Readmissions to the ICU Among Children With Tracheostomies Placed After Cardiac Arrest

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ABSTRACT

OBJECTIVE: Describe clinical outcomes and risk factors for ICU readmissions in a cohort of children who underwent tracheostomy placement after cardiac arrest.

METHODS: A retrospective, multicenter cohort analysis of children <18 years old admitted to a Virtual Pediatric Systems, LLC–participating PICU from January 2009 to December 2016 and underwent tracheostomy after cardiac arrest.

RESULTS: Among 394 index admissions, the median age was 16.8 months (interquartile range [IQR] 5.3–89.3), and Pediatric Risk of Mortality 3 scores (median 9 [IQR 4.75–16]) indicated severe illness. Baseline neurologic function was generally age appropriate (Pediatric Cerebral Performance Category score: median 2 [IQR 1–3]). The most common primary diagnosis categories were respiratory (31.0%), cardiac (21.6%), and injury and/or poisoning (18.3%). Post-tracheostomy mortality during the index admission was 9.3%. Among the 358 patients who survived to discharge, 334 had >180 days of available follow-up data. Two hundred and five (61.4%) patients were readmitted at least once for a total of 643 readmissions (range 0–30; median 1 [IQR 0–2]). We observed 0.54 readmissions per patient-year. The median time to first readmission was 50.3 days (IQR 12.8–173.7). Significant risk factors for readmission included a pre-existing diagnosis of chronic lung disease, congenital heart disease and/or heart failure, prematurity, and new seizures during the index admission. The most common indication for readmission was respiratory illness (46.2%). Mortality (3.3%) and procedural burden during readmission were consistent with general PICU care.

CONCLUSIONS: ICU readmission among children who undergo postarrest tracheostomy is common, usually due to respiratory causes, and involves outcomes and resource use similar to other ICU admissions. Risk factors for readmission are largely nonmodifiable.

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Thousands of children suffer cardiac arrests each year in the United States, and neurologic morbidity is frequent among survivors.[1] Severe neurologic disability occurs in 13% to 32% of survivors of in-hospital cardiac arrest and >50% of survivors of out-of-hospital cardiac arrest.[2–7] Children with severe neurologic injury may not be able to separate from mechanical ventilation, necessitating either withdrawal of life-sustaining technological support or the placement of a tracheostomy for chronic mechanical ventilation. The decision to perform a tracheostomy is influenced by each child's expected long-term prognosis and need for subsequent medical care as well as parental preference.[8–10] Substantial medical resource use and prolonged hospitalization are common among children requiring chronic mechanical ventilation, especially in children with neurologic injury.[11,12] Outcomes of children undergoing tracheostomy specifically after cardiac arrest, however, have not been thoroughly described.

The paucity of available long-term outcome data for pediatric patients who have suffered cardiac arrest and undergone tracheostomy limits the ability of medical providers to counsel families considering the treatment options for children who cannot be liberated from the ventilator after cardiac arrest. We aim to provide the most comprehensive outcomes and readmissions data after postarrest tracheostomy placement to date. We hypothesized that ICU readmission in this patient cohort would be associated with prearrest comorbid conditions and characteristics of the index admission.

METHODS

Data Source

After review by the institutional review board, the Virtual Pediatric Systems, LLC (VPS) database was queried for children <18 years of age admitted to a participating PICU or pediatric cardiac ICU from January 2009 to December 2016. VPS is a prospective, observational cohort database of consecutive PICU admissions at >100 participant centers and has been previously described.[13] Most contributing hospitals are in the United States; there are 6 international sites. The collection of a mandatory data set with standardized data definitions is performed by trained data coordinators at participating institutions, and participating ICUs can additionally report nonmandatory data. VPS staff assess for interrelater reliability and perform frequent data quality-control checks, including before release to investigators, ensuring the validity of the data.[14] VPS data collection was transitioned to being Web-based in 2009, so only data after this transition are included to improve consistency in how data are reported.

Mandatory variables include patients' demographics (age, sex, weight, etc) and clinical characteristics (including primary diagnosis, mortality, outcome, Pediatric Risk of Mortality [PRISM 3] score, and select ICU therapeutic procedures [eg, central venous or arterial catheterization]). Each quarter, each site decides a priori whether it will collect each nonmandatory variable. Tracheostomy is a nonmandatory variable, so data were drawn only from sites that indicated they collected tracheostomy data throughout the duration of the study period. In total, patients were drawn from 51 different PICUs as part of this study. VPS data were provided by VPS. No endorsement or editorial restriction of the interpretation of these data or opinions of the authors have been implied or stated.

Study Procedure

An "index admission" was defined as an admission that included both a cardiac arrest and the placement of a novel tracheostomy. The occurrence of a cardiac arrest was either part of the presentation for the index admission or occurred during the index admission. It was defined as either a VPS diagnosis of "cardiac arrest" or an affirmation of cardiac arrest as part of a standardized scoring system (eg, PRISM 3). Using VPS-provided clinical-event timing data, only children who had a tracheostomy performed after the cardiac arrest occurred were included. Data extracted from index admissions and each subject's subsequent VPS admissions ("readmissions") during the study period included demographics, admission diagnoses, procedures, PRISM 3 scores, and Pediatric Cerebral Performance Category (PCPC) scores.[15] PCPC scores at admission reflect preillness and/or preinjury performance, and higher scores reflect more severe dysfunction with a range of 1 to 6. PRISM 3 scores use physiologic data from the 12 hours before and 12 hours after PICU admission. Higher scores reflect more severe physiologic derangements with a possible range of 0 to 74. Diagnoses were identified as primary or nonprimary and grouped into categories that were predetermined by VPS.[16] Per VPS data definitions, "unscheduled" admissions were those that occurred with <12 hours of advance notice.

The VPS data set captures ICU length of stay (LOS) as the actual time in the ICU at all institutions and as the time to readiness for ICU discharge as determined by the care team at some institutions. When these were both available and differed, the shorter of the times was used to define LOS in this study. Time to readmission was defined as the amount of time elapsed between the ICU discharge date for the index admission and the date of the first ICU readmission.

Statistical Methods

Counts (percentages) are reported for categorical variables, and medians (interquartile range; IQR) are reported for continuous variables because the continuous variables were not normally distributed. Denominators used in prevalence calculations for nonmandatory variables were adjusted to reflect the number of patients treated at institutions collecting the variable to account for the fact that not all institutions collected all variables.

Children who survived the index admission and had at least 180 days of follow-up were included in the follow-up group. Subjects in the follow-up group were categorized as having either 0 readmissions or at least 1 readmission. Follow-up time was considered to be the time from discharge from the index admission to the end of the study period (December 2016) unless there was evidence of death before that available in the VPS database.

Comparisons of categorical demographic and clinical characteristics from the index admissions in patients with and without readmissions were performed by using odds ratio (OR) testing. Statistical significance was defined as a 95% confidence interval (CI) not including an OR of 1.0. χ^2 testing was used to identify variables loosely associated ($P < .1$) with readmission, and those variables were included in a logistic regression model with readmission as the outcome variable. Wilcoxon rank sum analysis was used to compare nonparametric distributions of index and readmission hospital characteristics. All analyses were performed by using IBM SPSS Statistics version 22.0 (IBM SPSS Statistics, IBM Corporation).

RESULTS

A total of 394 subjects with index admissions from January 2009 to December 2016 were identified (Table 1). The median age at admission was 16.8 months (IQR 5.3–89.3), fewer than half of the subjects were girls (42.4%), and approximately one-quarter were postoperative patients (28.9%). The median PCPC score at admission was 2 (IQR 1–3), indicating generally age-appropriate neurologic function, and the median PRISM 3 score was 9 (IQR 4.75–16), indicating severe illness. At least 1 pre-existing comorbid condition was identified in 280 (71.1%) patients; 141 had neurologic conditions (eg, static encephalopathy and muscular dystrophy; 35.8%), and 112 had congenital heart disease or heart failure (28.4%).

The most common primary admission diagnosis categories were respiratory (31.0%), cardiac (21.6%), and injury and/or poisoning, including drowning (18.3%). The median ICU LOS was 38.3 days (IQR 22.9–68.0). Half of the tracheostomies (50.0%) were placed within 3 weeks of admission. After tracheostomy placement, 36 patients (9.1%) died during the index admission. Survivors had a median discharge PCPC score of 3 (IQR 2–5), and were most frequently discharged from the ICU to the general care unit (41.1%), a technology-dependent or step-down unit (18.5%), a rehabilitation or long-term care facility (12.2%), or home (11.7%). There were 191 patients (48.5%) discharged with a need for positive pressure ventilation via tracheostomy.

Among the 334 survivors with >180 days of follow-up data, there were 643 readmissions, and 205 patients (61.4%) were readmitted at least once. A total of 1187.5 patient-years of follow-up data were available for the patients included in the follow-up group, with a median of 3.09 patient-years (IQR 1.69–5.29) of follow-up data for each patient. The median age at readmission was 23.1 months (IQR 12.6–49.6). The median number of readmissions per subject was 1 (IQR 0–2) with a range of 0 to 30. There were 0.54 readmissions per patient-year, with a median time to first readmission of 50.3 days (IQR 12.8–173.7) among those who were readmitted (Fig 1). Most patients (53.0%) in the follow-up group had at least 1 readmission within 1 year of discharge. The median ICU LOS for readmissions was 2.3 days (IQR 1.2–6.7).

The primary diagnosis category as assigned by VPS data definitions for all readmissions was most commonly respiratory (46.2%), followed by neurologic (10.3%), "nonspecific symptoms" (eg, apnea, tachypnea, failure to thrive, and nausea and/or vomiting; 10.1%), cardiovascular (9.5%), and infectious (8.2%). Many readmissions also had respiratory (18.9%), cardiovascular (13.4%), and neurologic (12.7%) secondary diagnoses. Most readmissions were unscheduled (78.1%), and approximately one-quarter of patients were postoperative (22.8%). At readmission, median PCPC scores (3 [IQR 3–4]) were similar to scores at the time of discharge from the index admission, and the median PRISM 3 score was 1 (IQR 0–5). Procedures performed during readmission included central venous catheterization (21.2%), arterial catheterization (9.8%), and cardiopulmonary resuscitation (3.4%). Fourteen readmissions (4.2%) included tracheostomy decannulation.

Death occurred during 21 readmissions (3.3%). Survivors of readmissions had a median discharge PCPC score of 3 (IQR 3–4), and were most commonly transferred from the ICU to home (39.3%), the general care unit (30.8%), a technology-dependent or step-down unit (12.6%), or a rehabilitation or chronic care facility (6.4%).

Compared with readmissions, index admissions were more likely to be unscheduled (OR 1.56; 95% CI 1.12–2.18) or postoperative (OR 1.39; 95% CI 1.04–1.84) (Supplemental Table 4). The primary diagnosis category was more likely to be cardiac for index admissions (OR 2.62; 95% CI 1.84–3.75) and respiratory for readmissions (OR 0.52; 95% CI 0.4–0.68). Illness severity as measured by using PRISM 3 scores ($P < .0001$) and mortality (OR 2.98; 95% CI 1.71–5.18) were significantly higher during the index admission. LOS was significantly longer for index admissions ($P < .0001$). Index admissions were more likely to be discharged to a general care unit (OR 1.34; 95% CI 1.03–1.74) or a rehabilitation or chronic care facility (OR 1.80; 95% CI 1.15–2.81) as opposed to home (OR 0.18; 95% CI 0.13–0.26).

Factors that were significantly associated with readmission in univariate analysis (Table 2) included age <12 months at the time of index admission; pre-existing diagnoses of chronic lung disease, congenital heart disease or heart failure, or prematurity; the development of seizures during the index admission; and the need for positive pressure ventilation at ICU discharge. There were no statistically significant associations between ICU readmission and either the patient's primary diagnosis category or ICU therapeutics used during the index hospitalization. In multivariate analysis (Table 3), no factors were significantly associated with readmission.

DISCUSSION

In this multicenter, retrospective database study, we observed that children who underwent tracheostomy after cardiac arrest frequently required subsequent ICU admission. Although our results are not surprising, actual quantification of post-tracheostomy burden may be informative for stakeholders making treatment decisions after cardiac arrest. We had hypothesized that ICU readmission in this patient population would be associated with pre-existing comorbid conditions and a need for ICU therapeutics, but this was not fully borne out.

TABLE 1 Demographic and Clinical Characteristics

Patient Characteristic	Index Admissions (*N* = 394)	Follow-up Group (*N* = 334)
Age, mo, median (IQR)	16.8 (5.3–89.3)	15.6 (5.2–69.9)
Wt, kg, median (IQR)	10.0 (5.7–23.6)	10.0 (5.7–20.0)
Sex, *n* (%)		
Girls	167 (42.4)	139 (41.6)
Boys	227 (57.6)	195 (58.4)
Race, *n* (%)		
African American	75 (19.0)	69 (20.7)
White	200 (50.8)	165 (49.4)
Hispanic	40 (10.2)	33 (9.9)
Unknown or other	79 (20.1)	67 (20.0)
Admission status, *n* (%)		
Scheduled	60 (15.2)	52 (15.6)
Unscheduled	334 (84.8)	282 (84.4)
Trauma status, *n* (%)		
Trauma	92 (23.4)	78 (23.4)
Not trauma	302 (76.6)	256 (76.6)
Operative status, *n* (%)		
Postoperative	114 (28.9)	89 (26.6)
Not postoperative	280 (71.1)	245 (73.4)
Pre-existing comorbid diagnoses, *n* (%)		
Chromosomal abnormalities	44 (11.2)	36 (10.8)
Chronic lung disease	33 (8.4)	29 (8.7)
Congenital heart disease and/or heart failure	112 (28.4)	89 (26.7)
Dialysis dependence	3 (0.8)	1 (0.3)
Neurologic conditions[a]	141 (35.8)	122 (36.5)
Oncologic diagnosis	12 (3.0)	12 (3.6)
Prematurity	43 (10.9)	38 (11.4)
Transplant recipient	6 (1.5)	3 (0.9)
Primary diagnosis category,[b] *n* (%)		
Cardiovascular	85 (21.6)	74 (22.2)
Infectious	29 (7.4)	25 (7.5)
Injury and/or poisoning	72 (18.3)	63 (18.9)
Neurologic	45 (11.5)	36 (10.8)
Respiratory	122 (31.0)	106 (31.7)
Other	41 (10.2)	30 (9.0)

There were no significant differences between the groups.
[a] Neurologic conditions include pre-existing diagnoses of anoxic brain injury, hypoxic-ischemic encephalopathy, epilepsy, muscular dystrophy, and quadriparesis.
[b] Other primary diagnosis categories included gastrointestinal, genetic and/or metabolic, orthopedic, renal, rheumatologic, and "symptoms."

Risk factors associated with readmission were identified in univariate analyses, including seizures during the index hospitalization and a discharge requirement of positive pressure ventilation, but most identified risk factors were pre-existing comorbid diagnoses that are nonmodifiable, and no factor was significant in multivariate analysis. Readmissions were most commonly for respiratory illnesses, similar to patterns described for children with tracheostomies[17] and general PICU patients,[18,19] and usually occurred within the first year after discharge from the index admission. Although PRISM 3 scores at readmission reflected modest disease severity, rates of central venous catheterization[19,20] and arterial catheterization[20] were similar to what has been previously described in the literature for the overall PICU population, as were mortality rates and LOS.[18,20] Overall, these data suggest that readmissions of children previously undergoing postarrest tracheostomy confer similar risks of morbidity and mortality as PICU admissions in other populations and should be perceived comparably.

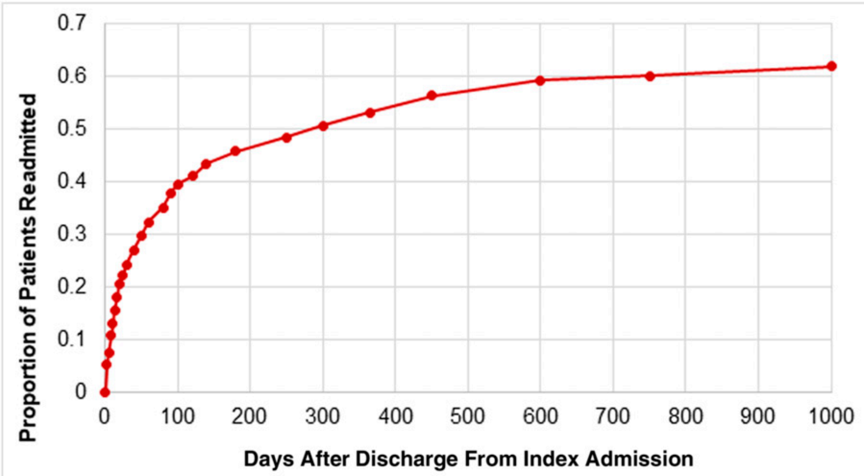

FIGURE 1 Kaplan-Meier curve of the proportion of patients readmitted to the ICU by days after discharge from the index admission. Patients were censored from analysis either when no more follow-up data were available because of the end of the study period or at the time of their death (if available).

Readmission is an increasingly studied outcome measure because of its impact on families and caregivers[21] and its role in the reimbursement policies of the US government.[22] Studies of PICU readmissions have been rare and have frequently focused on readmissions during the index hospital stay or shortly thereafter.[23–25] Our data suggest that children undergoing tracheostomy after cardiac arrest may be at particular risk of readmission compared with other studied populations. Adults who survive out-of-hospital cardiac arrest have a 1-year readmission rate of 37.3%, including readmissions to the general ward.[26] Children with complex chronic conditions have been shown to be at risk for more frequent readmission to the hospital when compared with children without these complex conditions, with ~43.2% of these children having at least 1 readmission over a 5-year follow-up period in a Pediatric Health Information Services study, although this study also includes admissions outside the ICU.[27]

The 1-year readmission rate to the ICU observed in our study (53%) is also higher than previously published rates among PICU patients in general, which were reported as 31% at 1 Australian center[28] and 6% in the Truven Health Analytics administrative claims database.[29] Children undergoing tracheostomy for any cause had a 56% hospital readmission rate in the Truven database.[20] Children with tracheostomies in a large, national sample of children's hospitals were admitted to the hospital an average of 0.76 times per year compared with our observed rate of 0.54 admissions per patient-year to the ICU, but approximately half of such readmissions did not involve ICU services.[17]

Within our follow-up group, 14 patients (4.2%) underwent tracheal decannulation. This may be an underestimation given our inability to capture non-ICU admissions and practice variation regarding whether children require ICU admission after decannulation. Rates of decannulation after tracheostomy vary and are poorly described in the pediatric literature. An 8.8% decannulation rate over a 5-year follow-up period was observed in the Pediatric Health Information Systems database, although 1 single-center study reported a 31.9% decannulation rate.[17,30] Placement of a tracheostomy in our cohort was likely often due to severe encephalopathy, which may be less likely to improve over time than the pulmonary or airway diseases for which children most often require tracheostomy.[10,15,17]

Survivors of pediatric cardiac arrest with initially unfavorable neurologic outcomes rarely have significant improvement in neurologic function after ICU discharge,[31] and our patient population similarly showed no change in cerebral performance scores during their observed hospitalizations. However, only patients who were readmitted to an ICU were evaluated, so our findings may not be generalizable to patients without ICU readmissions. The identification of pediatric patients who suffered cardiac arrest with substantial delayed improvements in neurologic function enabling decannulation would be an important addition to the literature. However, it is possible that the children in our database who underwent decannulation did not undergo tracheostomy solely because of neurologic dysfunction, so further study is needed.

Although we provide the most thorough description of long-term outcomes of children who undergo tracheostomy after cardiac arrest to date with this study, there were limitations to our methods. First, as with any database study, the risk of inappropriate coding of patient-level data is present. However, VPS data are prospectively collected by trained data extractors specifically for inclusion in the database. Second, we did not examine the initial courses and ICU readmissions of children who suffered a cardiac arrest but did not undergo tracheostomy placement. Third, ~7% of the patients who survived to initial discharge had <180 days of available follow-up data and were therefore excluded from our follow-up group to more accurately represent the readmission rate, which may have limited the power of our analyses of factors associated with readmission. Fourth, like all database studies, we are limited by the variables available in the database. For example, detailed characteristics of the cardiac arrest (eg, etiology, location, duration) were not sufficiently characterized in the database for analysis, although it is unlikely that brief periods of cardiopulmonary resuscitation not meeting Utstein definitions of cardiac arrest[32] were included given that all subjects subsequently underwent tracheostomy. Fifth, it was not possible to censor children who died before readmission to a VPS ICU from our

TABLE 2 Comparison of Children With 0 Readmissions and at Least 1 Readmission

Patient Characteristic	Currently Not Readmitted (N = 129), n (%)[a]	Readmitted (N = 205), n (%)[a]	OR	95% CI
Age at index admission, mo				
<12	46 (31.7)	99 (68.3)	1.69	1.07–2.65
≥12	83 (43.9)	106 (56.1)	Reference	—
Sex				
Girls	51 (36.7)	88 (63.3)	0.87	0.56–1.36
Boys	78 (40.0)	117 (60.0)	Reference	—
Admission status				
Scheduled	106 (37.6)	176 (62.4)	0.76	0.41–1.38
Unscheduled	23 (44.2)	29 (55.8)	Reference	—
Trauma status				
Trauma	36 (46.2)	42 (53.8)	0.67	0.40–1.11
Not trauma	93 (36.3)	163 (63.7)	Reference	—
Operative status				
Postoperative	39 (43.9)	50 (56.1)	0.74	0.46–1.22
Not postoperative	90 (36.7)	155 (63.3)	Reference	—
Pre-existing comorbid diagnoses				
Chromosomal abnormalities	11 (30.6)	25 (69.4)	1.49	0.71–3.14
Chronic lung disease	4 (13.8)	25 (86.2)	4.34	1.47–12.8
Congenital heart disease and/or heart failure	23 (67.8)	66 (32.2)	2.19	1.28–3.75
Dialysis dependence	0 (0.0)	1 (100.0)	0.21	0.01–5.16
Neurologic conditions[b]	43 (35.2)	79 (64.8)	1.25	0.79–1.99
Oncologic diagnosis	5 (41.7)	7 (58.3)	0.88	0.27–2.82
Prematurity	9 (23.7)	29 (76.3)	2.20	1.004–4.80
Transplant recipient	1 (33.3)	2 (66.7)	1.26	0.11–14.1
Primary diagnostic category[c]				
Cardiovascular	29 (39.2)	45 (60.8)	1.09	0.55–2.16
Infectious	7 (28.0)	18 (72.0)	1.81	0.66–4.95
Injury and/or poisoning	26 (41.3)	37 (58.7)	Reference	—
Neurologic	16 (44.4)	20 (55.6)	0.88	0.38–2.01
Respiratory	40 (37.7)	66 (62.3)	1.16	0.61–2.19
Other	11 (36.7)	19 (63.3)	1.21	0.50–2.97
ICU therapeutics[d]				
Extracorporeal membrane oxygenation (N = 334)	9 (27.3)	24 (72.7)	1.77	0.79–3.94
Gastronomy tube and/or gastronomy-jejunostomy tube placement (N = 333)	68 (39.5)	104 (60.5)	0.91	0.58–1.41
High-frequency oscillatory ventilation (N = 334)	21 (46.7)	24 (53.3)	0.68	0.36–1.28
Hypothermia (N = 243)	7 (53.8)	6 (46.2)	0.53	0.17–1.63
Inhaled nitric oxide (N = 276)	18 (28.1)	46 (71.9)	1.74	0.95–1.63
Renal replacement therapy (N = 304)	7 (26.9)	19 (73.1)	1.83	0.75–4.50
Ventriculoperitoneal shunt placement (N = 331)	4 (50.0)	4 (50.0)	0.62	0.15–2.53
Acquired comorbidities				
Acute kidney injury	6 (24.0)	19 (76.0)	2.09	0.81–5.34
Bacteremia and/or sepsis	13 (27.1)	35 (72.9)	1.84	0.93–3.62
Central venous line infection	2 (18.2)	9 (81.8)	2.92	0.62–13.7
Intracranial hemorrhage	3 (21.4)	11 (45.8)	2.38	0.65–8.70

TABLE 2 Continued

Patient Characteristic	Currently Not Readmitted (N = 129), n (%)[a]	Readmitted (N = 205), n (%)[a]	OR	95% CI
Need for positive pressure ventilation at discharge	58 (33.5)	115 (66.5)	1.56	1.004–2.44
Pituitary dysfunction	4 (44.4)	5 (55.6)	0.78	0.21–2.96
Seizures	6 (20.7)	23 (79.3)	2.59	1.03–6.55
Ventilator-associated pneumonia	0 (0.0)	4 (100.0)	5.78	0.31–108.34
Venothromboembolism	6 (27.3)	16 (72.7)	1.74	0.66–4.56
Time to tracheostomy, d				
Early, <21	67 (41.4)	95 (58.6)	1.25	0.81–1.95
Late, ≥21	62 (36.0)	110 (64.0)	Reference	—
Index ICU LOS[e]				
Short, less than median	72 (43.1)	95 (56.9)	Reference	—
Long, greater than median	57 (34.1)	110 (65.9)	1.46	0.94–2.28

All variables listed are for the index admission. —, not applicable.

[a] Shown are percentages of readmitted patients within each grouping (eg, 68.3% of patients who were <12 mo old at index admission were readmitted, as compared to 31.7% who were not readmitted).

[b] Neurologic conditions included pre-existing diagnoses of anoxic brain injury, hypoxic-ischemic encephalopathy, epilepsy, muscular dystrophy, and quadriparesis.

[c] Other primary diagnosis categories included gastrointestinal, genetic and/or metabolic, orthopedic, renal, rheumatologic, and "symptoms."

[d] Not all "ICU therapeutics" were recorded at all sites. The number of patients for whom data were collected is indicated for each variable.

[e] Median LOS was 38.3 d.

analysis. Finally, and perhaps most importantly, our observations of readmission and medical resource use for these children almost certainly underestimate the true burden of their medical resource use because the VPS database captures only ICU readmissions.

Given the proportion of children who were transferred from the ICU to a general ward or step-down unit, these children clearly are cared for in other areas of some VPS hospitals, although there are many important differences in regional practices of care for patients with tracheostomies and ventilators that remain unexamined in this study, including access to robust outpatient-support processes for children with medical complexity, which may mitigate the risk of acute illnesses in this population. In addition, some facilities mandate ICU admission for all children with tracheostomies. Prospective studies are needed to better understand and adjust for differences between centers. Readmissions exclusively to non-ICU parts of the hospital are not included in our analysis but may be important to families and care providers considering tracheostomy after cardiac arrest, especially because post-tracheostomy death is not limited to the ICU setting.[11,12] Similarly, our analysis does not include readmissions to PICUs that do not contribute data to VPS or that did not report tracheostomy data throughout the study period, although patients can be tracked between participant institutions. Despite these limitations, we identified an ICU readmission rate of 0.54 readmissions per patient-year and found that 53.0% of patients required readmission within 1 year of discharge. Families of children who suffer cardiac arrest and are unable to separate from mechanical ventilation and for whom tracheostomy is being discussed may find this level of resource use informative in their decision-making process. Further work is needed to confirm that children who undergo tracheostomy after cardiac arrest are at increased risk for ICU readmission and identify ways to reduce medical resource use.

TABLE 3 Multivariate Regression Analysis Results

Variable	OR (95% CI)
Age <12 mo	0.93 (0.54–1.61)
Chronic lung disease	2.82 (0.76–10.53)
Congenital heart disease and/or heart failure	1.65 (0.83–3.25)
Inhaled nitric oxide	1.05 (0.52–2.12)
Need for positive pressure ventilation at discharge	1.20 (0.71–2.03)
New bacteremia and/or sepsis	1.51 (0.67–3.39)
New onset seizures	2.39 (0.91–6.27)
Prematurity	1.69 (0.68–4.17)

χ^2 testing was used to identify variables loosely associated ($P < .1$) with readmission, and those variables were included in a logistic regression model with readmission as the outcome variable.

CONCLUSIONS

In this multicenter database study, children who underwent tracheostomy after cardiac arrest were frequently readmitted to the PICU with acute respiratory illnesses. Identified univariate risk factors for these readmissions were largely present before admission for cardiac arrest, whereas many patient- and intervention-level factors during the index admission were noncontributory to readmission risk, and no risk factors remained significant in multivariate analysis. Mortality and the burden of invasive procedures during readmission were consistent with the general PICU population. These data may be useful for counseling families of children who suffer cardiac arrest and subsequently are unable to separate from mechanical ventilation.

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