OBSERVATIONAL STUDY

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Child Opportunity Index and Hospital Utilization in Children With Traumatic Brain Injury Admitted to the PICU

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IMPORTANCE: The need to understand how *Community-based disparities impact morbidity and mortality in pediatric critical illness, such as traumatic brain injury.* Test the hypothesis that ZIP code-based disparities in hospital utilization, including length of stay (LOS) and hospital costs, exist in a cohort of children with traumatic brain injury (TBI) admitted to a PICU using the Child Opportunity Index (COI).

DESIGN: Multicenter retrospective cohort study.

SETTING: Pediatric Health Information System (PHIS) database.

PATIENTS: Children 0–18 years old admitted to a PHIS hospital with a diagnosis of TBI from January 2016 to December 2020 requiring PICU care. To identify the most severely injured children, a study-specific definition of "Complicated TBI" was created based on radiology, pharmacy, and procedure codes.

INTERVENTIONS: None.

MAIN OUTCOMES AND MEASURES: Using nationally normed ZIP code-level COI data, patients were categorized into COI quintiles. A low COI ZIP code has low childhood opportunity based on weighted indicators within educational, health and environmental, and social and economic domains. Population-averaged generalized estimating equation (GEE) models, adjusted for patient and clinical characteristics examined the association between COI and study outcomes, including hospital LOS and accrued hospital costs. The median age of this cohort of 8,055 children was 58 months (interquartile range [IQR], 8–145 mo). There were differences in patient demographics and rates of Complicated TBI between COI levels. The median hospital LOS was 3.0 days (IQR, 2.0–6.0 d) and in population-averaged GEE models, children living in very low COI ZIP codes were expected to have a hospital LOS 10.2% (95% CI, 4.1–16.8%; $p = 0.0142$) longer than children living in very high COI ZIP codes. For the 11% of children with a Complicated TBI, the relationship between COI and LOS was lost in multivariable models. COI level was not predictive of accrued hospital costs in this study.

CONCLUSIONS: Children with TBI requiring PICU care living in low-opportunity ZIP codes have higher injury severity and longer hospital LOS compared with children living in higher-opportunity ZIP codes. Additional studies are needed to understand why these differences exist.

KEY WORDS: pediatric critical care medicine; social determinants of health; traumatic brain injury; ZIP code

Traumatic brain injury (TBI) is a leading cause of pediatric mortality and long-term morbidity, affecting nearly 1.7 million children annually (1). For TBI-related hospital admissions, costs can exceed $400,000 and length of stay (LOS) can exceed 30 days (1, 2). While all severely injured children are at risk for mortality, morbidity, and high healthcare use, disparate

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KEY POINTS

Question: Do children living in low-resource communities admitted to a PICU with a traumatic brain injury (TBI) have longer lengths of stay and accrue higher hospital costs when compared with children from higher-resource ZIP codes?

Findings: In this multicenter cohort study of greater than 8,000 children using the Pediatric Health Information System database, children living in ZIP codes with fewer resources and poorer conditions (very low and low Child Opportunity Index [COI]) had higher injury severity and longer hospital length of stay than children living in higher opportunity ZIP codes. COI level was not predictive of accrued hospital costs in this study.

Meaning: Community-based disparities in pediatric TBI injury severity and hospital outcomes exist. Future studies should explore potential mechanisms, including identifying communities with the highest risk, deficiencies in access to pediatric trauma care, and disparities in healthcare delivery for hospitalized children.

health outcomes based on the social determinants of health exist (3–6). Compared with children living in relative affluence, it is known that children living in low-resource neighborhoods are at risk for higher injury severity and pre-hospital mortality (7, 8). Children from low-income neighborhoods have higher rates of lethal trauma mechanisms, including firearms and pedestrian versus motor vehicle accidents (8, 9). However, for children with severe TBI surviving to hospital admission and requiring care in a PICU, it is unclear if disparities in hospital outcomes exist.

Previous studies have described associations between unidimensional variables including estimated household income as a proxy for neighborhood health determinants and trauma-related hospital outcomes in children (4–6). Another measure of social disparity is with the Child Opportunity Index (COI). The COI is a publicly available multidimensional measure of neighborhood condition encompassing 29 educational, societal, and health factors known to be related to child health and wellness (10). The recently available COI Version 2.0 facilitates comparisons between ZIP codes across the United States (11). Previous studies using the COI have demonstrated children living in low-opportunity ZIP codes carry a disproportionate burden of illness including an increased odds of complicated appendicitis and higher rates of Emergency Department encounters and hospital admissions (12, 13). However, the relationship between COI and hospital outcomes in pediatric TBI is unknown.

Poor neighborhood conditions such as limited greenspace availability for safe play and pedestrian safety concerns could place children at risk for higher injury severity (13). Furthermore, it is known that access to pediatric critical care services and pediatric trauma centers are inequitably distributed in the United States, and proximity to PICU care is associated with decreased odds of trauma-related mortality (10–12). Identifying the existence of differential hospital utilization in pediatric TBI based on the COI has the potential to improve trauma-related health outcomes and reduce healthcare-associated expenditures through public health initiatives including better allocation of pediatric trauma care services and community improvement initiatives (14). Therefore, the primary objective of this study was to use a quality-controlled multicenter database of U.S. children's hospitals to test the hypothesis that children from low-opportunity communities requiring PICU care after a TBI would have longer hospital LOS and higher accrued hospital costs compared with those children living in higher opportunity communities.

MATERIALS AND METHODS

Study Design and Participants

We performed a retrospective cohort analysis of the Pediatric Health Information System (PHIS) database to identify children less than 19 years old with a any diagnosis of TBI who were admitted to a participating PICU from January 2016 to December 2020. To reduce confounders that could influence study outcomes including LOS, children with a chronic complex condition (CCC) were excluded using the CCC "flag" (15). Children with missing COI data were also excluded from the study (**Fig. 1**). The University Hospitals of Cleveland Medical Center Institutional Review Board (IRB) reviewed the study protocol, Characterization of Economic and Social Distress of Children Admitted to the PICU Using the Pediatric Information Health System Database Version 2 (Lenexa, KS), and deemed it

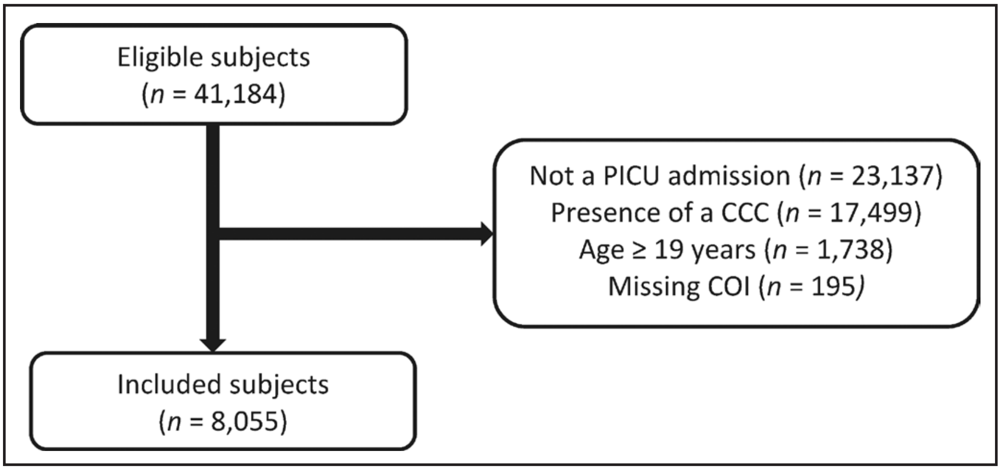

Figure 1. Flow diagram showing included subjects. CCC = chronic comorbid condition, COI = Child Opportunity Index.

exempt from oversight (IRB number STUDY20190286, June, 29, 2019). The IRB determined that the proposed activity was not research involving human subjects and thus IRB review and approval was not required.

Data Source

Accounting for approximately 15% of U.S. pediatric hospitalizations, PHIS contains inpatient, observation, emergency department, and ambulatory surgery encounter data from over 50 U.S. tertiary children's hospitals affiliated with the Children's Hospital Association. (Lenexa, KS) (16). Created for the purposes of external benchmarking and quality improvement, the validity and reliability of the dataset is ensured jointly by the Children's Hospital Association and participating hospitals. The dataset includes patient demographics, admission and discharge dates, and diagnoses and procedures based on *International Classification of Diseases*, 9th Revision and 10th Revision, Clinical Modification (ICD-9/10-CM) and Current Procedural Terminology codes. Hospitals also submit resource utilization data based on clinical, pharmaceutical, laboratory, and imaging charges.

Study Procedures

Subjects with a diagnosis of TBI were identified using the ICD-10-CM diagnosis code S06.x for the years 2016–2020 (**Supplemental Table 1**, http://links.lww.com/CCX/B120). PICU care was defined by the PHIS PICU "flag," denoting children billed for PICU-level care during their hospital stay. The primary predictor variable was overall child opportunity, defined by a nationally normed, ZIP code-specific COI. The COI is a composite measure of 29 indicators of community health across three domains—education, health and environment, and social and economic (10). Examples of specific indicators included within the composite score are access to early childhood education (education), proximity to healthcare facilities and green space (health and environment), and community poverty rate (social and economic). An average of standardized indicators, weighted by how strongly they predict child health and economic outcomes, was used to create average domain *z* scores. These average domain *z* scores were then combined into an overall composite score. The COI categories were defined by ranking U.S. ZIP codes along their overall and domain-specific average *z* scores and dividing them into five levels (very low, low, moderate, high, very high), each containing 20% of the U.S. child population (10).

Additional demographic predictor variables included age at admission, sex, ethnicity, race, payer source, and whether the subject lives in an urban ZIP code. Race was defined as White, Black, or "Other," which included Asian, American Indian, Pacific Islander, and others. Payer source was categorized as public, private, uninsured, or "Other," including active duty service members/dependents insurance (TRICARE) or other payer. Collected clinical characteristics included the four All Patient Refined Diagnosis Related Group (APR-DRG) severity of illness subclasses—extreme, major, moderate, and minor (17). The Glasgow Coma Scale (GCS), the most common measure of TBI severity, is not available within the PHIS database. To better identify the most severely injured children, a study-specific definition was created for "Complicated TBI," defined as subjects with two or more of the following: placement of an intracranial pressure (ICP) monitor, placement of an external ventricular drain (EVD), use of IV hypertonic saline, use of mannitol, need for CT of head and/or brain, or placement of a central venous line. These interventions are easily captured with pharmacy, radiology, and procedure codes and are recommended in current clinical guidelines for use in children with a severe TBI (GCS < 8) (18). Injury mechanism was identified using ICD-10-CM codes and placed into categories defined by the external cause of injury framework published by the National Center for Health Statistics (19).

Statistical Analysis

The primary outcome of interest was hospital LOS, and the secondary outcome was total hospital costs adjusted for inflation. Costs are estimated from charges using hospital-specific and year-specific cost-to-charge ratios; they represent costs to hospitals, rather than costs to payors or patients. Additional outcomes collected included in-hospital mortality and 30-day hospital readmission. Differences in demographics and clinical characteristics were compared using the Pearson chi-square test for categorical variables and the Wilcoxon rank-sum test for continuous variables, as appropriate. Differences in complicated TBI frequency between COI levels were compared using a pairwise comparison of proportions with Bonferroni adjustment. Population-averaged generalized estimating equation (GEE) multivariable models were created to study the association between hospital LOS, hospital costs, and chosen predictors. Gamma distribution was used for the GEE model, as we observed a positively skewed distribution. As study outcomes may vary by hospitals and some patients in the cohort were admitted several times during the study inclusion period, hospitals and patients were treated as cluster effects in the models. Chosen covariates for the multivariable models included patient demographics (age, race, ethnicity, insurance, and urban residence), illness characteristics (APR-DRG severity of illness, presence of a complicated TBI, and injury mechanism), hospital region, and PICU LOS. Collinearity between predictor variables was examined using the variance inflation factor before adjusting into the GEE analysis, and model fit was ensured with goodness of fit tests. As a sensitivity analysis, the GEE analyses were repeated using a definition of Complicated TBI, which only included subjects requiring an ICP monitor or EVD. A p value of less than 0.05 was considered statistically significant. All the analyses were performed using SAS software, Version 9.4 (SAS Institute, Cary, NC) and R software, Version 4.1.2 (Vienna, Austria).

RESULTS

During the study period, 41,184 children were admitted to a PHIS hospital with a primary diagnosis of TBI, and 8,055 children met criteria for inclusion. Patient demographics, clinical characteristics, and hospital characteristics are shown in (**Table 1**). There were differences in age, race, ethnicity, and insurance status across the COI levels. Injury severity in this cohort of PICU patients was relatively modest; 38% of subjects were categorized as having a "minor" severity of illness, and 11% of children (n = 896) met the study-specific definition of Complicated TBI. Children living in very high COI ZIP codes had the lowest proportion of Complicated TBI (8.6%), with differences seen both across COI levels ($p < 0.001$) and between COI levels (**Supplemental Table 2**, http://links.lww.com/CCX/B120). Use of mechanical ventilation was highest in the very low (33%) and low (32%) COI levels, and lowest in the very high (23%) COI level, with differences seen across levels ($p < 0.001$). Differences in injury mechanism across COI levels are shown in **Supplemental Table 3** (http://links.lww.com/CCX/B120).

The median hospital LOS was 3.0 days (interquartile range [IQR], 2.0–6.0 d), and differences were found across the COI levels (**Table 2**). In population-averaged GEE models adjusted for demographics and clinical characteristics including injury severity and PICU LOS, child opportunity, and hospital LOS were inversely related (**Table 3**). In this model, children living in the very low, low, moderate, and high COI levels had longer LOS than those living in the very high COI ZIP codes. Children living in very low COI ZIP codes were expected to have a hospital LOS 10.2% (95% CI, 4.1–16.8; $p = 0.014$) longer than children living in very high COI ZIP codes. The relationship between COI and LOS was preserved in a sensitivity analysis using a stricter definition of Complicated TBI, only including those subjects with an ICP monitor or EVD in place (**Supplemental Table 4**, http://links.lww.com/CCX/B120).

TABLE 1.

Patient Demographics, Injury Severity, and Hospital Characteristics in a Cohort of Children With Traumatic Brain Injury, Based on Child Opportunity Index

Characteristics	Overall, *n* = 8,055	Very Low, *n* = 1,770	Low, *n* = 1,648	Moderate, *n* = 1,662	High, *n* = 1,453	Very High, *n* = 1,522	*p*[f]
Age, mo, median (interquartile range)	58 (8–145)	48 (7–134)	53 (9–137)	56 (8–147)	71 (9–153)	68 (9–155)	< 0.001
Male sex[a], *n* (%)	5,100 (64)	1,094 (62)	1,015 (62)	1,060 (64)	957 (66)	974 (64)	0.088
Race[b], *n* (%)							< 0.001
White	4,800 (64)	633 (39)	996 (64)	1,072 (69)	1,015 (76)	1,084 (77)	
Black	1,436 (19)	711 (44)	286 (18)	222 (14)	134 (10)	83 (5.9)	
Others	1,233 (17)	273 (17)	270 (17)	250 (16)	194 (14)	246 (17)	
Hispanic or Latino ethnicity[c], *n* (%)	1,510 (20)	458 (28)	388 (26)	312 (20)	209 (15)	143 (10)	< 0.001
Urban residence[d], *n* (%)	6,546 (82)	1,528 (87)	1,124 (69)	1,236 (75)	1,219 (85)	1,439 (97)	< 0.001
Insurance[e], *n* (%)							< 0.001
Private	2,954 (37)	242 (14)	401 (25)	563 (34)	697 (48)	1,051 (70)	
Public	4,326 (55)	1,400 (81)	1,055 (66)	908 (56)	610 (42)	353 (23)	
Uninsured	278 (3.5)	39 (2.2)	71 (4.4)	77 (4.7)	49 (3.4)	42 (2.8)	
Others	369 (4.7)	57 (3.3)	79 (4.9)	85 (5.2)	82 (5.7)	66 (4.4)	
Severity of illness, *n* (%)							< 0.001
Minor	3,042 (38)	572 (32)	558 (34)	608 (37)	597 (41)	707 (46)	
Moderate	2,004 (25)	434 (25)	418 (25)	417 (25)	350 (24)	385 (25)	
Major	1,634 (20)	398 (22)	354 (21)	348 (21)	288 (20)	246 (16)	
Extreme	1,375 (17)	366 (21)	318 (19)	289 (17)	218 (15)	184 (12)	
Complicated traumatic brain injury, *n* (%)	896 (11)	234 (13)	208 (13)	178 (11)	145 (10)	131 (8.6)	< 0.001
Mechanical ventilation, *n* (%)	2,320 (29)	576 (33)	524 (32)	498 (30)	379 (26)	343 (23)	< 0.001
Hospital region, *n* (%)							< 0.001
Midwest	2,157 (27)	489 (28)	382 (23)	439 (26)	397 (27)	450 (30)	
Northeast	1,043 (13)	204 (12)	134 (8.1)	212 (13)	209 (14)	284 (19)	
South	2,797 (35)	654 (37)	699 (42)	592 (36)	502 (35)	350 (23)	
West	2,058 (26)	423 (24)	433 (26)	419 (25)	345 (24)	438 (29)	

[a]Twenty-eight subjects with unknown sex.
[b]Five hundred eighty-six subjects with unknown race.
[c]Six hundred thirty-eight subjects with unknown ethnicity.
[d]One hundred nineteen urban residence unknown.
[e]One hundred twenty-eight subjects with unknown insurance.
[f]*p* values determined by Kruskal-Wallis rank sum test or Pearson χ^2 test, as appropriate.

In this cohort of children, median hospital costs were $15,188 (IQR, $8,508–$29,354). In unadjusted analysis, differences in total hospital costs were seen across all COI levels ($p < 0.001$). After adjusting for confounders, this relationship was lost (**Supplemental Table 5**, http://links.lww.com/CCX/B120). Overall, in-hospital mortality was low (1.8%), with small differences seen across COI levels ($p = 0.04$) (Table 2). For those children surviving to hospital discharge ($n = 7{,}909$), 6.4% ($n = 514$) were readmitted to

TABLE 2.
Univariate Analysis of Mortality, Length of Stay, Costs, and Readmission in a Cohort of Children With Traumatic Brain Injury, Based on Child Opportunity Index

Outcomes	Overall, *n* = 8,055	Very Low, *n* = 1,770	Low, *n* = 1,648	Moderate, *n* = 1,662	High, *n* = 1,453	Very High, *n* = 1,522	p^a
Mortality, *n* (%)	146 (1.8)	46 (2.6)	22 (1.3)	29 (1.7)	28 (1.9)	21 (1.4)	0.024
Hospital length of stay, d, median (IQR)	3.0 (2.0–6.0)	3.0 (2.0–7.0)	3.0 (2.0–6.0)	3.0 (2.0–6.0)	3.0 (2.0–6.0)	3.0 (1.0–5.0)	< 0.001
Total costs, $, median (IQR)	15,188 (8,508–29,354)	16,433 (8,984–32,936)	16,594 (8,957–31,082)	15,088 (8,362–28,456)	14,722 (8,570–26,434)	13,158 (7,733–27,441)	< 0.001
30-d readmission, *n* (%)	514 (6.4)	108 (6.1)	123 (7.5)	110 (6.6)	80 (5.5)	93 (6.1)	0.200

IQR = interquartile range.

[a] *p* values determined by Pearson χ^2 test or Kruskal-Wallis rank sum test, as appropriate.

a PHIS hospital within 30 days after hospital discharge, with no differences in readmission rates observed across COI levels ($p = 0.2$) (Table 2).

Patient demographics and injury characteristics of the subset of children meeting the study-specific definition of Complicated TBI are shown in **Table 4**. There were differences in age, race, urban residence, insurance status, illness severity, and hospital region across COI levels in this subset of subjects. In univariate analyses, there were no differences in hospital LOS, accrued hospital costs, mortality, or 30-day readmission rate among children with a Complicated TBI living in different COI ZIP codes (**Supplemental Table 6**, http://links.lww.com/CCX/B120). In multivariable GEE analysis, COI level was not predictive of either hospital LOS or accrued hospital costs among children with a Complicated TBI (**Supplemental Tables 7** and **8**, http://links.lww.com/CCX/B120).

DISCUSSION

This multicenter database study of U.S. children admitted to a PICU with a TBI demonstrated higher illness severity and longer hospital LOS among children living in ZIP codes with low childhood opportunity. Children living in the very low and low COI ZIP codes had higher injury severity, based on the study-specific definition of complicated TBI. After adjusting for confounders including demographics and injury characteristics, our model suggests compared with children living in very high COI ZIP codes, children living at all other COI levels have longer expected hospital LOS (ranging from 5% longer LOS in moderate COI to 10% longer LOS in very low COI ZIP codes). These results emphasize the urgent need to consider neighborhood risk factors when developing strategies aimed at decreasing healthcare utilization and improving health outcomes in injured children (5, 7, 8, 20, 21).

The American Academy of Pediatrics recently released a "call to action" for children's hospitals to explicitly name advocacy as a central tenet of their academic mission to improve the health of communities and children (22). Our results highlight the responsibility all pediatricians, including intensivists, must share in advocating for children living in unsafe communities at the local, state, and federal policy level (23). In our study, children from lower COI levels had higher rates of complicated TBI. Our methodology

TABLE 3.
Multivariable Analysis of Patient and Clinical Factors Associated With Hospital Length of Stay in a Cohort of Children With Traumatic Brain Injury

Characteristic	Expected % Change (95% CI)	p[a]
Child Opportunity Index		
Very low	10.2 (4.1–16.8)	0.014
Low	6.3 (0.2–12.7)	0.042
Moderate	5.2 (−0.2 to 10.9)	0.006
High	7 (1.4–12.9)	0.001
Very high	Reference	–
Admit age, yr	0.4 (0.1–0.8)	0.014
Race		
Black	0.8 (−4.0 to 5.9)	0.750
Others	−4.8 (−8.9 to −0.5)	0.029
White	Reference	–
Insurance		
Public	3.6 (−0.5 to 7.8)	0.139
Uninsured	−5.0 (−12.4 to 3.1)	0.222
Others	5.7 (−1.8 to 13.9)	0.086
Private	Reference	–
Urban residence		
No	1.1 (−3.4 to 5.8)	0.643
Yes	Reference	–
Hospital region		
Northeast	−6.2 (−10.9 to −1.2)	0.017
South	10 (5.1–15.1)	< 0.001
West	−3.7 (−8.3 to −1.1)	0.125
Midwest	Reference	–
Complicated Traumatic brain injury		
Yes	12 (4.9–19.7)	0.001
No	Reference	–
Mechanism of injury		
Transportation	28.5 (22.3–35.1)	< 0.001
Struck by	11.7 (3.7–20.2)	0.003
Others	27.4 (19.9–35.4)	< 0.001
Fall	Reference	–
Severity of illness		
Extreme	122.7 (107.9–138.5)	< 0.001
Major	104.0 (93.7–114.8)	< 0.001
Moderate	43.7 (37.5–50.3)	< 0.001
Minor	Reference	–
PICU length of stay	15.9 (15.1–16.8)	< 0.001

[a]p values determined by a population-averaged generalized estimating equation multivariable model.
Dashes indicate there is no value to report, as it is a reference point.
Children living in very low Child Opportunity Index (COI) ZIP codes are expected to have a hospital length of stay 10.2% (95% CI, 4.1–16.8) longer than children living in very high COI ZIP codes.

precludes identifying why this relationship exists. Differences in neighborhood condition leading to differences in injury severity and differential access to critical care services could contribute to the results seen in this study (24, 25).

It is well-established low socioeconomic status predisposes children and adults to traumatic injury (5, 8, 26, 27). Data from the National Center for Health Statistics shows age-adjusted mortality rates from unintentional injuries are nearly 80% higher among people living in U.S. counties with greater than 20% poverty rates compared with those living in counties with less than 5% poverty rates (28). A recent PHIS-based study including over 50,000 children demonstrated an association between lower median household income, estimated from ZIP codes, and higher proportions of ballistic injuries and mortality in pediatric TBI patients (9). Proposed mechanisms for increased risk include higher traffic volumes, inadequate pedestrian safety, substandard housing, the high cost of safety equipment, and higher exposure to violence (6, 29). Public health interventions are effective at preventing and mitigating pediatric injuries. Community-based programs can improve pedestrian safety for children, and states with stricter gun safety laws have lower pediatric firearm-related death rates (30, 31). Studies like

TABLE 4.

Patient Demographics, Injury Severity, and Hospital Characteristics in a Subset of Children With Complicated Traumatic Brain Injury, Based on Child Opportunity Index

Characteristics	Overall, *n* = 896	Very Low, *n* = 234	Low, *n* = 208	Moderate, *n* = 178	High, *n* = 145	Very High, *n* = 131	*p*[f]
Age, mo, median (interquartile range)	78 (22–152)	57 (20–140)	61 (18–133)	81 (25–155)	100 (26–158)	115 (28–177)	0.003
Male sex[a], *n* (%)	571 (64)	138 (60)	128 (62)	116 (66)	98 (68)	81 (71)	0.200
Race[b], *n* (%)							< 0.001
White	488 (58)	68 (30)	126 (64)	98 (61)	101 (75)	95 (75)	
Black	233 (28)	123 (55)	48 (24)	28 (17)	22 (16)	12 (9.4)	
Others	123 (15)	36 (14)	26 (14)	30 (19)	13 (9.6)	18 (16)	
Hispanic or Latino ethnicity[c], *n* (%)	136 (17)	38 (18)	32 (18)	33 (22)	15 (11)	18 (15)	0.088
Urban residence[d], *n* (%)	690 (78)	197 (84)	127 (62)	128 (74)	115 (80)	123 (95)	< 0.001
Insurance[e], *n* (%)							< 0.001
Private	269 (30)	30 (13)	44 (21)	67 (38)	54 (37)	74 (57)	
Public	537 (61)	186 (81)	138 (67)	96 (55)	76 (52)	41 (32)	
Uninsured	26 (2.9)	7 (3.0)	7 (3.4)	6 (3.4)	5 (3.4)	1 (0.8)	
Others	54 (6.1)	7 (3.0)	16 (7.8)	7 (4.0)	10 (6.9)	14 (11)	
Severity of illness, *n* (%)							0.037
Minor	51 (5.7)	8 (3.4)	10 (4.8)	10 (5.6)	14 (9.7)	9 (6.9)	
Moderate	50 (5.6)	9 (3.8)	13 (6.2)	4 (2.2)	9 (6.2)	15 (11)	
Major	230 (26)	60 (26)	54 (26)	47 (26)	36 (25)	33 (25)	
Extreme	565 (63)	157 (67)	131 (63)	117 (66)	86 (59)	74 (56)	
Mechanical ventilation, *n* (%)	867 (97)	229 (98)	199 (96)	172 (97)	139 (96)	128 (98)	0.600
Hospital region, *n* (%)							0.018
Midwest	278 (31)	72 (31)	63 (30)	46 (26)	51 (35)	46 (35)	
Northeast	101 (11)	21 (9.0)	17 (8.2)	21 (12)	16 (11)	26 (20)	
South	384 (43)	111 (47)	97 (47)	80 (50)	58 (40)	38 (29)	
West	133 (15)	30 (13)	31 (15)	318 (17)	20 (14)	21 (16)	

[a]Seven subjects with unknown sex.
[b]Fifty-three subjects with unknown race.
[c]One hundred two subjects with unknown ethnicity.
[d]Eleven subjects with unknown urban residence.
[e]Ten subjects with unknown insurance.
[f]*p* values determined by Pearson χ^2 test or Wilcoxon rank-sum test, as appropriate.

ours, showing higher injury severity in children living in low-opportunity neighborhoods, provide additional evidence for the need to advocate for public health initiatives to create safer communities for all children.

The Agency for Healthcare Research and Quality has prioritized reduction in LOS for hospitalized patients, specifically noting the need for research focused on patients with high social and economic risk (32). In our multivariable models that adjusted for illness severity and patient demographics, children living in low COI ZIP codes had longer hospital LOS than children living in high COI ZIP codes. This relationship persisted in children with the highest injury severity—those categorized as Complicated TBI. Our results complement previous studies showing an association between low COI ZIP codes and higher hospital utilization in children with medical complexity and children with ambulatory care-sensitive conditions (33, 34). Our study methodology precludes understanding reasons for these findings but may be reflective of inefficient discharge processes or insufficient availability of post-hospital rehabilitation services contributing to unnecessary hospitals days in families living in communities with low opportunity (35, 36). Discharge improvement initiatives that consider social risk in hospitals serving critically injured children may decrease LOS for these vulnerable patients (37).

LOS is an important marker of healthcare quality because unnecessary hospital days drive higher healthcare costs (32). In our study, costs were over $3,000 higher per hospitalization in very low COI patients compared with very high COI patients; over the 4-year study period, children living in very low COI ZIP codes accrued over $8.8 million more in hospital costs. Similar findings of higher expenditures are reported among hospitalized children with medical complexity living in very low COI ZIP codes and in low-income children hospitalized with asthma, bronchiolitis, pneumonia, diabetes, and congenital heart disease (7, 20, 26, 34). Since U.S. children's hospitals tend to serve patients with the greatest medical complexity and social vulnerability, they are disproportionately burdened by the financial losses associated with Medicaid reimbursements (38). Ensuring equitable, high-quality healthcare delivery for hospitalized children could mitigate these financial losses by eliminating the cost differences associated with social inequities.

To our knowledge, this is the largest study to date examining community-based differences in hospital LOS and costs in a cohort of children with brain injury requiring PICU care. Nonetheless, this study has limitations to consider, primarily related to its retrospective study design, and use of a multicenter, administrative database that has the potential to produce overpowered, statistically significant, yet clinically insignificant results (39, 40). The PHIS dataset is limited to metropolitan, tertiary children's hospitals, accounting for approximately 15% of pediatric hospital admissions (16). There is a potential our study results have less generalizability to other centers, although the medical care provided at PHIS hospitals is likely reflective of the greater than 200 pediatric facilities providing critical care services to U.S. children (16). PHIS reports COI data based on residential ZIP codes, and this composite score is based on neighborhood condition measured at the census tract level. Although the method for aggregating census tract COI data into ZIP code data has been validated, and our results are similar to previously published data, ZIP codes can contain neighborhoods with diverse opportunity and condition, raising concerns for patients being misclassified into the wrong COI level in our study (11, 40).

Despite limiting the study population to patients requiring PICU care, our cohort had low injury severity and short hospital LOS. Pediatric TBI is a heterogeneous disease and categorizing patients by injury mechanism or severity is challenging using administrative data (41, 42). However, our study population is likely representative of many United States and European PICUs, which often care for children with a range of injury severity, including those classified as "mild" TBI, but whose injury mechanism may warrant closer monitoring than can be provided on a general care nursing floor (43, 44). Additionally, institutional differences in PICU admission criteria and provider bias could contribute to children living in affluent ZIP codes being over-triaged (45, 46). Regardless of the factors influencing triage patterns, the overall low injury severity and short LOS seen in this cohort of children suggest that U.S. academic children's hospitals have an opportunity to decrease resource utilization by prospectively studying PICU admission criteria for children with TBI (47, 48). Finally, the observational study design precludes establishing a causal relationship between COI level and hospital outcomes in TBI. This hinders our ability to correct for the other factors, including medical decision-making, differences in patient populations and institutional practice variation, including PICU and hospital admission and discharge criteria, that influence a child's hospital course.

CONCLUSIONS

With nearly 30 million U.S. children living in low-resource neighborhoods, identifying community-based disparities in health outcomes is critical. This study demonstrated an association between low childhood ZIP code opportunity, higher illness severity and longer hospital LOS in a cohort of children with TBI requiring PICU care. Future studies should explore potential mechanisms for these differences including identifying neighborhoods placing children at the highest risk, deficiencies in access to pediatric trauma care, and disparities in healthcare delivery for hospitalized children.

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