# Unscheduled Readmissions to the PICU: Epidemiology, Risk Factors, and Variation Among Centers

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**Objectives:** To determine the rate of, and potential risk factors for, unscheduled PICU readmission and assess for variability among PICUs within the United States.

**Design and Data Source:** This retrospective cohort study used 2005–2008 data from 73 PICUs in the Virtual PICU Systems database.

**Methods and Measurements:** Early (within 48 hr of PICU discharge) and late (later than 48 hr) unscheduled readmission rates were calculated. Hierarchical logistic regression, with a random intercept for site, was used to identify factors independently associated with early readmission. Significant random effects identified sites with an outlying risk of readmission, adjusting for patient and admission characteristics.

**Main Results:** For 117,923 children meeting inclusion criteria, the unscheduled readmission rate was 3.7% with 38% (1.4%) occurring early. Half of early readmissions had the same primary diagnosis as the first admission. Patients with late readmissions had a higher mortality (6.6% vs 3.3%, $p < 0.001$) and longer median total PICU length of stay (11 d vs 6 d, $p < 0.0001$) than those with early readmission. Patient characteristics strongly associated with increased risk of early readmission included the following: age < 6 months, acute respiratory and renal disease, and several underlying chronic conditions such as liver disease, bone marrow transplant, airway stenosis, and abnormal antidiuretic hormone balances. An initial PICU admission that was unscheduled, originated from the general floor, or with a discharge time between 4 PM and 8 AM was associated with higher risk of readmission. A quarter of sites were identified as potential high (16%) or low (8%) outliers.

**Conclusions:** The rate of unscheduled PICU readmission was low but associated with worse outcomes. Patient and admission/discharge characteristics associated with increased risk of readmissions could be used to target high-risk populations or modifiable factors to improve outcome. Variation of risk among centers suggests room for improvement. (*Pediatr Crit Care Med* 2013; 14:571–579)

**Key Words:** epidemiology; outcomes research; patient readmissions; quality indicators (healthcare); risk factors

Unscheduled readmission to the PICU within 24–48 hours has been proposed as a quality metric by the Society of Critical Care Medicine (SCCM), the National Association of Children's Hospitals and Related Institutions, and the National Quality Forum (1). Despite national interest, data on readmissions in the PICU population have been limited (2, 3). The rates of early unscheduled PICU readmission are unknown as is the population at greatest risk. Yet both adult and pediatric studies suggest worse outcomes for those patients requiring more than one ICU or PICU admission during a single hospitalization (3–6).

Although the use of early readmission rates as an ICU quality measure has been called into question, a portion of these may be preventable by altering ICU-based management decisions such as premature ICU discharge (7). A better understanding of the frequency of unscheduled readmissions and the patient population requiring readmissions will help guide interventions to reduce unnecessary readmissions and potentially improve patient outcome. Therefore, we used a large multicenter PICU database to determine the rate of

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early unscheduled readmissions, identify potential patient and admission characteristics associated with the risk of readmission, and assess for potential center variation in risk.

## MATERIALS AND METHODS

### Study Design and Data Source

We performed a retrospective cohort analysis using data from a multicenter pediatric intensive care database, the Virtual PICU Systems (VPS, LLC, Los Angeles, CA, https://portal.myvps.org). Over the time span for this study, 73 PICUs within the United States prospectively contributed data to the VPS database (**Table 1**). Among the contributing sites, about half had more than 16 licensed PICU beds in their unit. Although almost two thirds had an open heart program, only a third had a separate intermediate ICU. Most were academic centers with an accredited pediatric residency training program, a smaller proportion with an accredited pediatric critical care fellowship program. Although almost all sites had in-house attending coverage during the day, a minority had attending in-house during the night. The mean and median number of cases from each site over the 4-year study period was 1,615 and 1,138, respectively, with an interquartile range of 684–4369.

**TABLE 1. Characteristics of PICUs Included in the Study**

| PICU Site Characteristic | No. of Sites (%), *n* = 73 |
|---|---|
| No. of licensed PICU beds | |
| 0–8 | 13 (18) |
| 9–16 | 25 (34) |
| 17–24 | 18 (25) |
| More than 24 | 17 (23) |
| Has a separate intermediate unit | 23 (32) |
| Has an open heart program | 43 (59) |
| Primary teaching site for an accredited pediatric residency training program | 55 (75) |
| Has an accredited pediatric critical care fellowship training program | 29 (40) |
| Minimum daytime coverage | |
| PICU attending in-house | 66 (90) |
| Fellows in-house (attending back-up) | 2 (3) |
| Residents in-house (attending back-up) | 1 (1) |
| Minimum nighttime coverage | |
| PICU attending in-house | 28 (38) |
| Fellows in-house (attending back-up) | 13 (18) |
| Residents in-house (attending back-up) | 19 (26) |
| Hospitalist or mid-level practitioner in-house (attending back-up) | 4 (6) |
| No in-house coverage (attending back-up) | 9 (12) |

De-identified data obtained for our analysis included demographic information, admission and discharge characteristics, primary and secondary diagnoses, risk of mortality scores as measured by the Pediatric Index of Mortality (PIM)-2, operative status, interventions and surgical procedures performed during the PICU stay, and outcome at PICU discharge (8). Each patient had a unique identifier for determining multiple PICU admissions within a single hospitalization. All data elements were collected by trained data collectors and abstracted from the clinical medical record at each site. Diagnoses were determined by medical record review rather than from administrative data used for billing purposes and were not mutually exclusive. The data quality assurance procedures used by the VPS system include mandated standardized training of data collectors at each site, initial and quarterly inter-rater reliability assessments, automated and manual validation checks of entered data, and review of data that are unusual compared with other sites (C. Gall, personal communication, VPS LLC, 2012).

### Cohort and Outcome Definition

The cohort was selected from patients admitted to the PICU from January 1, 2005, to December 31, 2008. Children who died on their first admission or were directly discharged to home from the ICU would not be considered an at-risk population and therefore were excluded from the final analyses. Additional exclusionary criteria included discharge to another hospital as the outcome could not be verified and invalid date and time data for PICU admission and discharge. The primary outcome of interest was an unscheduled readmission occurring at least 1 hour after PICU discharge within the same hospitalization. An unscheduled admission was defined by the VPS criteria (admission had not been scheduled within 12 hr of PICU arrival) and was determined by each site. Admissions with a discharge to, and then transferred from, the operating room or another ICU within the same hospital were considered to be the same PICU admission to reduce the risk of misclassification. Similarly, second admissions occurring within 1 hour of discharge ($n = 9$, two scheduled and seven unscheduled) were considered to be the same PICU admission to minimize misclassification.

"Early" and "late" readmissions were defined by the time between first PICU physical discharge date and time and first PICU readmission: within 48 hours and more than 48 hours, respectively. To ensure independence among observations, we limited our analyses to the first hospitalization for any one patient and focused on the first two PICU admissions within that hospitalization. The final risk analysis compared children who had an unscheduled readmission within 48 hours of PICU discharge (the proposed quality measure by SCCM) with those who did not.

### Statistical Analyses

Descriptive statistics were used to determine the pattern of all unscheduled readmissions and the cohort outcomes such

as death and length of stay (LOS). Categorical variables were compared using chi-square analysis, and non-normally distributed variables were compared using Wilcoxon rank sum tests. We used logistic regression to measure the association between various patient and admission characteristics and the risk of an unscheduled readmission within 48 hours. Risk factors determined clinically significant a priori and with an alpha of less than or equal to 0.05 on the bivariable analyses were identified as candidate variables for a multivariable model (**Supplementary Table 1**, Supplemental Digital Content 1, http://links.lww.com/PCC/A67). Backward elimination, with an exit criterion of a *p* value of less than 0.05, was performed 10 times using bootstrapped samples of 90% of the cohort. Variables appearing in at least 50% of the bootstrapped models were then entered into a multivariable logistic regression model. Bootstrapping was performed for two purposes: 1) to produce a more manageable set of variables; and 2) to reduce the risk of false-positive rates given the large number of variables being evaluated (9, 10). Recognizing the risk of false negatives and the exploratory nature of our analysis, we present the full model and the frequency of selection in the bootstrap models in Supplementary Table 1 (Supplemental Digital Content 1, http://links.lww.com/PCC/A67). To account for potential center effects, all regression analyses were performed using mixed modeling with PROC GLIMMIX. Risk estimates were presented as odds ratios with 95% CI. Discrimination and calibration for the final model were estimated by the C-statistic and Hosmer–Lemeshow test, respectively.

The random effect, by center, was estimated to examine variability in risk among the different centers, accounting for patient-level factors (11). Centers with a statistically significant random effect, defined as the 95% CI of the odds ratio did not include 1, were characterized as potential outliers. Those with a risk estimate above 1 and a 95% CI exclusive of 1 were considered to be high outliers. Those with a risk estimate less than 1 and a 95% CI exclusive of 1 were considered to be low outliers. All analyses were done using SAS Enterprise Guide 4 (SAS Institute Inc, Cary, NC).

This study was approved, with the need for informed consent waived, by the Colorado Multiple Institutional Review Board.

## RESULTS

A total of 147,314 children had at least one PICU admission captured in the VPS database over the 4-year study period. Among this cohort, 117,923 patients met criteria for being at risk for a readmission and had appropriate follow-up data. Of the eligible subjects, 3,798 (3.2%) had at least one unscheduled PICU readmission during the same hospitalization (**Fig. 1**). For the at-risk cohort, the rate of unscheduled readmissions per total PICU admissions, over the 4 years, was 3.7% with a slight decline from 2005 to 2008 (4.1% to 3.6%, $p = 0.006$). The average rate of unscheduled readmissions within 48 hours was 1.4%. Most patients (85%) with a readmission had only one additional PICU admission during their hospitalization. Thirty-eight percent of all unscheduled readmissions occurred within 2 days of PICU discharge (**Fig. 2**). The average time between PICU discharge and an unscheduled readmission was 200 hours (8.3 d) with a median of 76 hours (3.2 d). Early readmissions had a mean and median time of 22 hours from discharge, whereas the later readmissions had a mean and median time of 304 hours (12.7 d) and 151 hours (6.3 d), respectively.

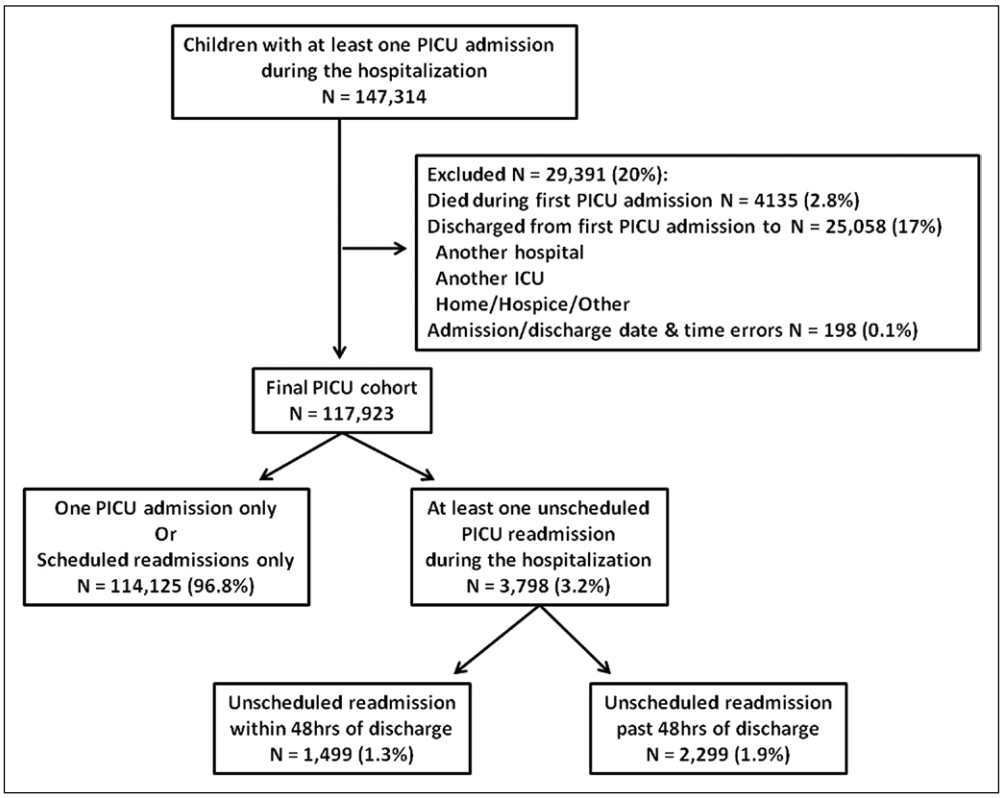


**Figure 1.** Cohort development and categorization of subjects by readmission status and timing of readmission.

Subjects readmitted within 48 hours were more likely than those readmitted after 48 hours to have the same primary diagnosis on first and second PICU admissions (53% vs 45%, respectively, $p < 0.0001$). The top diagnoses for those readmitted with the same primary diagnosis were infections, respiratory disease, and cardiovascular disease. Patients with an early unplanned readmission had a slightly lower risk of mortality on first admission (median PIM-2 predicted mortality 1.0%; interquartile range [IQR], 0.6–2.9%) compared with those readmitted late

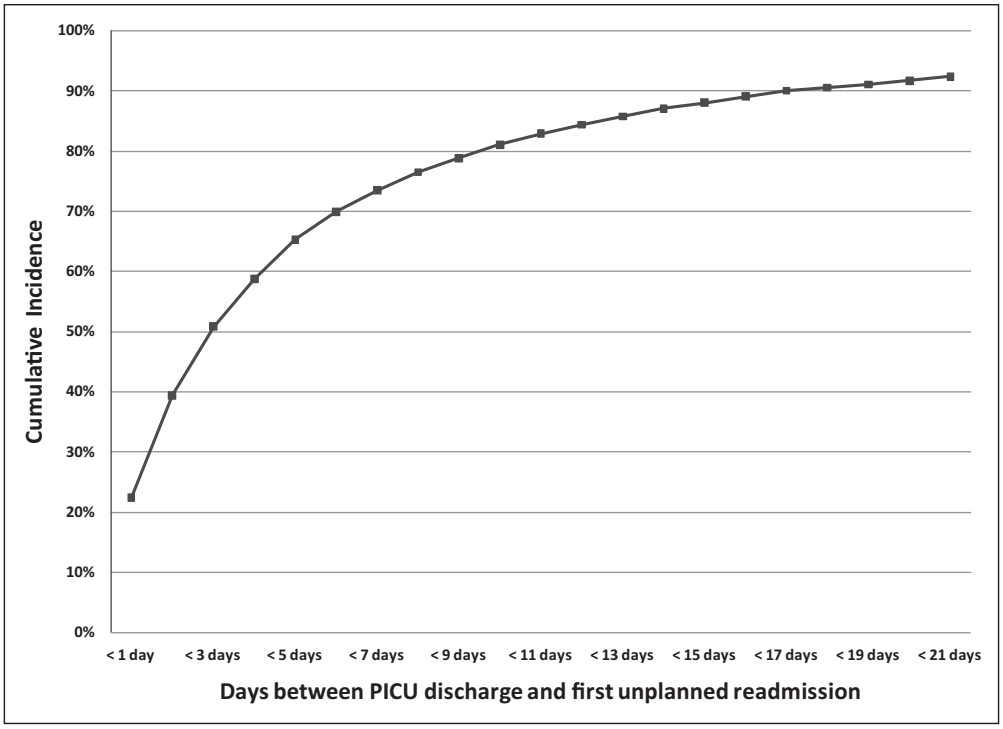


**Figure 2.** Cumulative incidence of unscheduled readmissions to the PICU from first PICU discharge.

(median PIM-2 predicted mortality 1.3%; IQR, 0.8–4.4%, $p < 0.0001$)

Among children with at least one unscheduled PICU readmission, 200 (5.2%) died during their ICU stay. Those with an unscheduled admission greater than 48 hours after discharge had a higher mortality (6.5%) than those readmitted within 48 hours (3.3%), $p < 0.0001$. The average PICU LOS for patients who survived their first PICU admission but were not readmitted was 3.8 days (median 39 hr). Those who were readmitted within 48 hours of discharge had an average total PICU LOS (summation of all PICU admissions within the hospitalization) of 13 days (median 6.5 d) versus those readmitted after 48 hours, who had an average total PICU LOS of 22 days (median 11 d), with a $p$ value of less than 0.0001.

### Patient and Admission Characteristics Associated With Early Readmission

Many patient and admission characteristics identified on the first PICU admission were associated with the risk of readmission (Supplementary Table 1, Supplemental Digital Content 1, http://links.lww.com/PCC/A67). Twenty-seven candidate variables were selected in at least half of the bootstrapped models as independent risk factors associated with an unscheduled readmission within 48 hours (**Table 2**). Patients younger than 6 months of age were more likely to be readmitted than older patients. Those with acute organ dysfunction, especially respiratory or renal, were at highest risk of readmission as were those with certain underlying conditions. The greatest risk was associated with chronic liver disease, prior bone marrow or solid organ transplant, airway anomalies, and diabetes insipidus or syndrome of inappropriate antidiuretic hormone (SAIDH). Children who required neurosurgical intervention were also at increased risk of readmission.

Several admission characteristics were also associated with a higher risk of readmission. Patients who were admitted to the PICU after admission to the hospital and those with an unscheduled first PICU admission were at greater risk of PICU readmission. Admission origin was also associated with risk of readmission, in that children admitted from the general ward were more likely to be readmitted than those admitted from the emergency department, step-down unit, or another hospital. Finally, being discharged from the PICU outside the hours of 8 AM and 4 PM was associated with an increased risk of readmission.

There were also several factors independently associated with a decreased risk of readmission. Patients without underlying chronic conditions at first PICU admission were less likely to be readmitted as were those admitted with asthma, diabetes, or craniosynostosis repair. Children admitted for trauma without head injury also had a lower risk of early unplanned readmission. Finally, those who were transferred to other locations including a rehabilitation ward had a lowered risk of readmission compared with those transferred to the general ward or step-down unit.

### Center-Specific Effects on Risk of Early Readmission

Using the random-effects variable as a marker for center-specific effects beyond the identified patient and admission risk factors, the average risk of readmission varied among centers (**Fig. 3**). Twelve centers were considered to be potential high outliers (i.e., at higher risk of readmission after accounting for center differences in patient and admission characteristics) with odds ratios ranging from 1.43 to 2.18. Six centers, on the other hand, were identified as potential low outliers with odds ratios ranging from 0.47 to 0.58.

## DISCUSSION

From this large multicenter U.S. study, we found the average rate of unplanned PICU readmission within the same hospitalization to be 3.7%. Thirty-eight percent of readmissions occurred within 48 hours of PICU discharge. Of those early readmissions, half returned within 24 hours, whereas the late readmission, on average, occurred 1–2 weeks after PICU

**TABLE 2. Unadjusted and Adjusted Associations Between Patient and Admissions Characteristics on the First PICU Admission and Unscheduled Readmission Within 48 Hr**

| Patient and Admission Characteristic on First PICU Admission | Unadjusted Odds Ratio (95% CI) | Bootstrap Models (%) | Adjusted Odds Ratio[a] (95% CI) |
|---|---|---|---|
| Demographics | | | |
| Age less than 6 mo (vs greater than 6 mo) | 1.87 (1.67–2.09) | 100 | 1.56 (1.38–1.77) |
| Diagnoses present on first PICU admission (acute and chronic)[b] | | | |
| Respiratory | | | |
| Acute respiratory disease including acute respiratory distress syndrome | 1.82 (1.61–2.05) | 100 | 1.31 (1.15–1.49) |
| Chronic respiratory diseases including bronchopulmonary dysplasia | 1.58 (1.36–1.84) | 100 | 1.28 (1.10–1.49) |
| Airway stenosis | 1.76 (1.10–2.83) | 50 | 1.77 (1.11–2.83) |
| Asthma with or without status asthmaticus | 0.61 (0.49–0.77) | 100 | 0.64 (0.50–0.81) |
| Neurologic | | | |
| Cerebral palsy/developmental delay | 1.68 (1.38–2.04) | 100 | 1.65 (1.35–2.02) |
| Stroke (thrombotic, embolic and hemorrhagic) | 1.53 (1.15–2.05) | 80 | 1.44 (1.07–1.94) |
| Head injury | 1.17 (0.87–1.57) | 80 | 1.44 (1.05–1.98) |
| Immunologic | | | |
| Bone marrow transplant with or without complications | 2.87 (1.61–5.12) | 60 | 1.81 (1.01–3.25) |
| Oncologic diagnosis | 1.14 (0.95–1.38) | 70 | 1.27 (1.04–1.55) |
| Endocrine | | | |
| Diabetes insipidus or syndrome of inappropriate antidiuretic hormone | 2.36 (1.34–4.16) | 60 | 1.88 (1.07–3.31) |
| Insulin-dependent diabetes mellitus with or without diabetic ketoacidosis | 0.28 (0.17–0.45) | 100 | 0.34 (0.21–0.55) |
| Other organ systems | | | |
| Chronic liver disease | 3.35 (2.24–5.00) | 100 | 3.03 (2.03–4.53) |
| Acute renal failure | 2.29 (1.63–3.22) | 100 | 1.79 (1.27–2.52) |
| Cardiac disorders including congenital heart defects | 1.23 (1.08–1.40) | 50 | 1.19 (1.04–1.38) |
| Hematologic disorders (except white cell) | 1.01 (0.78–1.30) | 70 | 0.74 (0.58–0.96) |
| Other diagnoses | | | |
| Child abuse diagnosis | 2.09 (1.35–3.23) | 50 | 1.55 (0.98–2.46) |
| Chromosomal anomalies or syndromes | 1.33 (1.13–1.56) | 100 | 1.27 (1.08–1.49) |
| Nonhead injuries | 0.51 (0.42–0.62) | 100 | 0.51 (0.41–0.62) |
| Craniosynostosis or other skull anomalies | 0.27 (0.13–0.55) | 100 | 0.40 (0.20–0.81) |
| No chronic conditions at first PICU admission | 0.40 (0.30–0.52) | 100 | 0.58 (0.44–0.76) |
| Interventions during first PICU admission | | | |
| Subdural tap/ventricular drain/intracranial pressure monitor/ventricular tap | 1.61 (1.10–2.36) | 60 | 1.49 (1.02–2.20) |
| First PICU admission characteristics | | | |
| Time between hospital and PICU admission dates (vs same date) | | | |
| 1–2 d | 1.43 (1.24–1.65) | 100 | 1.15 (0.98–1.34) |
| More than 2 d | 1.89 (1.62–2.21) | 100 | 1.38 (1.15–1.65) |

(*Continued*)

**TABLE 2. (*Continued*). Unadjusted and Adjusted Associations Between Patient and Admissions Characteristics on the First PICU Admission and Unscheduled Readmission Within 48 Hr**

| Patient and Admission Characteristic on First PICU Admission | Unadjusted Odds Ratio (95% CI) | Bootstrap Models (%) | Adjusted Odds Ratio[a] (95% CI) |
|---|---|---|---|
| Origin of first PICU admission (vs emergency room) | | 100 | |
| General floor | 1.99 (1.70–2.34) | | 1.32 (1.10–1.59) |
| Step-down unit/intermediate care unit/telemetry unit of same hospital | 1.63 (1.09–2.44) | | 0.97 (0.64–1.48) |
| Other locations including outside hospital | 0.92 (0.81–1.04) | | 0.94 (0.82–1.09) |
| Unscheduled admission (vs scheduled) | 1.63 (1.44–1.86) | 100 | 1.65 (1.41–1.92) |
| Hour of first PICU discharge (vs 8:00–15:59) | | 100 | |
| 16:00–22:59 | 1.23 (1.10–1.37) | | 1.19 (1.06–1.32) |
| Midnight–7:59 | 1.53 (1.20–1.95) | | 1.50 (1.17–1.92) |
| First PICU discharge location (vs general care floor) | | 100 | |
| Step-down unit/intermediate care unit/telemetry unit of same hospital | 1.26 (1.08–1.47) | | 1.12 (0.95–1.33) |
| Other locations including rehabilitation ward | 0.33 (0.20–0.53) | | 0.27 (0.17–0.44) |

Variables included in the final adjusted model were selected based on frequency in bootstrapped models (at least 50%).

[a]Fully adjusted model C-statistic 0.72, Hosmer–Lemeshow test, $p = 0.07$.

[b]Diagnoses were not mutually exclusive, with the referent category as not having the diagnosis.

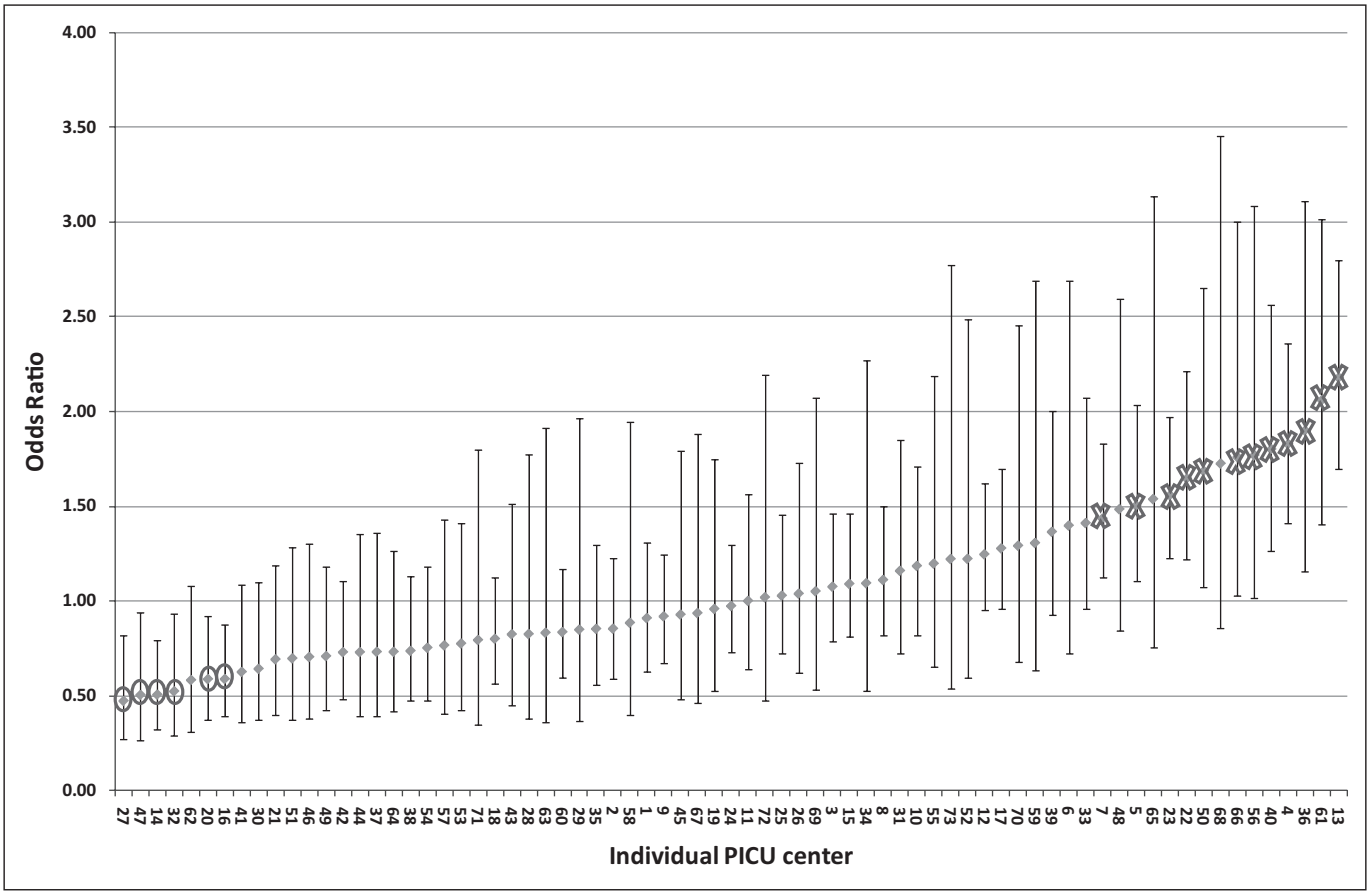


**Figure 3.** Center-specific odds ratio with 95% CIs after adjustment for center variation in individual patient and admission characteristics. *Circle* = potential low outliers, *X* = potential high outliers.

discharge. Children with an unscheduled readmission had longer total PICU length of stay compared with those without an unscheduled readmission. Patients readmitted within 48 hours had a slightly higher mortality than observed for anyone with at least one PICU admission, whereas those readmitted later had a much higher mortality. Young infants and those with several chronic conditions, including respiratory, neurologic, cardiac, and oncologic, were at highest risk of unscheduled readmission within 48 hours. Unscheduled first PICU admissions, admission from the general ward, and admission being discharged during the evening and nighttime hours were also independently associated with increased risk of readmission. Accounting for these patient and admission/discharge characteristics, there remained variability in risk of readmission associated with specific centers.

Although recent large adult studies on ICU readmissions report similar rates (2%–3%) as those found in our study, these rates are considerably lower than those described in the pediatric literature (8%–31%), which may be due to the inclusion of all readmissions occurring after PICU discharge, irrespective of timing or nature of the readmission (i.e., scheduled vs unscheduled) (3, 5, 12, 13). This would result in higher rates of readmission than those limited to early unscheduled readmission. Although late readmissions are associated with worse outcome and deserve attention, they may not necessarily reflect care and decision making by the critical care team. Thus, it may not be appropriate to combine early and late readmissions when estimating readmission rates for quality assessment purposes as recognized by national organizations (1).

Early readmission as a quality measure presents particular challenges. Unlike other ICU quality measures such as catheter-associated bloodstream infection, a zero readmission rate may not be desirable. Some children will always be at risk of return to the PICU, no matter how stable they were at PICU discharge or how optimized their care was prior to discharge. For example, in this study, very young patients and those with chronic conditions were more likely to be readmitted within 48 hours, consistent with other studies (2, 3, 13, 14). This population may have more difficulty resolving critical illness, a greater likelihood of recurrent problems and/or new complications arise—making these children more likely to require critical care support again. This explanation is supported by our findings of an increased risk associated with an unscheduled first PICU admission and the same primary diagnosis present in half of the early readmissions.

Being able to account for this underlying vulnerability would be optimal in comparative reporting. However, developing appropriate adjustment tools to standardize readmission rates across institutions may be difficult given the heterogeneity of the intensive care population. Most models of readmission risk in the adult literature have, at best, a C-statistic of less than 0.75 on their receiver operating characteristic curves reflecting moderate discrimination (5, 12, 15–19). Although a pediatric score to predict risk of readmission has been published, it has yet to be validated and may not yield better discrimination ability (2). Therefore, rather than being used as adjustment tools, such models may be better suited for identifying the highest risk population toward whom to direct interventions. For example, children with acute and chronic respiratory disease, as well as neurologic compromise, had an increased risk of unscheduled readmission. These children may require more supportive care related to chest physiotherapy and airway clearance. With additional respiratory support, they may not escalate to an unscheduled ICU readmission. Other children who require frequent laboratory monitoring and adjustments in management such as those with diabetes insipidus or renal failure may need a longer period of stability prior to transfer out of the ICU. Thus, the most successful intervention may depend on the particular population at risk.

Accurate assessments at the time of discharge and clear discharge criteria are essential first steps. National guidelines for developing discharge policies in the PICU were published in 1999 but the recommended criteria were broad and lacked precision(20). To better identify specific physiologic variables associated with increased risk of readmission, more information about patient status on PICU discharge is needed. Unfortunately, to the best of our knowledge, currently there is no large pediatric database capturing this information. Efforts to use the electronic medical record system to quickly determine a patient's level of risk have shown some promise in adult critical care and may emerge as a useful tool for identifying high-risk patients (21).

Critical care beds are a limited resource, and there is constant pressure to maximize their use (22). The challenge of accommodating all patients requiring critical care services and providing high quality care to those patients has been characterized as "ICU capacity strain" (23). This strain, when at its limits, may result in premature discharges from the ICU and potentially higher readmission rates. Indeed, many studies have demonstrated a clear association between measures of ICU capacity strain (high ICU census, high patient inflow, and after-hours discharge) and a higher risk of readmission (24–27). Although our study could not measure ICU census or patient flow, we did find a greater risk association with discharge in the evening and nighttime hours, which may reflect ICU strain. Yet, prohibiting discharges during certain hours or under certain ICU volumes, particularly in the face of uncertain risk of readmission, may result in unnecessarily long PICU stays and/or patients in need of critical care services not receiving them.

Recognizing the tension between maximizing efficiency and reducing complications, some have proposed using critical care outreach or rapid response teams to reduce the risk of readmission (28). Several studies have evaluated the impact of such programs on the rate of readmissions (29–32). The reported effect on readmission rates has varied between studies, possibly secondary to differences in team composition and approach (mandatory follow-up vs evaluation by request). Further study on variables associated with greater ability of critical outreach teams to reduce unscheduled readmissions would be helpful in developing and implementing such programs.

Our cohort of patients with an early unscheduled readmission had a lower mortality than reported in other pediatric

studies that included patients with late readmissions, who had a two-fold greater mortality rate in our study. However, these patients had longer total PICU length of stay, which may not only result in increased resource use but also be associated with greater morbidity. Furthermore, an unexpected return to the ICU can often result in significant stress and distress felt by the patient, their family, and care team members. Although the specific psychological impact of ICU readmission has not been evaluated, a growing body of literature has shown the adverse psychosocial and emotional effects of critical illness on patients and their families (33–36). A single unexpected PICU admission has been associated with more severe and prolonged psychological morbidities in patients and parents (33, 34). Multiple unexpected PICU admissions could potentially have an even greater adverse impact. Therefore, reduction of preventable PICU readmission may result in some improvement in mortality and reduce morbidity.

Several limitations of our study should be recognized. As described in the section Materials and Methods, VPS uses a standard approach to data quality assurance to reduce the risk of data entry error and inconsistencies in diagnostic variables. However, the retrospective nature of the study limits our ability to eliminate error completely. Furthermore, we did not have any data on a patient physiologic status or ICU capacity strain on the day of discharge, or information about the care received among ICU admissions. These data would likely be important in refining assessments of risk and identifying modifiable factors to intervene upon. Future efforts in this area of research and quality improvement should include this information.

An additional limitation is the generalizability of our findings. Our data only included U.S. centers and did not include some large centers that do not participate in the Virtual PICU Systems. Although the patient populations may not differ significantly from other countries, there may be healthcare delivery differences among differing national healthcare systems. Furthermore, although we did have a mix of unit sizes and academic versus nonacademic units, sites that choose to contribute data to VPS may be particularly interested in quality improvement and benchmarking quality measures. Thus, there may have been a selection bias resulting in lower rates than might be seen in other institutions. Although we had summary information on unit types contributing data, we did not have access to these characteristics on an individual unit level to assess for potential factors associated with the variation in center-specific risk observed. Additionally, any center-specific variation may be secondary to residual confounding given the C-statistic of 0.72.

Finally, our analysis was intended to be exploratory and hypothesis generating for future studies. We made certain statistical judgments, balancing the false discovery rate with the potential for false negative findings, and thus, our findings should be interpreted with care. With additional external studies, certain risk factors identified in our study may become less important, or conversely, risk factors eliminated in our reduced model emerge as significant factors for future intervention.

## CONCLUSIONS

In summary, despite the challenges, early unscheduled readmissions remain a potentially meaningful PICU quality measure. It captures multiple domains of quality as outlined by the Institute of Medicine—safety, effectiveness, efficiency, and patient centeredness (37, 38). With this study, we have characterized national rates of readmission and identified the patient and admission/discharge characteristics highly associated with risk of readmission. Furthermore, we have shown variation among centers suggesting a potential for improvement. In addition to confirming our findings, future efforts should be directed at characterizing additional discharge day variables and the between-ICU admission factors associated with the risk of readmission. Research in this direction will help identify high-impact interventions to reduce preventable early readmissions and potentially improve the outcomes of patients and their families.

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