# Child Opportunity Index and Pediatric Intensive Care Outcomes: A Multicenter Retrospective Study in the United States



**OBJECTIVES:** To evaluate for associations between a child's neighborhood, as categorized by Child Opportunity Index (COI 2.0), and 1) PICU mortality, 2) severity of illness at PICU admission, and 3) PICU length of stay (LOS).

**DESIGN:** Retrospective cohort study.

**SETTING:** Fifteen PICUs in the United States.

**PATIENTS:** Children younger than 18 years admitted from 2019 to 2020, excluding those after cardiac procedures. Nationally-normed COI category (very low, low, moderate, high, very high) was determined for each admission by census tract, and clinical features were obtained from the Virtual Pediatric Systems LLC (Los Angeles, CA) data from each site.

**INTERVENTIONS:** None.

**MEASUREMENTS AND MAIN RESULTS:** Among 33,901 index PICU admissions during the time period, median patient age was 4.9 years and PICU mortality was 2.1%. There was a higher percentage of admissions from the very low COI category (27.3%) than other COI categories (17.2–19.5%, $p < 0.0001$). Patient admissions from the high and very high COI categories had a lower median Pediatric Index of Mortality 3 risk of mortality (0.70) than those from the very low, low, and moderate COI groups (0.71) ($p < 0.001$). PICU mortality was lowest in the very high (1.7%) and high (1.9%) COI groups and highest in the moderate group (2.5%), followed by very low (2.3%) and low (2.2%) ($p = 0.001$ across categories). Median PICU LOS was between 1.37 and 1.50 days in all COI categories. Multivariable regression revealed adjusted odds of PICU mortality of 1.30 (95% CI, 0.94–1.79; $p = 0.11$) for children from a very low versus very high COI neighborhood, with an odds ratio [OR] of 0.996 (95% CI, 0.993–1.00; $p = 0.05$) for mortality for COI as an ordinal value from 0 to 100. Children without insurance coverage had an OR for mortality of 3.58 (95% CI, 2.46–5.20; $p < 0.0001$) as compared with those with commercial insurance.

**CONCLUSIONS:** Children admitted to a cohort of U.S. PICUs were often from very low COI neighborhoods. Children from very high COI neighborhoods had the lowest risk of mortality and observed mortality; however, odds of mortality were not statistically different by COI category in a multivariable model. Children without insurance coverage had significantly higher odds of PICU mortality regardless of neighborhood.

**KEYWORDS:** intensive care unit; outcomes; pediatric; social determinants of health

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Lower socioeconomic status has been associated with increased use of emergency medical services, hospitalizations, and revisits for a variety of acute conditions in children (1–8). The underlying etiologies of association between social determinants and acute illness are incompletely



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## RESEARCH IN CONTEXT

- Socioeconomic status is associated with increased use of emergency services and hospitalization in children, but little is known about any association with PICU outcomes.
- The Child Opportunity Index (COI 2.0) is a multifaceted child-specific indicator of neighborhood environment incorporating 29 elements in three domains (Education, Health and Environment, Social and Economic).
- No previous study has evaluated PICU outcomes by census-tract assigned COI, using clinical data with adjustment for severity of illness.

understood, but may include inequities in access to preventive services and acute care, environmental factors, health literacy, increased comorbidity prevalence, and differences in healthcare delivery, among other factors (9, 10).

Child poverty has been associated with PICU admission (11), severity of illness (12, 13), mortality (13, 14), and readmission (15) in various populations of critically ill children. However, these studies used only estimated income or insurance status to assign socioeconomic status. The Child Opportunity Index (COI) is a more robust indicator that synthesizes multidimensional, pediatric-specific elements to describe neighborhood health (16), including nationally normed quintiles from very low to very high, each containing approximately 20% of the U.S. population. Recent studies demonstrated a predominance of lower COI groups in children hospitalized for acute illness (17), admitted to the PICU for asthma or acute respiratory failure (18, 19), as well as emergently readmitted to the PICU (20). However, each of these studies was limited by the use of zip code rather than census tract to assign COI and use of single-center (18, 19) or administrative (17, 20) data.

The purpose of this study was to evaluate for an association between the neighborhood in which a child lives and characteristics and outcomes of PICU admission from a large, multicenter, geographically diverse cohort using census-tract designated COI and clinical data. The specific objectives of this study were to evaluate whether COI was associated with 1) PICU mortality, 2) severity of illness on PICU admission, or 3) PICU length of stay (LOS) in children admitted to a cohort of U.S. PICUs. We hypothesized that lower COI would be associated with higher mortality, severity of illness, and LOS in PICU patients.

## MATERIALS AND METHODS

### Study Design and Population

This was a retrospective cohort study of index patient admissions from January 1, 2019, to December 31, 2020, to 15 PICUs across the United States (**Supplemental Fig. 1**, http://links.lww.com/PCC/C462). Admissions were queried from the Virtual Pediatric Systems (VPS) data, which is used for benchmarking, quality improvement, and research at each site (21). Prespecified exclusion criteria included age greater than or equal to 18 years, admission after cardiac surgical or catheterization procedure, severity of illness data or outcome data unavailable, and readmission of the same patient during the study period. No endorsement or editorial restriction of the interpretation of these data or the opinions of the authors has been implied or stated by VPS (LLC). The Wake Forest University School of Medicine Institutional Review Board (IRB number 00080442, title "Child Opportunity and PICU Outcome," date February 17, 2022), as well as the IRB of each participating center, approved the study (**Supplemental Table 1**, http://links.lww.com/PCC/C462). The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional or regional) and with the Helsinki Declaration of 1975, as most recently amended.

### Data Collection

Demographic, clinical, and outcome data were obtained from each site as previously entered into the VPS database, including severity of illness by Pediatric Index of Mortality 3 (PIM3) (22) and Pediatric Risk of Mortality III (PRISM III) (23). Limitations on care were designated in the database as a documented decision to either not offer or not escalate a therapy, with or without alteration of code status.

The local electronic medical record at each site was queried to obtain the patient address (at the time of

admission if possible), as well as primary payor and primary language spoken for each admission. Each of these indices, as well as race and ethnicity, have been shown to be relevant to health delivery and outcomes in acutely ill children and were thus considered important to evaluate for a possible association with PICU outcomes (3, 10, 12, 24–35). Addresses were mapped to census tract and subsequently assigned nationally normed overall COI categories of very low, low, moderate, high, or very high as well as a continuous ordinal variable (0–100) of neighborhood opportunity using the COI 2.0 (16). Census tracts are subdivisions of counties that are delineated by visible or nonvisible boundaries, typically remain relatively unchanged between census iterations, and contain between 1200 and 8000 people (26). The COI is a publicly available tool that measures and maps the resources and conditions in U.S. neighborhoods, using 29 component measures within three domains: education (e.g., early childhood education centers. Third-grade reading proficiency), health and environment (e.g., access to healthy food and green space, hazardous waste dump sites), and social and economic (e.g., employment rate, home ownership) (16). Post office boxes, addresses outside of the United States, and institutional addresses (such as long-term care facilities or hospitals) were excluded due to inability to accurately assign COI. Site principal investigators were encouraged to partner with site resources, such as complex care providers or discharge planners, to identify institutional addresses relevant to their patient population. Primary payor was categorized for each admission as government (Medicaid and Medicare), commercial, other (including those categorized as Tricare), self-pay, and missing/none. Medicaid or Medicare managed care plans were classified as government insurance. Tricare was designated in the other rather than government category due to previous data indicating substantial differences in health exposures and outcomes of children with Tricare as compared with Medicaid or Medicare coverage (27). Deidentified data from each institution were compiled by the coordinating center.

### Analyses

Primary outcome was PICU mortality, with secondary outcomes of severity of illness at PICU admission by PIM3 and PICU LOS. Continuous data were compared using the Wilcoxon rank-sum or Kruskal-Wallis test. Proportions were compared using Pearson chi-square test. A two-tailed $p$ value of less than 0.05 was considered statistically significant. Demographic or clinical categories with less than or equal to 1% of the data were combined for the analysis. For the multivariable regression analysis, all a priori identified exposure variables of interest were included (COI, PIM3 risk of mortality, age, sex assigned at birth, race and ethnicity, payor, primary language spoken, and origin of admission), as well as a random effect for center. Collinearity was assessed using variance inflation factor and condition index, with a threshold variance inflation factor greater than 5 or condition index greater than 10 for exclusion. Data were analyzed using SAS software, version 9.4 (SAS Institute, Cary, NC) or R, version 4.0.4 (June 22, 2020; R Foundation for Statistical Computing, Vienna, Austria).

Exploratory analyses were performed evaluating 1) using PRISM III for severity of illness adjustment, 2) the COI subdomains (education, health and environment, social and economic), and 3) the period from March to December 2020 during which epidemiology of PICU admissions was different (28). Post hoc pairwise analyses were also performed between all COI categories when a statistically significant difference was identified for severity of illness and other clinical characteristics, with Bonferroni correction for multiple comparisons. Additionally, since addresses may not always map to a census tract (e.g., nonresidential or commercial address, housing unit recently constructed or destroyed/demolished, location with missing information, local addressing authority changed the address) (29) or the census tract may not be in the COI mapping file (16), a post hoc analysis with addresses mapped to zip code-assigned COI was also performed. Finally, separate exploratory analyses with interaction terms between insurance "None/Missing" and COI categories, as well as with very low/low/moderate COI categories combined, were performed after review of the results.

## RESULTS

A total of 33,901 patient admissions were included and mapped to 19,829 distinct census tracts, representing 90% of index admissions to the 15 participating PICUs during the 2-year study period (**Fig. 1**). Participating PICUs were located in the Northeast ($n$ = 3), South ($n$ = 4), Midwest ($n$ = 4), and West ($n$ = 4) regions of the United States (Supplemental Fig. 1, http://links.lww.com/PCC/C462). Address was obtained at the

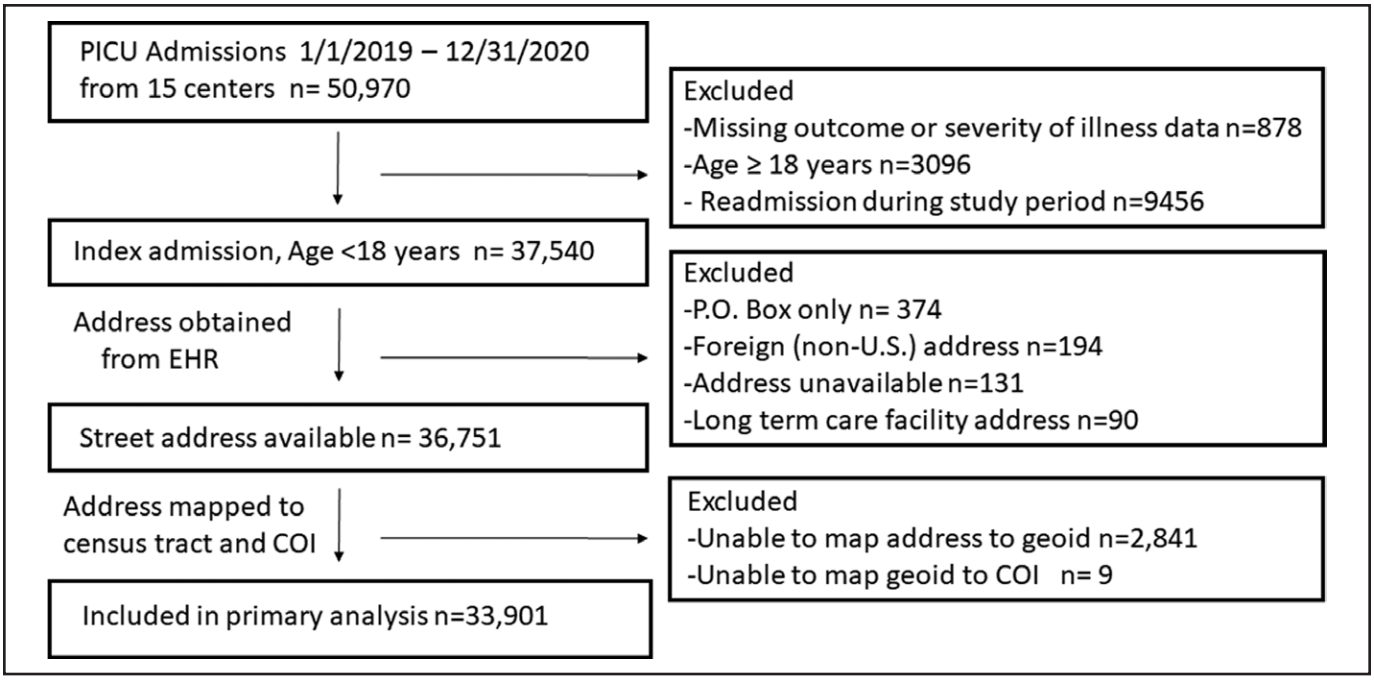


**Figure 1.** Study flow diagram. "Geoid" indicates 11-digit geographical identification number for census tract. COI = Child Opportunity Index, EHR = Electronic Health Record.



time of admission for 16,636 (49%) admissions, with the remainder obtained at the time of data pull.

COI category was very low in 9257 admissions (27.3%, range among centers, 13.4–38.3), low in 6596 (19.5%, range, 8.2–29.4), moderate in 6251 (18.4%, range, 15.8–27.6), high in 5951 (17.6%, range, 12.2–32.0), and very high in 5846 (17.2%, range, 4.7–29.3) ($p < 0.0001$ for comparison of proportions across categories). On post hoc pairwise comparison (Bonferroni adjusted), all pairs of proportions of COI categories were statistically significantly different except high versus very high (**Supplemental Table 2**, http://links.lww.com/PCC/C462). Median age was 4.9 years (interquartile range [IQR] 1.2–12.5), and 726 (2.14%) died during their PICU admission. Median PICU LOS was 1.4 days (IQR 0.8–3.0). Demographics stratified by COI category are displayed in **Table 1**.

Clinical characteristics by COI category are displayed in **Table 2**. Post hoc pairwise comparisons with Bonferroni adjustment revealed statistically significantly increased median PIM 3 risk of mortality for each of the very low, low, and moderate COI group when compared with the high or very high group, whereas observed mortality was only statistically significantly different between the moderate and very high groups (Supplemental Table 2, http://links.lww.com/PCC/C462). Use of invasive mechanical ventilation was highest in the moderate COI category and lowest in the very high category (post hoc pairwise comparisons in Supplemental Table 2, http://links.lww.com/PCC/C462), whereas limitations on care showed no statistically significant difference across groups. Median PICU LOS is displayed in **Figure 2**, and was within 3.1 hours for all groups (median [IQR] days by COI category: very low 1.37 [0.76–2.87], low 1.50 [0.78–3.25], moderate 1.46 [0.78–3.02], high 1.43 [0.78-2.95], very high 1.38 [0.78–2.85], $p = 0.001$ across categories [pairwise comparisons Supplemental Table 2, http://links.lww.com/PCC/C462]).

Results of multivariable logistic regression with the outcome of PICU mortality are displayed in **Table 3**. No substantial collinearity was found (all VIF < 5 and CI < 10). All other COI categories had an odds ratio [OR] greater than 1 for adjusted mortality compared with the very high group, with the highest adjusted odds in the very low group (OR 1.33; 95% CI, 0.95–1.87); however, all CIs included unity. Unknown race, none/missing insurance category, and certain origins of admission statistically significantly associated with increased odds of PICU mortality. When COI was used as a continuous variable (range, 0–100) and plotted against PICU mortality in the multivariable model, an OR of 0.996 (95% CI, 0.993–1.00; $p = 0.05$) was

## TABLE 1.
## Admission Characteristics by Child Opportunity Index Category

| Characteristic | All, *n* = 33,901, *n* (%) | Very Low, *n* = 9,257, *n* (%) | Low, *n* = 6,596, *n* (%) | Moderate, *n* = 6,251, *n* (%) | High, *n* = 5,951, *n* (%) | Very High, *n* = 5,846, *n* (%) |
|---|---|---|---|---|---|---|
| Age category | | | | | | |
| < 1 mo | 364 (1) | 82 (1) | 54 (1) | 82 (1) | 69 (1) | 77 (1) |
| 1 mo–<2 yr | 11,051 (31) | 3,038 (33) | 2,153 (33) | 2,014 (32) | 1,954 (33) | 1,892 (32) |
| 2–5 yr | 6846 (20) | 1,887 (20) | 1,327 (20) | 1,315 (21) | 1,143 (19) | 1,174 (20) |
| 6–12 yr | 7769 (23) | 2,235 (24) | 1,511 (23) | 1,406 (23) | 1,363 (23) | 1,254 (22) |
| 13–<18 yr | 7871 (23) | 2,015 (22) | 1,551 (23) | 1,434 (23) | 1,422 (24) | 1,449 (25) |
| Sex assigned at birth = female | 15,155 (45) | 4,116 (44) | 2,972 (45) | 2,744 (44) | 2,720 (46) | 2,603 (45) |
| Race/ethnicity | | | | | | |
| White | 15,656 (46) | 2,054 (22) | 2,796 (42) | 3,363 (54) | 3,608 (61) | 3,835 (66) |
| Black/African American | 7,301 (22) | 3,758 (41) | 1,282 (19) | 967 (15) | 748 (13) | 546 (9) |
| Hispanic or Latino | 5,321 (16) | 2,070 (22) | 1,367 (21) | 850 (14) | 622 (10) | 412 (7) |
| Other or mixed[a] | 3,556 (10) | 969 (11) | 822 (12) | 679 (11) | 571 (10) | 515 (9) |
| Asian | 1,218 (4) | 195 (2) | 164 (3) | 230 (3) | 253 (4) | 376 (6) |
| Unspecified | 849 (3) | 211 (2) | 165 (3) | 162 (3) | 149 (2) | 162 (3) |
| Payor | | | | | | |
| Government | 19,298(43) | 7,240 (78) | 4,350 (66) | 3,553 (57) | 2,593 (44) | 1,562 (27) |
| Commercial | 11,828(65) | 1,322 (14) | 1,618 (25) | 2,083 (33) | 2,839 (48) | 3,966 (68) |
| None/missing | 1,582 (5) | 466 (5) | 365 (5) | 351 (6) | 258 (4) | 142 (2) |
| Self-pay | 697 (2) | 163 (2) | 163 (2) | 140 (2) | 142 (2) | 89 (2) |
| Other | 496 (1) | 66 (1) | 100 (2) | 124 (2) | 119 (2) | 87 (1) |
| Primary language spoken | | | | | | |
| English | 30,302(89) | 7,655 (83) | 5,627 (85) | 5,735 (92) | 5,621 (94) | 5,664 (97) |
| Spanish | 2,956 (9) | 1,412 (15) | 837 (13) | 385 (6) | 231 (4) | 91 (2) |
| Other | 526 (2) | 145 (2) | 114 (2) | 110 (2) | 80 (1) | 77 (1) |
| Missing | 117 (< 1) | 45 (< 1) | 18 (< 1) | 19 (< 1) | 19 (< 1) | 14 (< 1) |
| Origin of admission | | | | | | |
| ED | 13,239(61) | 4,235 (46) | 2,567 (39) | 2,301 (37) | 2,110 (35) | 2,026 (35) |
| Outside ED | 5,943 (18) | 1,463 (16) | 1,204 (18) | 1,176 (19) | 1,098 (18) | 1,002 (17) |
| Operating room | 4,758 (14) | 1,145 (12) | 792 (12) | 829 (13) | 960 (16) | 1,032 (18) |
| General floor | 3,668 (11) | 1,043 (11) | 726 (11) | 634 (10) | 614 (10) | 651 (11) |
| Postanesthesia care unit | 2,895 (9) | 632 (7) | 625 (10) | 599 (10) | 523 (9) | 516 (9) |
| Outside ICU | 877 (3) | 214 (2) | 188 (3) | 183 (3) | 161 (3) | 131 (2) |
| Outside general floor | 733 (2) | 131 (1) | 144 (2) | 158 (3) | 152 (2) | 148 (2) |
| Other[b] | 1,788 (5) | 394 (4) | 350 (5) | 371 (6) | 333 (6) | 340 (6) |

[a]Those designated as American Indian or Alaska Native, Native Hawaiian/Pacific Islander, and other/mixed.

[b]Another ICU in same hospital, another location in an outside hospital, delivery room, home, physician's office/clinic, procedure suite, radiology, rehab center, step-down/intermediate unit, telemetry unit, transitional care/skilled nursing/chronic care facility, and other.

ED = emergency department.

## TABLE 2.
### Clinical Characteristics by Child Opportunity Index Category

| Characteristic | Very Low, *n* = 9255 | Low, *n* = 6,594 | Moderate, *n* = 6,250 | High, *n* = 5,950 | Very High, *n* = 5,846 | *p* |
|---|---|---|---|---|---|---|
| Pediatric Index of Mortality 3 risk of mortality, median (interquartile range) | 0.71 (0.23–1.09) | 0.71 (0.23–1.13) | 0.71 (0.23–1.15) | 0.70 (0.22–1.06) | 0.70 (0.22–1.05) | **< 0.0001** |
| Primary diagnosis category[a], *n* (%) | | | | | | |
| Respiratory | 3,729 (40) | 2,220 (34) | 2,024 (32) | 1,853 (31) | 1,979 (34) | **< 0.0001** |
| Neurologic | 1,226 (13) | 1,016 (15) | 986 (16) | 1,034 (17) | 950 (16) | |
| Infectious | 668 (7) | 498 (8) | 409 (7) | 412 (7) | 346 (6) | |
| Injury/poisoning/adverse effects | 611 (7) | 437 (7) | 468 (7) | 388 (7) | 338 (6) | |
| Endocrine | 510 (6) | 355 (5) | 314 (5) | 299 (5) | 248 (4) | |
| Oncologic | 341 (4) | 314 (5) | 313 (5) | 338 (6) | 422 (7) | |
| Other | 2,170 (23) | 1,644 (26) | 1,736 (28) | 1,626 (27) | 1,563 (27) | |
| Mortality, *n* (%) | 215 (2.3) | 143 (2.2) | 158 (2.5) | 110 (1.9) | 100 (1.7) | **0.001** |
| Invasive mechanical ventilation, *n*(%) | 1,991 (22) | 1,547 (23) | 1,542 (25) | 1,391 (23) | 1,191 (20) | **< 0.0001** |
| Limitations on care[b], *n* (%) | 112 (1.4) | 91 (1.5) | 89 (1.6) | 85 (1.6) | 57 (1.1) | 0.14 |

[a]Total *n* = 33,895 (99%) with primary diagnosis available. "Injury/poisoning/adverse effects" includes trauma. "Other" includes: cardiovascular, dermatologic, factors influencing health, gastrointestinal, genetic, gynecologic, hematologic, immunologic, metabolic, newborn/perinatal, ophthalmologic, orthopedic, psychiatric, renal/genitourinary, rheumatologic, symptoms, transplant, and ungroupable.
[b]Total *n* = 29,757 (88%) with limitations on care available.
Medians compared by Kruskal-Wallis test. Proportions compared by $\chi^2$. Boldface values indicate $p < 0.05$.

found with no nonlinear relationship between COI and mortality.

Children with none/missing insurance were similar to the overall cohort with respect to age, sex assigned at birth, and primary diagnosis category, but they were less commonly in the very high COI category (2% with none/missing insurance in very high category vs. 4–6% in other COI categories), and were more commonly categorized as White (57% White with none/missing insurance vs. 46% in all other categories) and less frequently categorized as Hispanic or Latino (2% Hispanic or Latino with none/missing insurance vs. 16% in all other categories) (**Supplemental Table 3**, http://links.lww.com/PCC/C462). When patient admissions with insurance "Missing" were excluded (*n* = 1425), those admissions with insurance category "None" (*n* = 157) had and OR for PICU mortality of 1.92 (95% CI, 0.77–4.77). When an interaction term was added into the model for each COI category with insurance category "None/Missing," none of the interactions were statistically significant (**Supplemental Table 4**, http://links.lww.com/PCC/C462).

No statistically significant associations between COI category and mortality were found in exploratory analyses using PRISM III for severity of illness adjustment (**Supplemental Table 5**, http://links.lww.com/PCC/C462), or when evaluating only the latter part of the study period (March–December 2020) (**Supplemental Table 6**, http://links.lww.com/PCC/C462). When each of the three COI subdomains (education, health and environment, social and economic) was separately evaluated in the multivariable model, the only statistically significant finding was a lower adjusted odds for the high group (as compared with very high) in the Health and Environment category (OR 0.60; IQR, 0.41–0.89; *p* = 0.01) (**Supplemental Table 7**, http://links.lww.com/PCC/C462). When patient addresses able to be matched to COI by zip code but not census tract (*n* = 2542) were added into the multivariable model (total *n* = 36,443, 97% of eligible admissions), the ORs for COI categories did not change substantially (**Supplemental Table 8**, http://links.lww.com/PCC/C462). When the three COI categories with higher severity of illness and OR greater than 1 on multivariable analysis (very

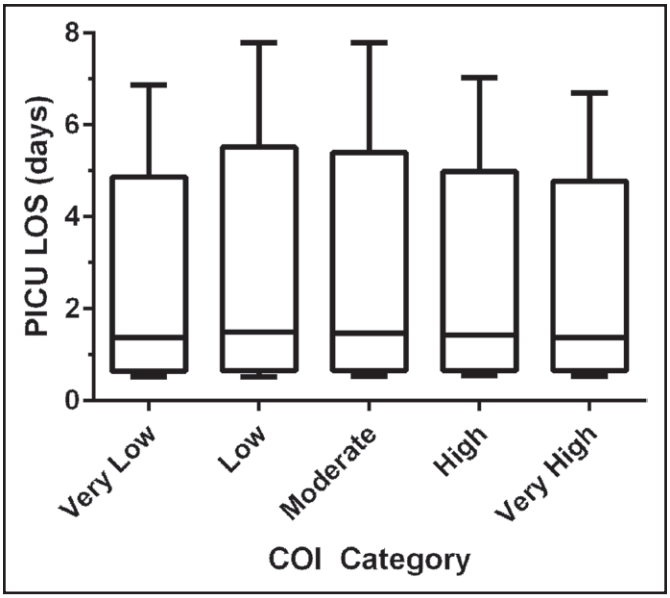


**Figure 2.** PICU length of stay (LOS) by Child Opportunity Index (COI) category. PICU LOS was available for 33,883 (> 99%) admissions. Central line represents median with box representing 25th–75th%, and whiskers representing 10th–90th% values.

low, low, and moderate) were combined and compared with the combined high/very high category on post hoc multivariable analysis, OR for PICU mortality for the lower three categories was 1.19 (95% CI, 0.97–1.45; $p = 0.10$).

## DISCUSSION

In this study, we demonstrated that children admitted to 15 PICUs across the United States were often from very low COI neighborhoods, and that children from the very high COI neighborhoods had the lowest severity of illness and observed PICU mortality. In the multivariable model, odds of PICU mortality decreased as COI increased and were highest for the very low compared with very high COI category; however, the ORs for these associations included unity. Odds of mortality were higher for children without a listed insurance payor as compared with children with commercial insurance, regardless of COI category. To our knowledge, this is the first study that has used clinical PICU data including severity of illness scoring, neighborhood opportunity mapped by census tract, and primary payor status across a multicenter cohort to evaluate the complex interplay of these factors in pediatric critical illness.

Children from lower opportunity neighborhoods have previously been shown to have lower life expectancy (30, 31). However, it remains unclear how severe illness or injury in childhood may contribute to this finding. The proportion of children from very low COI neighborhoods in our cohort of PICU admissions (27%) is consistent with other studies across acute care settings: prehospital emergency services (31% of children from very low COI) (4), emergency department (29% very low COI) (3), hospital admissions (22–32% very low COI) (1, 3, 7, 17), and PICU admissions and readmissions (26% very low COI) (20). Although low resource-intensity pediatric emergency visits (no laboratories, imaging, or admission) have also been shown to most commonly involve children from the very low COI category (312), our findings add to the evidence indicating that children in neighborhoods with the lowest opportunity or income (11) in the United States were the most common group to be admitted to the PICU in a cohort of children's hospitals.

Although the absolute differences in predicted mortality and observed mortality between COI groups were fairly low in this study (0.01% for median PIM3 and ≤ 0.8% for observed mortality), it is notable that the very high COI group had the lowest risk of mortality, mortality, and need for mechanical ventilation. Furthermore, in the context of an overall PICU mortality of ~2% and greater than 30,000 admissions, a mortality difference 0.8% higher in the moderate, and 0.5–0.6% higher in the very low and low groups, as compared with the very high group may be clinically significant. A previous study using administrative data similarly found higher severity of illness, as measured by resource intensity and other factors, for pediatric

### AT THE BEDSIDE

- PICU patients admitted to a cohort of children's hospitals were often from very low-opportunity neighborhoods.
- Children from very high-opportunity neighborhoods had the lowest severity of illness and raw mortality; however, adjusted odds ratios for mortality by COI category were not statistically different in a multivariable model.
- Children without insurance coverage, regardless of neighborhood, had higher risk-adjusted PICU mortality and deserve further study.

## TABLE 3.
### Multivariable Logistic Regression for PICU Mortality (Total, *n* = 33,901)

| Independent Variable | OR for PICU Mortality (95% CI) | *p* |
|---|---|---|
| Pediatric Index of Mortality 3 risk of mortality (logit) | 3.72 (3.50–3.96) | **< 0.0001** |
| Age category | | |
| < 1 mo | 1.21 (0.66–2.20) | 0.54 |
| 1 mo–< 2 yr | 0.91 (0.72–1.15) | 0.43 |
| 2–5 yr | 0.80 (0.60–1.06) | 0.12 |
| 6–12 yr | 1.00 (0.77–1.30) | 0.99 |
| 13–<18 yr | Reference | |
| Sex assigned at birth = female | 0.92 (0.77–1.11) | 0.38 |
| Race/ethnicity | | |
| Black or African American | 1.02 (0.79–1.32) | 0.90 |
| Hispanic | 0.91 (0.66–1.26) | 0.58 |
| Other or mixed | 1.13 (0.83–1.54) | 0.43 |
| Asian | 1.04 (0.64–1.70) | 0.87 |
| Unknown | 1.77 (1.12–2.79) | **0.01** |
| White | Reference | |
| Payor | | |
| Government | 0.92 (0.74–1.15) | 0.45 |
| None/missing | 3.58 (2.46–5.20) | **< 0.0001** |
| Self-pay | 0.65 (0.30–1.44) | 0.29 |
| Other | 1.68 (0.91–3.09) | 0.10 |
| Commercial | Reference | |
| Primary language spoken | | |
| Spanish | 0.89 (0.62–1.29) | 0.54 |
| Other/missing | 1.50 (0.89–2.54) | 0.13 |
| English | Reference | |
| Origin of admission | | |
| Outside hospital ED | 1.42 (1.12–1.79) | **0.003** |
| Operating room | 1.21 (0.82–1.77) | 0.34 |
| General care floor | 1.61 (1.19–2.18) | **0.002** |
| Postanesthesia care unit | 2.19 (1.03–4.62) | **0.04** |
| Outside hospital ICU | 2.99 (2.17–4.11) | **< 0.0001** |
| Outside hospital general care floor | 0.58 (0.18–1.88) | 0.36 |
| Other | 1.44 (0.95–2.18) | 0.08 |
| ED | Reference | |
| Child Opportunity Index category | | |
| Very low | 1.30 (0.94–1.79) | 0.11 |
| Low | 1.06 (0.77–1.47) | 0.71 |
| Moderate | 1.17 (0.85–1.61) | 0.33 |
| High | 1.00 (0.72–1.38) | 0.98 |
| Very high | Reference | |

ED = emergency department, OR = odds ratio.
Boldface values indicate $p < 0.05$.

inpatient admissions from very low COI neighborhoods (17). Other studies have reported higher severity of illness at PICU admission by neighborhood income (12), insurance status (12, 24), or race or ethnicity (12, 13, 24), but have not used a more multifaceted and child-specific indicator of neighborhood environment such as COI.

There was a decreasing odds of mortality as COI increased as an ordinal variable in the multivariable model, and when treated as categories the ORs for the very low, low, and moderate COI category as compared with very high were all greater than 1 (although none of these findings reached statistical significance). We were unable to exclude as much as 1.79-fold increased odds of PICU mortality for the very low as compared with the very high group. The equivalent median PIM3 risk of mortality between the high and very high categories, as well as OR of 1.0 for the high COI category (vs. very high) in the multivariable model, suggest a possible protective effect of these higher COI neighborhoods as compared with the very low, low, and moderate groups. When the three lower categories were combined and compared with the high/very high category in the multivariable model, the OR for mortality (1.18), although not reaching statistical significance, was quite similar to that found (1.13) in a meta-analysis of low versus higher socioeconomic status in the adult critical care population (33). In multivariable analysis of the Health and Environment subdomain, the high category had a significantly lower adjusted odds of mortality compared with all other groups; however, the very high group had essentially equivalent adjusted odds with all other COI groups, therefore it is unclear if this difference in the high group is meaningful. Additionally, children with no insurance payor had a greater than three-fold increased odds of PICU mortality as compared with children with commercial insurance on multivariable analysis, with no modifying effect by COI category. Two prior studies showed no difference in PICU mortality by insurance status when accounting for severity of illness (12, 13), whereas one other study found increased odds of PICU mortality for those with "other" but not "no" insurance (24).

Specific factors beyond severity of illness that could account for the higher odds of mortality by neighborhood environment, insurance status, or origin of admission were not able to be elucidated in this study, but may include patient or illness factors not captured in severity of illness scoring, or differences in care once in the PICU. Children without health insurance are less likely to have primary care providers (34, 35) or receive medical care for acute conditions (34–36), despite most often being eligible for public insurance (34). It is plausible that children in lower COI neighborhoods and/or uninsured children may experience a cumulative effect of worsened overall health that could lead to worse outcomes if they become critically ill (17–20, 34, 35). Although the Health and Environment subdomain would seem to be particularly important to children's health, the ORs for mortality for lower COI groups were actually higher in the Social and Economic and Education subdomains, suggesting a complex interplay of factors. Patients from outside ICUs and other origins have been previously shown to have higher severity-adjusted mortality (37, 38), possibly due to this groups being refractory to initial interventions in a way not fully captured by severity scoring systems. Although limitations on care were similar among COI groups in this study, and lower use of mechanical ventilation in the very high group may be explained by lower severity of illness, inequities and biases may be present in aspects of PICU care by socioeconomic status and deserve careful consideration in future studies (10, 39, 40).

Strengths of this study include a relatively large number of patient admissions from multiple centers across the United States, using data from a well-established clinical database. The addresses were mapped by census tract rather than zip code, allowing for more specific assignment of neighborhood. Although multiple area-level socioeconomic indices exist, COI has the broadest set of child-specific indicators of neighborhood environment (41). Severity of illness at the time of admission by established clinical scoring tools were used, which has not been incorporated into previous studies evaluating PICU outcome relative to COI. Race and ethnicity, which is imbalanced across COI categories especially in metropolitan areas (42), was also included in the multivariable analysis.

Limitations of this study include that participating centers are large academic centers, mostly in urban areas, and thus admissions included may not be generalizable to all PICUs. The race/ethnicity composition in this cohort was different from the overall pediatric population in the United States, with a lower percentage of those categorized as White, non-Hispanic (46% in

this study vs. 50% in the United States in 2020), and Hispanic (16% vs. 26%), and a higher percentage of those categorized as Black (22% vs. 14%) (43). Race and ethnicity classification were obtained from VPS data and chart review, and accuracy or self-reporting of this information was not able to be determined. We did not have information about the specific catchment areas of each hospital, therefore could not make conclusions regarding incidence of PICU admission relative to the particular denominator of possible PICU admissions for that center. The addresses obtained from the medical record were not current in about half of cases. Nearly 10% of index admissions did not have an address which could be mapped to census tract and/or COI for various reasons, and missing addresses are likely not randomly distributed among COI groups. However, a post hoc analysis using zip code-assigned COI for most of the missing admissions yielded similar results. The COI category assigned may not have applied to that particular family, and we were not able to account for patients who were homeless or did not have an address that was able to be mapped to census tract and COI. Children in out-of-home placements other than known institutional addresses also may not have had an accurate assignment of their environment. Although we had information regarding mechanical ventilation use and limitations on care, other aspects of intensity of PICU care, such as vasopressor use, were not available in our dataset. Finally, longer-term mortality or functional decline were not available in the dataset, and these may be more prevalent and sensitive to neighborhood exposures.



## CONCLUSIONS

Children admitted to a cohort of the U.S. PICUs were commonly from very low COI neighborhoods. Admissions from the highest COI categories had the lowest severity of illness and observed mortality, with no statistically significant difference in PICU mortality on multivariable analysis, while lack of insurance coverage was associated with higher risk-adjusted mortality. Future studies are needed as part of a call to equity toward the best possible health outcomes for children regardless of socioeconomic factors.

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