be an essential issue for all ages and healthcare programs. Abroad, there is growing concern for

Table 2. Classification of reasons for returning to the CICU

Classification	Diagnosis	Number of cases (n)
Respiratory system (41.4%)	Pulmonary fibrosis	2 (6.9%)
	Severe pneumonia	5 (17.2%)
	Pneumothorax	2 (6.9%)
	Stubborn pleural effusion	3 (10.3%)
Circulatory system (44.8%)	Residual cardiac disease	4 (13.8%)
	Arrhythmia	4 (13.8%)
	Heart failure	3 (10.3%)
	Symptomatic pericardial effusion	2 (6.9%)
Nervous system (3.5%)	Seizures	1 (3.4%)
Others (10.3%)	Septicemia	1 (3.4%)
	Severe allergies	1 (3.4%)
	Aspiration	1 (3.4%)

Table 3. Differences based on return status across the cohort

Classification	Unplanned return ($N = 29$)	No reentry ($N = 357$)	Single factor	Multivariate	
			P	OR (95% CI)	P
Gender	16 (55.2%)	201 (56.3%)	0.9		
Age (months)	4.5±0.8	5.4±1.0	0.14		
Weight	4.2±0.9	6.8±1.2	0.04		
Chromosomal abnormalities	17 (58.6%)	109 (30.5%)	0.005	4.7 (3.5-13.9)	0.002
Operation time (min)	221 ±13	196±24	0.09		
Cardiopulmonary bypass duration (min)	111 ± 20	64±18	<0.001	2.015 (2.007-2.02)	<0.001
The duration of use of the ventilator (d)	7±1.7	2±2.3	0.002	3.7 (2-9.6)	0.001
CICU stay duration (d)	12 ± 2.5	8 ± 3.4	0.03		
Night transfer	2 (6.9%)	14 (3.9%)	0.44		
Weekend transfer	3 (10.3%)	10 (2.8%)	0.03		
Mortality rate	4 (13.8%)	2 (0.56%)	<0.001		

these particular patients as insurance companies propose refusing to reimburse additional costs for readmissions [Kogon 2012]. Magruder et al. showed a 128% increase in hospital costs associated with ICU readmission [Magruder 2015]. Patients who were readmitted had a 2.5-fold longer hospital stay compared with those who were not readmitted [Oster 2013]. Numerous studies have examined readmissions in children with asthma and other chronic diseases [Chen 2003; Kelly 2000; Beck 2006]. Clinically, the number of patients re-entered into the CICU after cardiac surgery varies from region to region, with some medical centers as high as 19% [Zhong 2021; Boreland 2015; Liu 2019]. However, although studies have shown that re-entry to the CICU is associated with mortality in children, there is little data on the steps taken to prevent re-entry in these children [Saharan 2014; Brunetti 2015]. In addition, re-entry to the CICU usually implies a significant change in condition related to multiple factors, such as patient age, weight, cardiac function, renal function, therapeutic drugs, and surgical trauma [Arora 2017]. In addition to the inherent characteristics of the patient, some human factors, such as nurse staffing, physician experience level, and the care of the patient's family, may also contribute to unplanned return.

In a meta-analysis of return to CICU, respiratory failure accounted for 13.6% to 48.6%, and hemodynamic instability accounted for 21.6% to 51.9% of the primary reasons for return to CICU [Lv 2022]. In our study, the primary reason children returned to the CICU was respiratory problems. Most children with congenital heart disease had increased pulmonary blood flow and were prone to recurrent pneumonia. Postoperative ventilator-assisted breathing and tracheal intubation could lead to airway secretions. The wound pain after thoracotomy, coupled with the young child's inability to cough effectively, makes it difficult for secretions to be discharged, making it ineffective to clear the airway, quickly causing difficulty breathing, labored breathing, and dark complexion. In addition, the children cannot express their needs clearly and correctly, and any discomfort will cause crying, causing rapid heart rate, abdominal distension, etc. Parents cannot handle this situation, thereby increasing the probability of returning to the CICU. Pulmonary infection is a common cause of return, and pulmonary infection is more familiar with multidrug-resistant strains, and it is easy to combine with fungal infection. For such children, the treatment and prevention of pulmonary infection should be strengthened. In particular, children with pulmonary infections require timely intervention.

Hemodynamic instability is one of the important reasons. This includes cardiac arrest due to ventricular fibrillation or cardiac arrest, other hypotensive patients unresponsive to therapy due to persistent arrhythmias or heart failure, which is not unexpected, and residual diseases, such as the atrioventricular valve reflux or postoperative ventricular dysfunction, are poorly tolerated. They may not be suitable for conservative medical management. Regarding return to the CICU diagnosis, Turley and colleagues analyzed 286 patients treated by the same pediatric cardiothoracic surgeon and reported readmissions within two weeks of discharge. Arrhythmias, postpericardiotomy syndrome, and infectious complications were the most common readmission diagnoses [Turley 1994]. In this study, among the children who returned due to cardiac problems, the children with arrhythmia and residual cardiac disease accounted for the majority. Such children have acute and severe diseases, and timely detection and treatment are the keys.

Table 4. Human factors differences in the cohort

Classification	Unplanned return (*N* = 29)	No reentry (*N* = 357)	Single factor *P*
CICU doctor			
Most experienced	12	121	0.41
Intermediate	7	72	0.61
Minimal experience	10	164	0.23
Surgeon			
A	9	142	0.35
B	9	118	0.82
C	11	97	0.21
Family care situation			
3-person	6	121	0.14
2-person	7	110	0.45
1 person	16	126	0.03

Across the cohort, the presence of chromosomal abnormalities, longer ventilator use duration, and more prolonged cardiopulmonary bypass were associated with higher rates of return. Therefore, an unplanned return to the CICU may reflect the need for ongoing disease process management. Chromosomal abnormalities reflect the complexity of these patients' conditions. In addition to cardiac problems, chromosomal abnormalities also may cause developmental delays and slow postoperative recovery. Dennis noted that underlying comorbidities with Down syndrome might increase postoperative complications and length of stay [Delany 2021]. Longer ventilator use may reflect worse postoperative lung conditions in these patients, requiring more extended hospital stays. Longer cardiopulmonary bypass time indicates more complicated cardiac malformations in children, which can be seen from the structure of patients returning to the CICU. More complex congenital hearts are not planned to return to the CICU. In terms of the influence of human factors, the experience level of the attending physician and surgeon in the CICU did not affect the unplanned return. We looked at the time of transfer out of the CICU and the time of re-entry into the CICU. We found that more patients had unplanned returns to the CICU at night (6.9% vs. 3.9%), and more patients were readmitted on weekends (10.3% vs. 7.8%). Bastero-Minon et al. published the only other study looking at the time to transfer and readmission. They also found that most readmissions initially were transferred out of the CICU during the day, and more patients were transferred out on weekends [Bastero-Miñón 2012].

Predictors of return to the CICU include weight, complex surgical procedures, heart failure, arrhythmias, respiratory complications, prolonged ventilator time, and weekend outs.

These factors underscore the increased mortality associated with the return. Therefore, it is imperative to establish a perfect standard of admission and exit of children in the CICU. It's important to fully and comprehensively evaluate the children who are planned to be transferred out of the CICU, strictly follow the standards, gradually reduce the monitoring equipment and treatment drugs, and ensure that the children's indicators meet the criteria before they can be transferred out of the CICU to the general ward. For children with many complications, young age, and low body weight, the stay time in CICU can be appropriately extended. Because children in extreme conditions can be identified more quickly in the CICU and receive salvage treatment sooner, observation of high-risk patients, such as those with complex cardiac anatomy or those with genetic abnormalities, before transfer to the general ward is more frequent in the CICU, staying for a while will reduce mortality. However, it is unclear how long the observation should be.

We noted that the level of care of family members was associated with unplanned return to the CICU. The transfer of the child from the CICU to the general ward is regarded as a sign of improvement. Still, the general ward is different from the CICU environment, and the child's "one-to-one" care and care of the CICU is lost, lack of safety and security, and the information communication and exchange between parents and nursing staff is insufficient. These are important factors that cause communication panic among parent. In addition, the number of caregivers for the child also is an essential factor. The fewer staff caring for family members, the more incapable of being able to face the heavier postoperative care work, and the more likely there will be an unplanned return to the CICU. It is worth noting that one child returned to CICU due to milk aspiration, suggesting that more attention should be paid to the assessment and guidance of parents' feeding ability, especially for young children with insufficient care or feeding ability. In addition to practical communication guidance, it is necessary to evaluate and judge whether the family members genuinely grasp the key points correctly to avoid adverse events in children due to improper feeding.

We also noticed a relatively high rate of patients returning to intensive care over the weekend. This may be due to changes in staffing, such as fewer doctors, nursing experience levels, or nurse staffing, such as nurse-to-patient ratio. We did not investigate these factors, but this warrants further study. Staffing changes may lead to more rapid recognition of children needing additional care and ultimately improve outcomes. Therefore, transfer out at midnight and on weekends should be minimized to reduce the occurrence of adverse events in children.

Unfortunately, there are some barriers to reducing reentry to the CICU. Many factors may be immutable. Patient characteristics, such as gender, age, cardiac abnormalities, insurance status, family status, and extended family or friends, may not be changed. On the other hand, the focus could be on hospital procedures, such as out-of-CICU guidance, nursing guidance, patient education, and medication adjustment, which are manipulative and may affect return rates. It is worth mentioning that the hospital has established a return visit system for patients transferred out of the CICU. CICU doctors regularly visit the patients who have been transferred out, check the recovery of the children, and follow up and make suggestions for follow-up treatment measures so that the patients who have been transferred out will be followed up. Patients in the CICU can still receive continuous therapeutic interventions.

CONCLUSION

Although outcomes for pediatric cardiac surgery patients have improved over the past few decades, interventions still are needed to improve outcomes for these complex congenital heart patients. In this study, irregular return to the CICU during the same hospital stay was uncommon, but the mortality rate was high. Chromosomal abnormalities, longer duration of ventilator use, and longer duration of cardiopulmonary bypass were the most critical risk factors for readmission. It is hoped that by changing the process of transferring these high-risk patients out of the CICU and early postoperative care, the number and impact of re-transfer to the CICU after congenital heart disease can be minimized.

Limitations: Our study has some limitations. The sample size included in this study was relatively small, and it may not be reasonable to apply our results to other study populations. This study identifies potential risk factors for unplanned return to the CICU. In addition to being retrospective, our study has several limitations. The study variables we selected focused primarily on patients. There also may be family-related variables that significantly influence unplanned returns. These factors may include parents' age, marital status, education level, and socioeconomic status. Multiple factors should be considered in the future, and studies with larger samples and longer follow ups should be completed to prove the conclusion.

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