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Frequency, characteristics, and outcomes of pediatric patients readmitted to the cardiac critical care unit

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Abstract *Purpose:* To describe the characteristics and outcomes of patients readmitted to a pediatric cardiac critical care unit (CCCU) from the ward within 72 h of their first discharge. *Methods:* This was a retrospective analysis of data collected on patients admitted to the CCCU between January 1, 2000 and January 31, 2007. The setting was an 18-bed pediatric CCCU in a tertiary care university hospital. No interventions were performed. *Results:* Among the 4,625 patients admitted to the CCCU, 112 (2.4 %) were readmitted from the ward within 72 h of their discharge. The most common cause for readmission was respiratory symptoms (42.9 %). Significant changes in the chest X-ray prior to discharge were identified retrospectively in 12.5 % of these patients. Cardiovascular symptoms

were similarly frequent (40.2 %) among these patients. Nine (8 %) of the patients died during the readmission period, a rate which is considerably higher than the overall CCCU mortality rate (3.8 %) in the same period of time. *Conclusions:* Respiratory reasons are the most common cause for early CCCU readmission among pediatric cardiac patients. The readmitted patients have higher rates of death compared to the overall pediatric cardiac critical care population. The development of objective predischarge scores might help planning appropriately for discharge to the ward and avoid readmission to the CCU.

Keywords Early readmission · Pediatric cardiac critical care unit · Respiratory causes · Mortality

Introduction

Readmission to the critical care unit (CCU) during the same hospitalization may be associated with significant morbidity and increase in mortality. According to current literature, non-planned readmission rates to the CCU range between 0.9 and 19 % with a tendency to increase over the years; therefore, mechanisms are required to cope with these problems [1–8].

In most adult series, age and severity of illness during the first admission to the CCU are the most common risk factors for subsequent CCU readmission [5, 9, 10]. This population of

patients has longer hospital stays and higher risk for hospital death compared to patients not readmitted to the CCU, ranging from 1.5 to 10 times higher death rates [5, 6, 9, 11].

The reason for readmission varies among the adult studies and is related to the specific CCU. However, respiratory problems, cardiovascular conditions, gastrointestinal hemorrhage, and neurological complications appear to be common [4].

The aim of our study was to describe frequency, characteristics, and outcome for pediatric cardiac patients requiring readmission to the cardiac critical care unit (CCCU) from the pediatric cardiac ward.

Methods

Study design

Retrospective chart review of pediatric patients readmitted to the CCCU and their subsequent outcome, at a tertiary pediatric medical center.

Setting and study population

The data had been prospectively collected within the CCU database between January 1, 2000 and January 31, 2007.

Patients readmitted to the CCCU within 72 h of discharge to the cardiac ward were included. Patients readmitted after scheduled surgery, cardiac catheterization, or imaging studies (requiring subsequent CCCU admission for continuation of temporary mechanical ventilatory support) were excluded.

Data collected include age at admission, gender, cardiac diagnosis, type of surgery leading to first CCCU admission (if applicable), significant comorbidities, dates and times of first admission and discharge from CCCU, dates and times of readmission to CCCU, reason for readmission, and outcome after readmission. In addition, results of laboratory tests, imaging tests, and medical or mechanical support were collected and analyzed. This included inotropic support, ventilation, extracorporeal membrane oxygenation (ECMO), and dialysis.

On chest X-ray small areas of atelectasis, trivial pleural effusions, and changes in association with the underlying cardiac defect were considered as minor findings. Bilateral atelectasis, bilateral pleural effusions, and/or progressive pulmonary edema were categorized as significant findings.

On echocardiography worsening cardiac function and/or new or increasing pericardial effusion, new or increased patch leak, new or worsening valvular regurgitation, new or progressing shunt narrowing, stenosis, or occlusion, or thrombus formation were classified as major findings.

Given the wide spectrum of patients with cardiac conditions admitted to the CCCU, ranging from those with congenital heart disease before and after surgery, to

acquired cardiac conditions, we created three groups. These were based on the underlying cardiac physiology: single ventricle physiology (group 1), biventricular physiology (group 2), and non-structural heart disease (group 3).

The decision to discharge patients from the CCCU was made on an individual patient-by-patient basis by the attending CCCU physician. Discharged patients were transferred to a step-down unit (within the general cardiac ward) or the general cardiac ward under the care of a staff cardiologist.

Working hours were arbitrarily divided as daytime (from 0800 to 1659 hours) and nighttime (from 1700 to 0759 hours) and weekends (from Friday 1700 to Monday 0759 hours), based on usual presence of a cardiology staff physician on the cardiac ward.

The study was approved by the Research Ethics Board of The Hospital for Sick Children, Toronto, Canada.

Statistical analysis

Descriptive statistics (average, median, range and percentage where appropriate) were used to analyze the study cohort with statistical analysis conducted using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Of 4,625 patients admitted to the CCCU between January 1, 2000 and January 31, 2007, a total of 833 (18.0 %) had single ventricle physiology, 3,427 (74.1 %) had biventricular physiology, and 365 (7.9 %) had non-structural heart disease (Table 1).

Frequency and reasons for readmission

A total of 112/4,625 patients (2.4 %) were readmitted from the ward to the CCCU within 72 h after their discharge.

The most common reason for readmission was respiratory symptoms (48/112, 42.9 %), followed by

Table 1 Main characteristic of the entire patient population and the readmitted cohort

	All patients	Readmitted patients
<i>n</i>	4,625	112
Biventricular physiology	3,427 (74.1 %)	67 (59.8 %)
Single ventricle physiology	83 (18.0 %)	34 (30.4 %)
Non-structural heart disease	365 (7.9 %)	11 (9.8 %)
Gender (male)	2,735 (59 %)	59 (53 %)
Median age (range)	2.8 years (1 day–18.3 years)	0.3 years (1 day–16 years)
Median length of stay in CCCU (first admission)	2.4 days (3 h–221 days)	3.9 days (19 h–112 days)

cardiovascular symptoms (CVS), e.g., perfusion, pulses, diaphoresis, or blood pressure related (45/112, 40.2 %). Infection-associated problems (suspected or proven) accounted for 8.9 % (10/112) of the readmissions, gastrointestinal complications for 3.6 % (4/112) of the cases, neurological complications for 3.6 % (4/112), and 0.9 % (1/112) were other reasons (i.e., renal dysfunction).

The reasons for readmission based on the cardiac physiology are summarized in Table 2.

Ninety-one patients (81.3 %) had a chest X-ray in the 24-h period prior to discharge to the ward, whereas in 21 patients (18.7 %) the last X-ray before discharge was done 25 h to 4 days previously. A total of 73 patients (65.2 %) had minor radiological changes on the last chest X-ray prior to discharge to the ward. Only seven patients (6.3 %) had significant changes on X-ray before going to the ward. Among the patients readmitted for respiratory reasons 60.7 % (68/112) showed minor changes in their last chest X-ray prior to their transfer and 12.5 % (14/112) had significant changes in their X-rays. Of those patients readmitted to the CCCU for respiratory reasons, 39.3 % (44/112) showed worsening on the readmission chest X-ray.

Forty-seven (42 %) of the readmitted patients had a significant change on the echocardiogram at time of clinical deterioration (performed either on the ward or at readmission to the CCCU): 29/47 (61.7 %) showed worsening cardiac function, 3/47 (6.4 %) new or increasing pericardial effusion, 4/47 (8.5 %) a new or increased patch leak, 4/47 (8.5 %) a new or worsening valvular regurgitation, 3/47 (6.3 %) a new or progressing shunt narrowing, stenosis, or occlusion, and 2/47 (4.3 %) a thrombus formation. Additionally there was anatomic narrowing (branch pulmonary artery, right ventricular outflow tract) in 2/47 (4.2 %) of the patients.

The median time for patient discharge to the ward was 1439 hours (range 0015–2200 hours) and median time for the patients to be readmitted to the CCCU was 1450 hours (range 0025–2335 hours).

Looking at the weekly distribution, the highest number of patients readmitted was originally discharged on a Friday.

Ninety-one patients (81.3 %) readmitted were discharged from the CCCU to the ward during daytime hours. Fifty-eight patients (51.8 %) were readmitted to the CCCU from the ward during nighttime hours and 11 (9.8 %) during weekends (daytime).

Table 2 Predominant symptoms for readmission to the cardiac critical care unit based on cardiac physiology

	Group 1 Single ventricle	Group 2 Biventricular	Group 3 Non-structural
<i>n</i>	34	67	11
Respiratory	13 (38 %)	30 (45 %)	5 (45 %)
Cardiovascular	11 (32 %)	29 (43 %)	5 (45 %)
Other	10 (29 %)	8 (12 %)	1 (9 %)

Patient characteristics

The median age at first admission to the CCCU was 0.3 years (mean 1.9 years, range 1 day to 16 years). Forty-six (41.1 %) of the patients were between 1 month and 1 year of age, 33 (29.5 %) were less than 1 month of age, 22 (19.6 %) were between 1 and 8 years of age, and 11 (9.8 %) were less than 8 years of age.

Fifty-nine (53 %) of the patients were male. Thirty-four (30.4 %) of the patients had single ventricle physiology (group 1), 67 (59.8 %) had biventricular physiology (group 2), and 11 (9.8 %) had non-structural heart diseases (group 3).

The median length of stay (LOS) of the patients in the CCCU was 3.9 days (range 19 h to 112 days) before to the first discharge to the ward, whereas the median LOS for all patients was only 2.4 days (range 3 h–221 days).

Identified comorbidities at the time of discharge to the ward were present in 11 patients. Eight had been diagnosed with a genetic disorder: Trisomy 21 ($n = 4$), 22q11 deletion syndrome ($n = 2$), Noonan's syndrome ($n = 1$), Cat's eye syndrome ($n = 1$), and one patient had multiple dysmorphic features. One patient had tracheomalacia and another patient had unilateral diaphragm palsy.

During their first admission to the CCCU, 87/112 patients (77 %) had required invasive mechanical ventilation with a median support time on the ventilator of 2.5 days (range 1–97 days), 28/112 patients (25 %) were supported by noninvasive mechanical ventilation, with a median of 2 days (range 1–11 days), 29/112 patients (25.9 %) required inotropic support with a median of 2.5 days (range 1–48 days), and 5/112 patients (4.5 %) were cannulated on to ECMO. During the first admission to the CCCU, three patients (2.7 %) required continuous renal replacement.

The time between blood work done and discharge from the CCCU to the ward is shown in Table 3; less than half of the patients had an arterial blood gas analysis done within 8 h before transfer to the ward.

In total, 65/112 (58 %) of the readmitted patients required intubation and invasive mechanical ventilation for a median of 5 days (range 1–206 days) and 34/112 (30.4 %) of the patients had to be supported on noninvasive ventilation during their readmission period for a median of 3 days (range 1–33 days). Inotropic support was started in 52/112 (46.4 %) of the readmitted patients and the duration was a median of 4 days (range 1–89 days). Of note, 10/112 (8.9 %) patients were cannulated on veno-arterial ECMO: nine patients needed emergency ECMO during readmission, one patient was cannulated because of acute arrhythmia. Three patients had cardiomyopathy, three patients had single ventricle physiology, and four patients had biventricular physiology. Mechanical support was provided for a median of 4.5 days (range 2–19 days).

Table 3 Time categories of blood work prior to discharge from the cardiac critical care unit

Hours	Arterial blood gas analysis/lactate	Glucose	Complete blood count	Electrolytes/liver and kidney function test
<4	22 (19.6 %)	33 (30.0 %)	16 (14.3 %)	37 (33.0 %)
4–8	30 (26.7 %)	36 (31.4 %)	24 (21.4 %)	35 (31.3 %)
8–12	19 (16.9 %)	18 (16.8 %)	30 (26.8 %)	19 (16.8 %)
>12	21 (20.1 %)	21 (18.8 %)	42 (37.5 %)	21 (18.8 %)
<12	Venous blood gas analysis 20 (17.9 %)			

Two patients (1.8 %) required veno-venous hemofiltration, one of them for 24 h, the other for 24 days. Three patients (2.7 %) needed peritoneal dialysis, one for 4 days, another for 11 days, the third for 24 days. The median lactate level at the time of readmission was 1.8 mmol/L (range 0.5–23).

Morbidity and outcome

Overall nine (8 %) patients died in the CCCU during the period of readmission, 102 (91.1 %) were discharged to the ward; one patient (0.9 %) was directly discharged home from the CCCU. Out of the nine deaths, five of the patients belonged to group 2, representing 7.3 % of the patients with two ventricle physiology. There were two deaths both in group 1 (5.4 %) and 3 (28.7 %). The most frequent reason for readmission to the CCCU among those patients that died was CVS (77.8 %).

Discussion

To our knowledge, this is the first study regarding readmission from a pediatric cardiac ward to a pediatric CCCU. As the relationship between patient illness and readmission to the critical care environment was documented in prior publications [3, 9], the main focus of this study was to identify specific causes for early readmission in the pediatric cardiac population.

In our study we found a 2.4 % readmission rate, which is lower than reports from adult studies which vary from 3.1 to 13 % in 72 h [12, 13] and 8 % in a mixed population of pediatric patients [14]. However, the mortality rate was 8 %, i.e., higher than the overall mortality rate in the CCCU during the same period of time. The morbidity was also significant with almost 59 % of the patients requiring intubation and mechanical ventilation, 30.4 % of the patients requiring noninvasive mechanical ventilation, close to half needing inotropic support for a mean of more than 4 days, and ten patients (0.9 %) requiring ECMO. Seven of the ten patients that required ECMO died during their readmission to the CCCU, representing 77.8 % of deaths during readmission.

The most common grounds for readmission were respiratory causes followed by CVS causes (42.9 and 40.2 %, respectively). Among those patients readmitted for respiratory causes, 12.5 % had shown significant chest X-ray changes before discharge to the ward. Whether a timely response to the X-ray changes prior to transfer could have been prevented readmissions is uncertain. However, “respiratory symptoms” may be in some cases a respiratory expression of cardiovascular decompensation.

Recently, a score for adult patients based on patient characteristics at the time of discharge from the CCU has been evaluated and validated [15]. These criteria do not work well in the pediatric CCCU setting, but an adjusted score with more objective criteria for pediatric cardiac patients might be beneficial. This would flag patients at risk of readmission to the CCU and these patients may get closer follow-up from the receiving team. We chose the period of time between January 1, 2000 and January 31, 2007 because in our center the critical care response team (CCRT) was not yet fully active, and we believe this might influence the readmission rate and eventually the morbidity and mortality of those patients.

There are limited data on the characteristics and outcome of CCU readmissions in the pediatric population. Odetola et al. [14] studied the mortality, LOS, and factors associated with readmission in a combined 16-bed medical-surgical CCU and 15-bed pediatric CCCU at a tertiary medical center. They found that readmitted patients were younger and had a greater severity of illness in the first admission, than those patients with single admissions.

Patient review prior to CCCU discharge, data exchange between the pediatric CCCU and the ward, and patient care once on the ward could benefit from these results. Implementation of CCRT may also lead to a reduction in readmission to the CCU [16].

Unfortunately there are not clearly defined discharge criteria from the critical care setting apart from invasive ventilatory support and other obvious treatment requiring CCU management. The task force of the American College of Critical Care Medicine on the guidelines for CCU discharge states [17]: “When a patient’s physiologic status has stabilized and the need for ICU monitoring and care is no longer necessary” and “When a patient’s

physiologic status has deteriorated and active interventions are no longer planned, discharge to a lower level of care is appropriate.” Frequently there is a lack of certainty on when a patient is “ready” for discharge or when it is “safe” for a patient to be transferred [15]. Different institutions and countries may have different guidelines and thresholds for discharging patients to the general floor and also monetary issues may play a role in patient allocation. These and other factors may make it impossible to compare data from different institutions; however, our data show trends as to where reasons for readmissions are, and these may allow the critical care physician and the accepting physician on the ward to look into these areas specifically to avoid a major part of readmissions. Clearly, avoiding readmissions should be a goal which may be achieved by thorough review of all available clinical data prior to discharge, but also through scheduled follow-up visits by a CCRT, basically an extended arm of the CCU.

Several reports share concerns about CCU readmissions, and readmissions after discharge from CCU within 48 h have been discussed as an index of CCU quality of care [17–21]. However, a zero readmission rate would also be unfavorable as this reflects that patients are kept

too long in the CCU setting. It remains uncertain if the decision to discharge patients from the CCU or the value of care provided on the general ward, or the interface of both, leads to readmission to the CCU.

There are certainly limitations to this study, most importantly it is a retrospective chart review from a single institution and interpretations of notes are restricted to the available data.

Conclusion

Respiratory symptoms are the most common cause for early readmission from the ward to the CCCU in pediatric cardiac patients. These early readmitted patients have higher rates of death compared to the overall pediatric cardiac critical care population. It may be helpful to develop objective predischARGE scores for pediatric cardiac patients to be used at the time of discharge to avoid early transfer and to track these patients by CCRT whilst in the step-down unit/ward with specific tools using modified early warning scores. This dual layer may circumvent most readmissions to the CCCU.

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