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Variation in Triage to Pediatric vs Adult ICUs Among Adolescents and Young Adults With Asthma Exacerbations

Burton H. Shen, MD,
Pulmonary Center, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Aaron C. Dobie, MD,
Pulmonary Center, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Sara L. Shusterman, MD,
Pulmonary Center, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Mine Duzgol, MD,
Pediatric Infectious Disease, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Collin Homer-Bouthiette, MD,
Pulmonary Center, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Lauren E. Kearney, MD,
Pulmonary Center, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Julia Newman, MD,
Pulmonary Center, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Brandon Pang, MD,
Pulmonary Center, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Divya A. Shankar, MD,
Pulmonary Center, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Jingzhou Zhang, MD, MPH,
Pulmonary Center, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Kari R. Gillmeyer, MD,

CORRESPONDENCE TO: Burton H. Shen, MD; BHShen@BU.edu.

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Pulmonary Center, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Nicholas A. Bosch, MD,
Pulmonary Center, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Anica C. Law, MD
Pulmonary Center, Boston University Chobanian & Avedisian School of Medicine, Boston, MA.

Abstract

BACKGROUND: More than 90,000 children and adults in the United States are hospitalized with an asthma exacerbation annually, and between 5% and 34% of these hospitalizations include admission to an ICU. It is unclear how adolescent and young adults with severe asthma exacerbations are triaged in the inpatient setting between PICUs and adult ICUs. Using a large multicenter US cohort, we characterized how hospitals triage adolescents and young adults with asthma exacerbations between PICUs and adult ICUs.

RESEARCH QUESTION: How do hospitals across the United States triage adolescents and young adults with asthma exacerbations between PICUs and adult ICUs?

STUDY DESIGN AND METHODS: This was a retrospective cohort study carried out from 2016 through 2022 using the enhanced-claims PINC AI database. Participants were patients aged 12 to 26 years who were hospitalized with an asthma exacerbation and admitted to a PICU or adult ICU. We used nested hierarchical multivariable regression models to quantify changes in the intraclass correlation coefficient (ICC; a measure of variation in triage decisions attributable to hospital of admission after accounting for covariables).

RESULTS: Analyses included 3,946 admissions from 93 hospitals. Stratified by age, the percent of patients admitted to PICUs dropped by 26.9% between 17 and 18 years of age. In the nested models, the ICC showed a large decrease going from the empty model (28.7%) to the age-adjusted model (4.5%), but was similar between the age-adjusted and fully adjusted model (3.4%).

INTERPRETATION: Our results showed that among adolescents and young adults with asthma exacerbations, age of 18 years or younger was a strong determinant of PICU triage. Further research is needed to understand differences in asthma care and outcomes between PICUs and adult ICUs, as well as how intermediate care units affect triage decision-making from wards and the ED.

Keywords

asthma; MICU; PICU; practice variation

More than 90,000 children and adults in the United States are hospitalized with an asthma exacerbation annually,[1] and between 5% and 34% of these hospitalizations include an admission to an ICU.[2,3] Prior studies have examined how adolescents and young adults with asthma are triaged between pediatric and adult providers in the outpatient setting,[4] revealing that patients transition from pediatric to adult providers at a wide range in ages because of a complex interplay of factors. Similarly, it is known that adults with some childhood-onset chronic conditions, such as cystic fibrosis, congenital heart disease, and cerebral palsy, continue to be admitted to PICUs.[5] It remains unclear how adolescents and young adults with severe asthma exacerbations—a chronic condition with variable age onset—are triaged in the inpatient setting between PICUs and adult ICUs.

Practice patterns for the same illness, such as asthma, may differ between pediatric and adult providers.[6-8] It is important to know the factors affecting how adolescents and young adults are triaged to understand whether such differences in care may be warranted (eg, because of a difference in clinical presentation or variance in physiologic features) or unwarranted (eg, because of logistic cutoffs that may not have a direct bearing on clinical presentation). As a first step toward optimizing the triage of critically ill adolescents and young adults with asthma exacerbations, we sought to characterize how hospitals across the United States triage adolescents and young adults with asthma exacerbations between PICUs and adult ICUs and whether availability of step-down units affected the acuity of patients in PICUs and adult ICUs.

Study Design and Methods

We used the Premier PINC AI Healthcare Database (2016-2022), an enhanced claims-based database including approximately 25% of US inpatient hospitalizations.[9] In the primary analysis, we identified all patients aged 12 to 26 years[10,11] with an asthma exacerbation (per adapted algorithm: International Classification of Disease, 10th Revision, codes [present on admission] J45.901-2, J45.21-2, J45.31-2, J45.41-2, or J45.51-2 and receipt of systemic corticosteroids on hospital day 1[12]) who were admitted to an ICU on hospital day 1. To capture a wide range of triage settings, patients could have been admitted to the ICU from any route, including the ED, from a general or intermediate care unit, or from the outpatient setting. The lower limit of adolescence was defined as 12 years of age to be consistent with the definition of adolescence in the Global Initiative for Asthma guidelines on inhaler use for asthma.[11] The upper limit of young adults was defined as 26 years of age, because individuals can remain on parents' insurance up that age; prior literature similarly has defined young adulthood as up to 26 years of age.[10] We performed a sensitivity analysis of patients 15 to 20 years of age to limit the potential effects resulting from physiologic differences in the primary cohort with a larger age range. Because our primary interest was inhospital triage practices between PICUs or adult ICUs, we included patients admitted to hospitals with both a PICU and an adult ICU. We excluded patients who received surgery on hospital day 1 or were admitted from an outside hospital, because triage decisions may be affected by external factors. The outcome was admission to PICU (vs adult ICU) on hospital day 1. We reported the percentage of patients admitted to PICUs overall and stratified by hospital and age.

To assess the role of patient-level and hospital-level characteristics in variation in PICU triage, we built a series of nested hierarchical logistic regression models that included: (1) only the admission hospital as random intercept (empty model), (2) age and admission hospital, and (3) all patient-level characteristics (demographics, chronic comorbidities using the Pediatric Medical Complexity Algorithm index,[13] and acute organ dysfunctions present on admission using a risk-adjustment algorithm validated against the Sequential Organ Failure Assessment score[14]), hospital-level characteristics (teaching status, region, safety net status, size), and admission hospital. Variables chosen for model inclusion were determined a priori based on literature review[5] and were augmented by group author input to capture all available variables that may have an explanatory role in ICU triage. International Classification of Disease, 10th Revision, codes used for diagnoses on admission are included in e-Table 1. Age was incorporated as a categorical variable to allow for assessment of odds of PICU admission at each age. For each model, we reported the intraclass correlation coefficient (ICC) to quantify the degree of between-hospital variation in triage remaining unexplained by fixed effects and the Akaike information criterion (AIC), a measure of model fit (lower numbers reflecting better fit). We also report adjusted ORs (95% CIs) to quantify the association between each fixed effect and PICU admission.

To characterize triage practices further, we performed a post hoc analysis examining admission to the so-called wrong ICU in two separate hierarchical logistic regression models with hospital of admission as the random intercept and the same fixed effects as in our primary analysis. We identified patient and hospital characteristics associated with (1) patients aged 15 to 17 years being admitted to an adult ICU and (2) patients aged 18 to 20 years being admitted to a PICU. We also quantified how all hospitalized patients aged 12 to 26 years (in the same set of hospitals with both PICUs and adult ICUs) admitted with an asthma exacerbation (using the same inclusion criteria as the primary analysis) were triaged at each age between ward units, intermediate care units, and ICUs. This study was deemed not human subjects research by the Boston University institutional review board (#H-41795).

Results

We identified 3,946 patients from 93 hospitals with asthma exacerbations admitted to ICUs (PICU: 2,546 [64.5%]; adult ICU: 1,400 [35.5%]). The median age was 17 years (interquartile range, 13-21 years; PICU: 14 years [interquartile range, 12.5-15.5 years]; adult ICU: 22 years [interquartile range, 20-24 years]; Table 1).

The percent of patients admitted to PICUs at each hospital ranged from 6.7% to 97.1%. Stratified by age, the percent of patients admitted to PICUs dropped by 26.9% between 17 and 18 years of age (Fig 1A). In the nested models, the ICC (proportion of between-hospital variance that remains unexplained after accounting for known characteristics) showed a large decrease going from the empty model (28.7%) to the age-adjusted model (4.5%), but was similar between the age-adjusted and fully adjusted model (3.4%). Likewise, the AIC decreased from the empty model (4,682) to the age-adjusted model (1,367), but not from the age-adjusted model to the fully adjusted model (1,343) (Fig 2). In sensitivity analyses of patients aged 15 to 20 years (1,596 patients from 93 hospitals), we observed higher ICCs in all three models, although the AIC similarly improved most significantly when adding age to the models (empty: 25.6% [AIC, 1,740]; age-adjusted, 25.8% [AIC, 836]; fully-adjusted ICC, 19.5% [AIC, 863]) (e-Table 2).

In the adjusted model (Table 1), age was associated strongly with admission to the PICU. Compared with the reference age of 12 years, the odds of PICU admission decreased for patients 17 years of age (adjusted OR [aOR], 0.30; 95% CI, 0.15-0.59) and patients older than 17 years (eg, 18; aOR, < 0.01; 95% CI, < 0.01-< 0.01]). Other characteristics associated with PICU admission included hospital location (Northeast vs Midwest; aOR, 38.74; 95% CI, 6.56-100).[15]

In the adjusted models assessing characteristics associated with admission to the so-called wrong ICUs, the only significant variable associated with patients aged 18 years or older being admitted to a PICU was admission to a hospital in the Northeast region ($P = .001$) and sickle cell disease ($P = .008$). No significant factors were associated with patients younger than 18 years admitted to adult ICUs (e-Tables 3, 4).

Among 12,548 patients admitted to the same set of hospitals with an asthma exacerbation, 6,857 patients (54.6%) were admitted to a ward, 1,745 patients (13.9%) were admitted to an intermediate care unit, and 3,946 patients (31.4%) were admitted to an ICU. The percentage of patients admitted to ward, intermediate care unit, and ICU stratified by age are shown in Figure 1B. Use of intermediate care units increased at 18 years of age, whereas admission to wards and ICUs decreased at 18 years of age.

Discussion

We characterized variation in triage practices to the PICU and adult ICU in adolescents and young adults with asthma exacerbations in the United States. Prior studies have shown that when adolescents transition to adult outpatient asthma providers, complex social, emotional, and physical challenges can impact asthma control, with the optimal age to transition determined on an individual basis.[4] However, we found that age—particularly between 17 and 18 years—was by far the strongest driver of triage to the PICU vs adult ICUs. Because the ICC and AIC can inform the degree of between-hospital variation that remains unexplained by variables in the model, the large drop in ICC and AIC from the empty model to the age-adjusted model (with minimal change on further adjustment of other variables) highlights the large explanatory role that age plays in determining triage to PICUs, whether by official hospital policy or by informal practice. It remains unclear if patient factors (eg, medical, social, emotional) might identify better patients who should preferentially receive treatment in PICUs, delaying transition to an adult ICU beyond 18 years of age. Future studies should explore patient perceptions of PICU vs adult ICU care, patient self-reported readiness for adult ICUs, and heterogeneity of management and outcomes between PICUs and adult ICUs based on patients' characteristics.

In our analysis of so-called wrong ICU admission, we found that admission in the Northeast region and sickle cell disease were associated with patients older than 18 years being admitted to the PICU. The sample size for this analysis is small and the CI for the effect of the Northeast region is wide, which limits the inferences that can be drawn. However, we note that the higher ratio of pediatric subspecialists per 100,000 pediatric patients in the Northeast census region may help to explain the practice variation results in the post hoc analysis.[16-19] We hypothesize that pediatric subspecialists (eg, outpatient pulmonologists who have a long-term relationship with patients from a pediatric age) may be more comfortable with managing complex diseases into early adulthood and may admit patients to pediatric beds preferentially, even beyond the age of 18 years. Among patients with concurrent sickle cell disease, the relative burden of mortality has shifted from childhood into young adulthood, which may cause subspecialists to avoid transitioning from pediatric to adult care during clinically tenuous young adulthood.[20] Patient-centric transition plans for patients with sickle cell disease also may be more flexible to allow for patients to choose to postpone their first admission to an adult unit until after age 18 years.[21]

Regarding differences in hospital-wide triage in adult and pediatric populations, we found that admission to ward units remained stable at all ages. However, starting at age 18 years, the use of intermediate care units directly and significantly supplanted the use of ICUs. Because it is physiologically unlikely that a significant change in asthma severity occurs at age 18 years that would align with the differences in level of monitoring, it is much more likely that the change in triage is an artifact of the lack of availability of intermediate care units in pediatrics,[22] which has been shown to affect triage decisions in other settings.[23,24] It remains unclear if (1) patients younger than 18 years all warrant ICU level of care and instead could be cared for safely in a less intensely monitored environment; (2) if patients 18 years of age and older admitted to an intermediate care unit (who otherwise might have been admitted to a PICU at a younger age) are all receiving sufficient monitoring and management; or (3) if triage of adolescent and young adult patients to intermediate care units, PICUs, or adult ICUs could be optimized better by tailoring to clinical characteristics, rather than age alone.

Our study has limitations. First, administrative data can be vulnerable to misclassification. However, we adapted a previously published algorithm for asthma hospitalizations by narrowing included diagnosis codes to increase specificity.[12] Second, circumstances not captured in administrative data (eg, having a pediatric pulmonologist) might have influenced whether a patient was admitted to a PICU or adult ICU; however, the ICC remaining after adjustment for covariables was low, suggesting that few strong explanatory factors of triage remain beyond those included in our model. Third, we were unable to assess the relationship between each hospital’s ED and inpatient units, or whether triage decisions are made primarily by the ED or an inpatient unit. Fourth, we were unable to assess whether the observed differences in asthma severity diagnostic codes between PICUs and adult ICUs actually represent a difference in practice between pediatric vs adult ICUs, rather than a driving factor in ICU triage. Finally, although we have the total number of beds for each hospital, we do not know how many beds are allocated to adult vs pediatric patients or how space constraints may factor into triage decisions.

Interpretation

Among adolescents and young adults hospitalized with asthma exacerbations, age of 18 years or younger was a strong driver of PICU triage. Adult patients also seemed more likely to be admitted to an intermediate care unit. Our results will inform future studies examining optimal ICU triage in young adults and adolescents. Further research is needed to understand differences in asthma care and outcomes between PICUs and adult ICUs, as well as how intermediate care units affect triage decision-making from wards and the ED.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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ABBREVIATIONS:

AIC	Akaike information criterion
aOR	adjusted odd ratio
ICC	intraclass correlation coefficient

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Take-home Points

Study Question:

Across the United States, what is the hospital variation in how adolescents and young adults with asthma exacerbations are triaged to either PICUs or adult ICUs?

Results:

Although the percent of adolescents and young adults with asthma exacerbations admitted to PICUs ranged from 6.7% to 97.1%, very little between-hospital variation was found after accounting for age alone (intraclass correlation, 4.5%). In hierarchical regression models, age was by far the strongest factor predicting PICU admission, rather than other clinical characteristics.

Interpretation:

In contrast to outpatient management of asthma or ICU triage of other chronic conditions, our results show that triage decisions between PICUs or adults ICUs for adolescents and young adults with asthma exacerbations seem to be determined almost entirely by age.

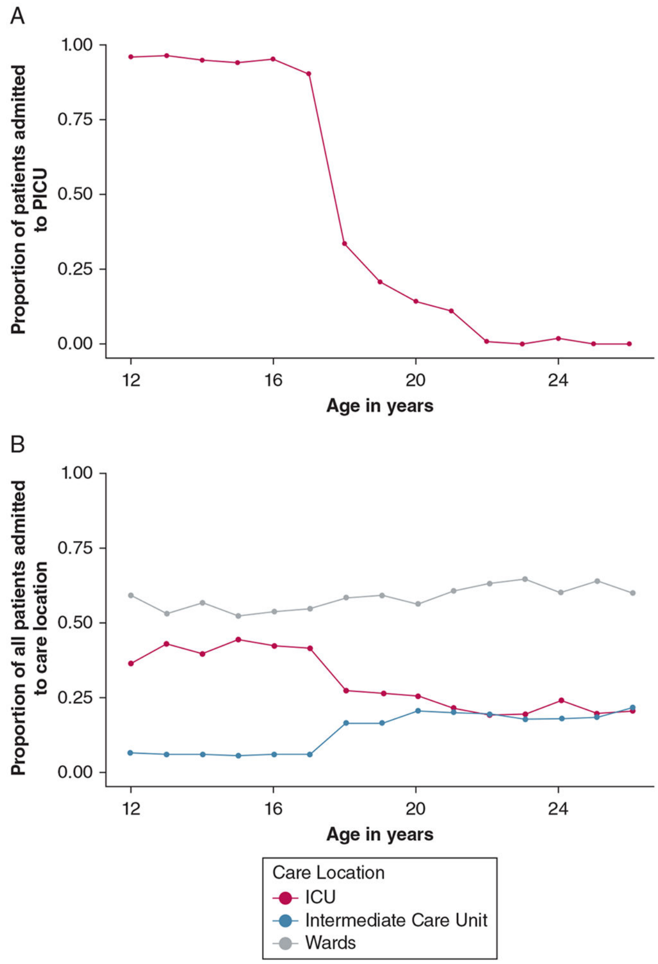

Figure 1 –.

A, Line graph showing unadjusted rates of PICU admission, stratified by age, among patients admitted to an ICU with an asthma exacerbation. B, Unadjusted proportion of patients admitted to a ward unit, intermediate care unit, and ICU stratified by age among all patients admitted to any hospital with an asthma exacerbation.

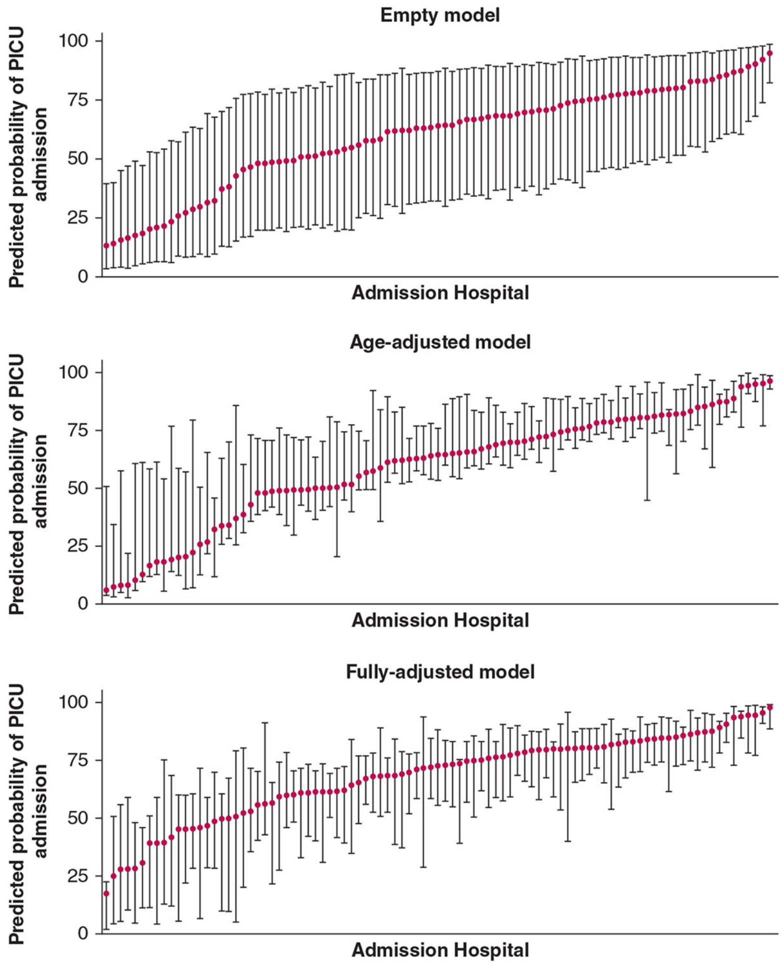

Figure 2 –.

Caterpillar plot showing empty model, age-adjusted model, and fully-adjusted model with variables listed in Table 1 (in each panel, hospitals are rank-ordered from lowest to highest predicted probability of PICU admission).

TABLE 1]

Baseline Characteristics for Patients With Asthma Exacerbations Admitted to PICU or Adult ICUs and Adjusted ORs for PICU Admission

Characteristics	PICU (n = 2,546)	Adult ICU (n = 1,400)	Adjusted OR[a] (95% CI)
Patient variables			
Age, y			
12	514 (20.2)	22 (1.6)	Reference
13	469 (18.4)	18 (1.3)	0.92 (0.43-1.98)
14	376 (14.8)	20 (1.4)	0.73 (0.34-1.57)
15	368 (14.5)	23 (1.6)	0.49 (0.23-1.04)
16	362 (14.2)	18 (1.3)	0.81 (0.37-1.78)
17	335 (13.2)	36 (2.6)	0.30 (0.15-0.59)
18	47 (1.8)	93 (6.6)	0.01 (< 0.01-0.01)
19	30 (1.2)	115 (8.2)	< 0.01 (< 0.01-< 0.01)
20	24 (0.9)	145 (10.4)	< 0.01 (< 0.01-< 0.01)
21	17 (0.7)	137 (9.8)	< 0.01 (< 0.01-< 0.01)
22	1 (0.0)	133 (9.5)	< 0.01 (< 0.01-> 100)
23	0 (0.0)	142 (10.1)	< 0.01 (< 0.01-> 100)
24	3 (0.1)	165 (11.8)	< 0.01 (< 0.01-< 0.01)
25	0 (0.0)	157 (11.2)	< 0.01 (< 0.01-> 100)
26	0 (0.0)	176 (12.6)	< 0.01 (< 0.01-> 100)
Sex			
Female	1,241 (48.7)	835 (59.6)	Reference
Male	1,305 (51.3)	565 (40.4)	1.01 (0.72-1.42)
Race			
Asian	39 (1.5)	17 (1.2)	Reference
Black	1,023 (40.2)	494 (38.6)	1.71 (0.43-6.91)
White	1,036 (40.7)	702 (50.1)	1.70 (0.43-6.82)
Other[b]	369 (14.5)	157 (11.2)	2.14 (0.50-9.16)
Unknown	79 (3.1)	30 (2.1)	1.69 (0.29-9.78)
Hispanic			
No	1,706 (67.0)	975 (69.6)	Reference

Characteristics	PICU (n = 2,546)	Adult ICU (n = 1,400)	Adjusted OR[a] (95% CI)
Yes	427 (16.8)	175 (12.5)	0.93 (0.51-1.69)
Unknown	413 (16.2)	250 (17.9)	0.74 (0.40-1.36)
Medicaid (vs other)	2,468 (96.9)	1,206 (86.1)	1.45 (0.71-2.98)
COVID-19 present on admission	94 (3.7)	68 (4.9)	0.93 (0.39-2.25)
Acute renal failure present on admission	1,285 (50.5)	1,026 (73.3)	0.99 (0.68-1.44)
Cystic fibrosis present on admission	2 (0.1)	3 (0.2)	0.64 (0.02-21.86)
Substance use disorder present on admission[c]	137 (5.4)	492 (35.1)	0.77 (0.37-1.58)
Nicotine use present on admission	79 (3.1)	492 (35.1)	0.98 (0.41-2.34)
Sickle cell disease present on admission	23 (0.9)	15 (1.1)	2.29 (0.51-10.22)
Pregnancy present on admission	5 (0.2)	18 (1.3)	0.38 (0.06-2.27)
Asthma severity			
Mild intermittent or persistent	362 (14.2)	93 (6.6)	Reference
Moderate persistent	688 (27.0)	132 (9.4)	1.35 (0.69-2.65)
Severe persistent	682 (26.8)	327 (23.4)	0.70 (0.38-1.31)
No diagnosis code for severity	814 (32.0)	848 (60.6)	0.55 (0.31-0.99)
Season			
January-March	641 (25.2)	410 (29.3)	Reference
April-June	652 (25.6)	333 (23.8)	1.46 (0.91-2.32)
July-September	584 (22.9)	315 (22.5)	1.47 (0.91-2.32)
October-December	669 (26.3)	342 (24.4)	1.15 (0.72-1.82)
Acute organ dysfunction			
Cardiac	81 (3.2)	117 (8.4)	1.31 (0.54-3.21)
Neurologic	69 (2.7)	141 (10.1)	0.52 (0.22-1.26)
Renal	67 (2.6)	114 (8.1)	1.06 (0.43-2.63)
Hepatic	4 (0.2)	21 (1.5)	0.63 (0.06-6.67)
Hematologic	32 (1.3)	39 (2.8)	1.70 (0.42-6.92)
Pediatric Medical Complexity Algorithm (noncomplex)[d]	1,510 (59.3)	509 (36.4)	0.89 (0.62-1.29)
Hospital variables			
Rural	87 (3.4)	63 (4.5)	Reference
Urban	2,459 (96.6)	1,337 (95.5)	2.82 (0.43-18.39)
Teaching hospital	1,932 (75.9)	996 (71.1)	1.27 (0.48-3.37)

Characteristics	PICU (n = 2,546)	Adult ICU (n = 1,400)	Adjusted OR[a] (95% CI)
Safety net hospital	1,251 (49.1)	630 (45.0)	1.12 (0.49-2.56)
US census region			
Midwest	586 (23.0)	325 (23.2)	Reference
South	1,331 (52.3)	688 (49.1)	1.27 (0.45-3.64)
West	359 (14.1)	269 (19.2)	0.94 (0.27-3.33)
Northeast	270 (10.6)	118 (8.4)	9.91 (2.14-45.95)
Hospital size			
≤ 500 beds	1,831 (71.9)	1,018 (72.7)	1.20 (0.50-2.89)

Data are presented as No. (%) unless otherwise indicated. All covariables shown were included in the fully adjusted model.

[a]ORs are the odds of being admitted to a PICU compared with an adult ICU from the fully adjusted model.

[b]Some race designations have been rolled into "Other" to ensure that the data set conforms to HIPAA and other regulatory requirements.

[c]Inclusive of tobacco use history.

[d]The Pediatric Medical Complexity Algorithm categorizes patients into: (1) no chronic disease, (2) noncomplex chronic disease, and (3) complex chronic disease. Because asthma was part of our cohort inclusion criteria, all patients by definition have either noncomplex or complex chronic disease, and noncomplex chronic disease was the reference group in our model.