OBSERVATIONAL STUDY

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Resources and Costs Associated With Repeated Admissions to PICUs

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OBJECTIVE: To determine the costs and hospital resource use from all PICU patients readmitted with a PICU stay within 12 months of hospital index discharge.

DESIGN: Cross-sectional, retrospective cohort study using Pediatric Health Information System.

SETTING: Fifty-two tertiary children's hospitals.

SUBJECTS: Pediatric patients under 18 years old admitted to the PICU from January 1, 2016, to December 31, 2017.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: Patient characteristics and costs of care were compared between those with readmission requiring PICU care and those with only a single PICU admission per annum. In this 2-year cohort, there were 239,157 index PICU patients of which 36,970 (15.5%) were readmitted and required PICU care during the 12 months following index admission. The total hospital cost for all index admissions and readmissions was $17.3 billion, of which 21.5% ($3.71 billion) were incurred during a readmission stay involving care in the PICU; of the 3,459,079 hospital days, 20.3% (702,200) were readmission days including those where PICU care was required. Of the readmitted patients, 11,703 (30.0%) received only PICU care, accounting for $662 million in costs and 110,215 PICU days. Although 43.6% of all costs were associated with patients who required readmission, these patients only accounted for 15.5% of the index patients and 28% of index hospitalization expenditures. More patients in the readmitted group had chronic complex conditions at index discharge compared with those not readmitted (83.9% vs 54.9%; $p < 0.001$). Compared with those discharged directly to home without home healthcare, patients discharged to a skilled nursing facility had 18% lower odds of readmission (odds ratio 0.82 [95% CI, 0.75–0.89]; $p < 0.001$) and those discharged home with home healthcare had 43% higher odds of readmission (odds ratio, 1.43 [95% CI, 1.36–1.51]; $p < 0.001$).

CONCLUSIONS: Repeated admissions with PICU care resulted in significant direct medical costs and resource use for U.S. children's hospitals.

KEY WORDS: healthcare costs; intensive care units, pediatric; patient readmission

Unplanned readmissions to the PICUs are an important ICU-level hospital quality metric, as they are often associated with worse clinical outcomes and higher medical costs (1–3). Current literature is generally limited to PICU readmissions within the same hospitalization ("bounce-back"

DOI: 10.1097/CCE.0000000000000347

patient) or 30-day all-cause hospital readmissions. There are only limited data examining readmissions to the PICU after hospital discharge beyond the 30-day window (4–6). In Brazil, 9.8% of patients were readmitted to the PICU within 1 year after index admission, accounting for 33.0% of PICU days (5). The median interval between primary discharge and readmission was 73 days, which suggests that the 30-day readmission metric may underestimate the burden placed on PICU resources as a result of any subsequent PICU readmission. In addition, a multiinstitutional study of North American PICUs demonstrated that 11.0% of discharged patients were readmitted to the PICU within 12 months, accounting for one-fifth of all PICU patient days (4). In Sweden, compared with children with a single PICU admission, those with repeated PICU admissions had a significant decrease in survival over time (6).

Hospital readmissions place a significant financial and resource burden on the healthcare system. The Healthcare Cost and Utilization Project (HCUP) estimated 13.8% of hospitalized American adults in 2011 required readmission within 30 days, resulting in $41.3 billion in hospital costs (7). The 30-day unadjusted readmission rate for hospitalized children in the United States is estimated between 4.5% and 6.5% and accounted for approximately $678 million healthcare dollars in 2014 (8–10). Children with higher medical complexity are known to account for a significant portion of PICU resources and costs, but aside from this unique population, there are limited data regarding resource use and financial implications of PICU patients who are readmitted after hospital discharge and require subsequent PICU care outside of a limited 30-day window (11, 12). It is also unclear how pediatric patients who require PICU admissions after index hospital discharge impact hospital expenditures and resource utilization compared with those not requiring readmission.

The purpose of this study was to identify patients with multiple discrete hospitalizations where PICU care was required within a 12-month period after initial hospital discharge, and to quantify the resource and financial impact of their care relative to the general PICU population. In addition, patient-specific risk factors for repeated PICU admissions including demographics, medical complexity, technology dependence, and primary diagnoses were assessed.

MATERIALS AND METHODS

Design and Data Source

This was a cross-sectional, retrospective cohort study of patients admitted to tertiary referral children's hospitals participating in the Pediatric Health Information System (PHIS; Children's Hospital Association, Lenexa, KS). The PHIS is a comparative administrative pediatric database including demographic and resource utilization data for inpatient, ambulatory surgery, emergency department, and observation unit patient encounters for more than 52 U.S. children's hospitals. Data available include standard hospital discharge abstract information, including demographics, procedures, *International Classification of Diseases*, 10th Edition (ICD-10) diagnoses, All Patients Refined Diagnosis Related Groups (APR-DRGs), as well as daily financial and resource use data.

Patient Selection

Index hospitalizations for all patients admitted to a participating PICU between January 1, 2016, and December 31, 2017, were identified, and data collection continued for 365 days after index admission, through December 31, 2018. In order to ensure a hospitalization was an index hospitalization, we excluded those cases where the patient had a prior PICU hospitalization within 365 days. To determine readmission status, individual subjects were linked via a unique patient identifier number in the PHIS dataset. Patients over 18 years old were excluded. Patients who died during the index admission were excluded from the study, as they could not undergo readmission after discharge. Each patient was followed for 12 consecutive months following discharge from their index hospitalization to determine the presence or absence of new hospitalization with readmission to the PICU and to quantify the number of readmissions in the ensuing 12 months after discharge.

Definitions

The cohort was separated into those who were discharged and subsequently readmitted to the hospital with PICU care within 12 months following the index discharge and those who were not readmitted to the PICU within 12 months of index discharge. PICU admissions were identified by a billed room charge for

a PICU bed in the hospital charges at any time during the hospital stay. For all index admissions, multiple demographic variables including sex, age, race, median household income, census region, payer, as well as dates of admission, discharge diagnoses, and procedures were assessed. Procedure codes and charges for invasive mechanical ventilation were used to identify patients who underwent tracheostomy tube placement, gastrostomy tube placement, internal diverting cerebral spinal fluid (CSF) shunt, or invasive mechanical ventilation during index hospitalization. Demographics included sex, age, race, insurance, and the number of complex chronic conditions (CCCs), as defined by Feudtner et al (13). The presence of CCC was determined at discharge of the index encounter. Financial data including the total cost of care, excluding professional physician fees, were estimated from charges using hospital and year-specific cost-to-charge ratios. The PHIS database includes hospital charges that are adjusted for a hospital's location. In addition, cost-to-charge ratios are available to estimate cost of services provided including the costs of per diem inpatient stay, laboratory tests, medications, and medical device, but does not include physicians' fees. Costs of individual index hospitalization as well as per patient total accrued annual costs were compared between those readmitted and those with only a single PICU admission per annum. A Hospitalization Resource Intensity Score for Kids (H-RISK) was calculated to compare hospital-level case-mix index between the two cohorts. The H-RISK is a validated risk adjustment measure that accounts for severity differences across pediatric populations (14). The H-RISK is a resource intensity weight derived from the HCUP KID 2016 database of all pediatric hospitalizations. The weight for a particular APR-DRG and severity level is calculated as the mean cost all patients in this group divided by the mean cost of all hospitalized patients. Every hospitalization in PHIS with the same APR-DRG and severity level is assigned the same H-RISK. To describe variation across hospitals and PICUs, the proportion of readmissions within a 12-month period among the participating sites was calculated and regional variations were assessed.

Statistical Analysis

Categorical variables were summarized with frequencies and percentages and compared between patients who did and did not experience a PICU readmission using chi-square tests. Continuous variables were summarized with geometric means and SDs due to their non-normal distributions and compared using Wilcoxon rank-sum tests. A generalized linear mixed-effects model with a binomial distribution was developed to assess factors associated with readmission. Included in the model were demographic and clinical factors found to be associated with readmission at p values of less than 0.10 in bivariable analyses. Additionally, we controlled for patient clustering through a random intercept for each hospital. All statistical analyses were performed using SAS v.9.4 (SAS Institute, Cary, NC), and p values of less than 0.05 were considered statistically significant. This study was considered nonhuman subjects research by the institutional review board at the University of Chicago (IRB20-0737).

RESULTS

There were 257,183 patients admitted to participating PICUs during the 2-year study period (**Fig. 1**). After applying exclusion criteria, a total of 239,157 patients were included in the analysis as index admissions. Overall, 36,970 patients (15.5%) discharged from the PICU required readmission to the PICU within 12 months of their index discharge. There was notable variation in PICU readmission rates between the contributing centers (**Fig. 2**). Risk factors for readmission identified on the index admission were identified (**Supplemental Digital Table**, http://links.lww.com/CCX/A510). Compared with those who were not readmitted to the PICU, readmitted patients had significant differences in age, race, median household income, discharge season, census region, payor, number of CCCs, and final discharge disposition. Of these, payor, CCC, and disposition were also clinically significant. Patients who were readmitted also had significantly higher mean H-RISK score on the index admission than those who did not require readmission (4.4 vs 2.6; $p < 0.001$).

Both per-patient PICU costs and total hospital costs were significantly higher during the index admission in patients ultimately readmitted than those who did not require readmission with PICU care within 12 months (**Table 1**). The total cost attributed to the 202,187 patients who were not readmitted was $9.72 billion and this group accounted for 1.97 million patient days (**Table 2**). The costs attributed to the 36,970 index admissions for readmitted patients were $3.83 billion.

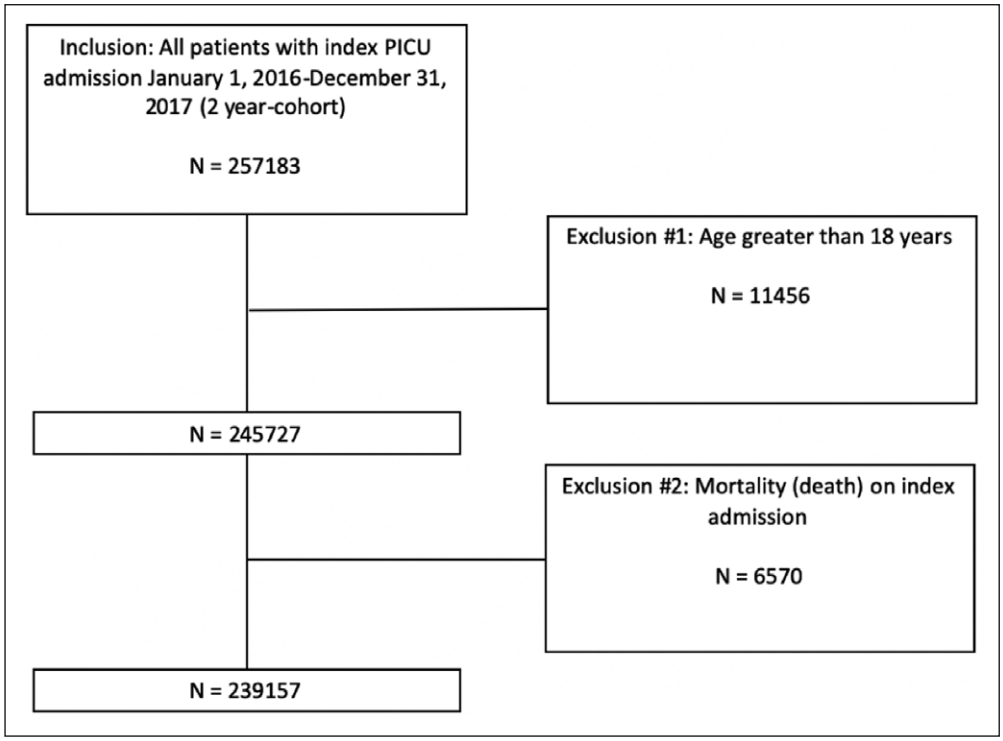

Figure 1. Consort diagram of patient cohort.

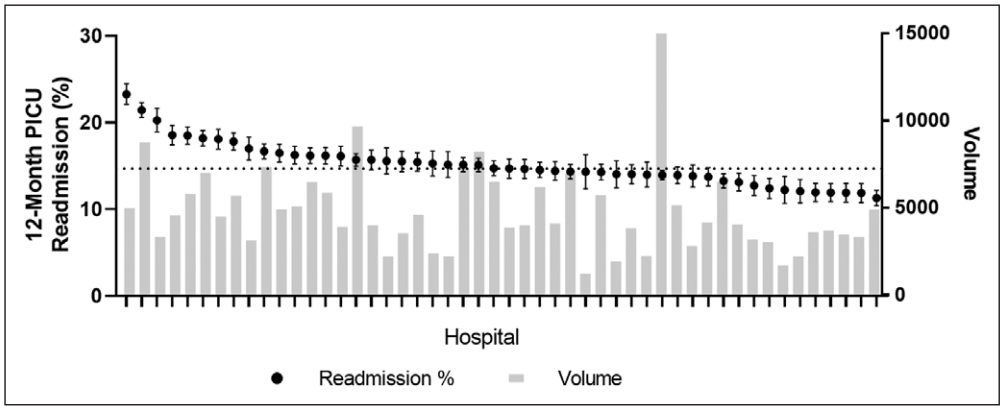

Figure 2. Variation in proportion of readmissions requiring PICU care within a 12-mo period among participating sites.

In total, readmitted patients requiring any PICU care within 12 months of their index admission accounted for an additional $3.71 billion in hospital care above the index admission costs and added 702,200 hospital days, including PICU days. Although 43.6% of all costs were spent on patients who required readmission, these patients who were readmitted with PICU care only accounted for 15.5% of the index patients and 28% of expenditures for the index stay. The total hospital cost for all index admissions and readmissions was $17.3 billion, of which 21.5% was incurred during a readmission stay involving care in the PICU; of the 3,459,079 hospital days, 20.3% were readmission hospital days including PICU days incurred during the readmission stay. Of the readmitted patients, 11,703 (30.0%) were admitted to and discharged directly from the PICU without spending any time in the general ward. These patients accounted for $662 million in costs (17.8% of readmission costs) and 110,215 PICU days (15.7% of readmission days). Additionally, mean index admission length of stay (LOS) was higher in those readmitted than in those not readmitted both for total hospital LOS (8.7 vs 4.9 d; $p < 0.001$) and PICU LOS (3.9 vs 2.3 d; $p < 0.001$). A total of 67.4% of the readmitted patients had a single readmission in the ensuing 12-month period following index discharge; however, 19.4% of the readmitted patients had two readmissions and 13.2% had three or more admissions requiring PICU care within 12 months of the index admission.

Three of the top five APR-DRGs at the index admission were identical between the patients with a single admission and those requiring readmission. These included "pulmonary edema and respiratory failure," "bronchiolitis and respiratory syncytial virus (RSV) pneumonia," and "craniotomy except for trauma." The two remaining APR-DRGs for patients who were not readmitted were "other cardiothoracic procedures" and "asthma," whereas in the patients requiring readmission, the two remaining APR-DRGs were "neonate birth weight greater than 2499 g with major cardiovascular procedure" and "seizure."

TABLE 1.
Per Patient Hospital Resources Used on the Index Admission by Those Readmitted

Resource	Overall	Not Readmitted	Readmitted	*p*
Total hospital costs, mean (SD), $	24,835 (3.2)	22,735 (3.1)	40,261 (3.7)	< 0.001
Clinical	2,149 (5.3)	1,916 (5.1)	3,937 (6)	< 0.001
Pharmacy	1,189 (6.8)	1,050 (6.6)	2,338 (7.1)	< 0.001
Imaging	1,140 (5)	1,045 (4.8)	1,752 (5.3)	< 0.001
Laboratory	1,780 (4.6)	1,620 (4.4)	2,955 (5.3)	< 0.001
Supply	656 (9)	610 (9)	947 (8.4)	< 0.001
Other	14,296 (3.1)	13,201 (2.9)	22,110 (3.6)	< 0.001
PICU costs, mean (SD), $	16,696 (3.4)	15,351 (3.2)	26,429 (4)	< 0.001
Clinical	1,499 (5.7)	1,342 (5.4)	2,652 (6.6)	< 0.001
Pharmacy	712 (7.3)	633 (7)	1,350 (7.8)	< 0.001
Imaging	834 (4.8)	761 (4.6)	1,293 (5.4)	< 0.001
Laboratory	1,317 (4.7)	1,204 (4.5)	2,135 (5.6)	< 0.001
Supply	602 (9.3)	564 (9.3)	830 (8.9)	< 0.001
Other	9,708 (3.2)	8,996 (3)	14,720 (3.8)	< 0.001
Total hospital LOS, mean (SD), d	5.4 (3)	4.9 (2.8)	8.7 (3.6)	< 0.001
PICU LOS, mean (SD), d	2.5 (2.7)	2.3 (2.5)	3.9 (3.4)	< 0.001

LOS = length of stay, mean = geometric mean.

TABLE 2.
Hospital Costs and Patient Days Associated With Patient Index Admission and Readmission (Total 12-mo Days and Costs)

Patient Cohort	*n*	Total Index Admission Costs ($)	Additional 12-mo Readmission Costs ($)	Total Index Admission Days	Total 12-mo Readmission Days
Without readmission	202,187	9,721,124,058	0	1,967,323	0
Readmission	36,970	3,830,325,519	3,711,324,783	789,556	702,200

A significantly higher proportion of patients with any CCC were readmitted to the PICU within 12 months of index discharge compared with those who were not readmitted (83.9% vs 54.9%; $p < 0.001$). In addition, in the multivariable analysis of factors associated with readmission, the odds of readmission increased significantly with each additional CCC (**Table 3**). Compared with patients discharged directly to home without home healthcare, patients discharged to a skilled nursing facility had 18% lower odds of readmission (odds ratio [OR], 0.82 [95% CI, 0.75–0.89]; $p < 0.001$) and those discharged to home with home healthcare had 43% higher odds of readmission (OR, 1.43 [95% CI, 1.36–1.51], $p < 0.001$). Finally, on the index admission, the presence of new technology including tracheostomy, gastrostomy tube, internal diverting CSF shunt, or the use of invasive mechanical ventilation during the index PICU admission all

TABLE 3.
Multivariable Analysis of Factors Associated With Readmission

Category	Characteristic	Adjusted OR (95% CI)	*p*
Age, yr	0–4	1.25 (1.21–1.3)	< 0.001
	5–9	0.96 (0.92–1.01)	0.100
	10–14	1.02 (0.98–1.07)	0.329
	15–18	Reference	
Race/ethnicity	Non-Hispanic White	Reference	
	Non-Hispanic Black	1.2 (1.16–1.24)	< 0.001
	Hispanic	1.12 (1.08–1.16)	< 0.001
	Asian	1.02 (0.95–1.09)	0.673
	Other	0.95 (0.91–0.99)	0.012
Median household income	Q1	1.15 (1.05–1.26)	0.003
	Q2	1.22 (1.13–1.33)	< 0.001
	Q3	1.2 (1.1–1.3)	< 0.001
	Q4	Reference	
Payer	Government	1.15 (1.12–1.18)	< 0.001
	Private	Reference	
	Other	0.97 (0.92–1.03)	0.340
Number of complex chronic conditions	0	Reference	
	1	2.48 (2.4–2.57)	< 0.001
	2	4.26 (4.1–4.43)	< 0.001
	3+	5.96 (5.7–6.24)	< 0.001
Disposition	Home health	1.43 (1.36–1.51)	< 0.001
	Home	Reference	
	Skilled facility	0.82 (0.75–0.89)	< 0.001
	Other	0.75 (0.71–0.8)	< 0.001
Calculated Hospitalization Resource Intensity Score for Kids Score		1.02 (1.01–1.02)	< 0.001
Resources	Tracheostomy tube	1.41 (1.34–1.49)	< 0.001
	Gastrostomy tube	1.56 (1.5–1.62)	< 0.001
	Diverting cerebral spinal fluid shunt	1.27 (1.2–1.34)	< 0.001
	Mechanical ventilation	1.07 (1.04–1.1)	< 0.001

OR = odds ratio.

increased the odds of readmission within 12 months of PICU discharge.

DISCUSSION

In this sample of U.S. children's hospitals, 15.5% of children discharged from the PICU required at least one readmission requiring PICU care within 12 months of discharge. These readmitted patients accounted for 20% of hospital bed use annually. The readmission rate for children who require PICU care in this study is comparable with prior data with PICU readmission rates ranging from 9.8% to 36% (4, 15–17). However, the rate of readmission requiring PICU care within 12 months after discharge is more than twice the unadjusted 30-day all-cause readmission rate for all hospitalized American children (10). This work builds on prior work by extending the readmission window to 12 months and includes hospital stays where PICU care was only part of the stay, rather than comprising the entire hospitalization. The financial impact of repeated discrete readmissions to the PICU was previously unknown and our study provides new data quantifying the costs generated by patients who have more than one annual hospitalization requiring PICU care.

PICU resources are more frequently used by children with CCCs (12, 18). Some medically complex children require the PICU for technological support and will require readmission for any hospital-based inpatient care. In our study, 30% of the patients readmitted to the PICU spent their entire readmission in the PICU, with no hospital days on the general ward. In addition, our data reinforce prior work that demonstrate the odds of readmission increase as the number of CCCs increases, with nearly six-fold higher odds of readmission for children with three or more CCCs compared to those without any CCC (19, 20).

Readmitted patients discharged with home health support had 43% higher odds of readmission and those discharged to a skilled nursing facility had 18% lower odds of readmission compared with those patients discharged directly to home without home healthcare. The reason for these differences is unclear but may reflect available community resources and differences in home-healthcare support services available for patients with medical complexity. It also may suggest that there is an underappreciation of the subacute medical needs of children with medical complexity who could benefit from ongoing care in a skilled nursing facility after discharge but prior to transitioning to home with home health support. In addition, prior studies have shown that social determinants of health are risk factors for readmission of individual children and also for readmission at the hospital level (15, 21–23). In our study, social determinants of health domains of minority race, government payer, and lower income quartiles were independent risk factors for 12-month readmission to the hospital requiring PICU care. Although not the focus of this study, identifying variations in care delivery as a result of socioeconomic factors may represent a critical step in reducing health disparities and improving quality of care.

To date, there are no multiinstitutional cost analyses for all children with recurrent hospitalizations requiring PICU care within 12 months following hospital discharge. Several single-institutional studies have proposed initiatives to reduce the high cost of PICU care specifically for technology-dependent children (24–26). Our study builds on prior literature, because it quantifies the financial impact and resources that readmissions requiring PICU care place on the medical system as a whole. In addition, we demonstrate that key driver to added costs of readmission is primarily the room charge associated with PICU care. Thus, cost savings to the medical system can be realized if hospitals ensure that only those patients who have true PICU-level care requirements occupy PICU beds. Finally, we note that the top five APR-DRGs are similar on the index admission between those with a single PICU stay and those requiring an additional hospital stay with PICU care in the subsequent 12 months. It is unlikely that patients with APR-DRGs including pulmonary edema and respiratory failure, bronchiolitis and RSV pneumonia, and seizure were planned readmissions to the PICU. In addition, although "craniotomy except for trauma" was likely due to a planned operative procedure, this DRG appeared in the top five APR-DRGs for both groups.

There are a number of limitations to this study. The data obtained from PHIS are limited to administrative discharge data without clinical information beyond what can be captured from billing and claims data derived from ICD-10 diagnosis and procedure codes. As such, clinical-level data that can inform whether readmissions were planned or unplanned can only be inferred. However, the top five APR-DRGs were similar

between both groups, suggesting that readmissions were not driven overall by staged surgical or intended readmissions. PHIS data cover 20–25% of freestanding children's hospitals and children's hospitals account for only about 30% of all pediatric hospitalizations in the United States, and thus, these data may underestimate the actual U.S. financial burden and may not reflect smaller community hospitals. Although patient readmission status was confirmed using unique patient identifier numbers, these data are limited to only those hospitals participating in the PHIS program. Only those patients who underwent procedures for tracheostomy, gastrostomy tube, or internal CSF shunt during their index hospital stay were considered to have these resources in place during the index admission, and thus, the technology resource calculations likely omit patients with these adjuncts in place prior to the index admission. The schema by Feudtner et al to classify children with CCC is imperfect, and not all children with special healthcare needs have a CCC (13). Although nearly a fifth of PICU readmissions in this study had no CCC, some may have had special medical needs. Lastly, the hospitals in this analysis are all pediatric tertiary-care hospitals in the U.S. and costs may not be representative of the broader pediatric healthcare system. Despite these limitations, this study provides previously unpublished financial information regarding hospital readmissions where PICU care is required, beyond the usual 30-day window.

CONCLUSIONS

In a cohort of U.S. children's hospitals, over a 2-year period, PICU patients who were readmitted within 12 months of hospital discharge accounted for 20% of hospital bed days and added an additional $3.7 billion (21.5%) to total healthcare costs. The current study provides novel readmission financial data that may inform resource utilization associated with PICU care. Although most children readmitted have complex medical conditions that may inherently require PICU resources, a sizable minority do not have any chronic comorbidities. Ultimately, these data may inform decisions regarding opportunities to optimize allocation of PICU resources.

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The authors have disclosed that they do not have any potential conflicts of interest.

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