Geography and age drive racial and ethnic disparities in hospital mortality for paediatric community-acquired pneumonia in the United States: a retrospective population based cohort study of hospitalized patients

Cody-Aaron L. Gathers,[a,b,*] Nadir Yehya,[a,b] Anireddy Reddy,[a,b] Paula M. Magee,[a] Vanessa C. Denny,[a] Michelle R. Mayeda,[a] Amanda O'Halloran,[a,b] Sanjiv D. Mehta,[a] Stephanie Wanamaker,[c] Jessica C. Fowler,[a] and Garrett Keim[a,b]

[a]Department of Anesthesiology & Critical Care Medicine, Children's Hospital of Philadelphia and Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA, USA
[b]Leonard Davis Institute of Health Economics, University of Pennsylvania, Philadelphia, PA, USA
[c]Department of Pediatrics, Children's Hospital of Philadelphia and Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA, USA

The Lancet Regional Health - Americas 2025;42: 101001
Published Online xxx
https://doi.org/10.1016/j.lana.2025.101001

Summary

Background Racial disparities in the outcomes of adult community-acquired pneumonia are well described. However, the presence of racial and ethnic disparities in paediatric community-acquired pneumonia and the mechanisms underlying these disparities remain unclear. Motivated by disparities related to age and geography in paediatric sepsis, we evaluated the association between the joint exposure of race/ethnicity, age, and geographic region and mortality for community-acquired pneumonia to provide opportunities for assessment of future interventions that provide equitable healthcare. We hypothesized that geographic region and age would inform the association between race or ethnicity and mortality in community-acquired pneumonia.

Methods This was a retrospective cohort study of children age < 18 years with community-acquired pneumonia hospitalized between 2016 and 2021 in the Public Health Information System (PHIS) database. Models included a priori stratification of age ≤ 1 year and geographic region. Racial and ethnic groups (White, Black, Hispanic/Latino, and Other), four geographic regions (Northeast, South, Midwest, or West), and two age categories (<1 and ≥1 year) were combined to create a joint exposure variable. Multivariable logistic regression, clustered by hospital and adjusting for sex, primary insurance payer, median household income quartile, urban identification, and the presence of a complex chronic condition(s), quantified the relationship between the joint exposure and all-cause mortality for paediatric community-acquired pneumonia.

Findings Among 783,744 patients (median age 4 years [interquartile range 1–9 years], 45.9% female) with CAP, the overall mortality rate was 0.9%. Region and age strongly impacted mortality in all racial and ethnic groups, with higher mortality for Black, Hispanic/Latino, and Other patients <1 year. Among patients <1 year, Black patients in the South (OR 2.35, 95% CI 1.52–3.63, p < 0.001) and West (OR 2.47, 95% CI 1.35–4.49, p = 0.003) and Hispanic/Latino patients in the Northeast (OR 2.36, 95% CI 1.46–3.66, p = 0.031) had the highest mortality, relative to White patients <1 year in the Northeast.

Interpretation We found evidence of racial and ethnic disparities in mortality for children diagnosed with community-acquired pneumonia. Joint associations of race, ethnicity, age, and geographic region may partially inform potential mechanisms underlying these disparities.

Funding Dr. Gathers' effort on this study was supported by a National Institutes of Health (NIH) Training Grant T32HL098054. Dr. Yehya is supported by NIH grant number R01-HL148054. Dr. Keim was supported by NIH Training Grant 2T32GM112596 and L40HL170463.

Abbreviations: CAP, community-acquired pneumonia; PHIS, Public Health Information System; IRB, Institutional Review Board; ICD, International Classification of Diseases; CCC, complex chronic condition; aOR, adjusted odds ratio; CI, confidence interval; IQR, interquartile range; BPD, bronchopulmonary dysplasia

*Corresponding author. Department of Anesthesiology and Critical Care Medicine, Children's Hospital of Philadelphia, 3401 Civic Center Blvd, Critical Care, 9 Main, Suite 9NW45, Philadelphia, PA 19104, USA.
E-mail address: gathersc@chop.edu (C.-A.L. Gathers).

Keywords: Disparities; Paediatric; Pneumonia; Race; Ethnicity; Geography

Research in context

Evidence before this study

Racial disparities in the incidence and outcomes for community-acquired pneumonia (CAP) exist in adults, with Black patients having higher incidence and mortality. While similar disparities in paediatric CAP have not yet been identified, racial disparities exist in mortality for paediatric sepsis (primarily caused by pneumonia), particularly for Black children in the South and West. We searched PubMed with the terms "community-acquired pneumonia," "bacterial," "race," "racial," "ethnic," "ethnicity," "disparities," and "hospital" to identify potential studies reporting on the association between race and/or ethnicity and bacterial CAP published in English up to September 30, 2024. One study reported racial and socioeconomic disparities in the incidence of bacterial CAP. Another study demonstrated that racial disparities in mortality from CAP can potentially be attributed to variations in hospital quality. However, these studies were limited to adults. A paediatric study published in 2004 revealed racial and ethnic disparities in hospital admission rates and procedures for children with pneumonia. Yet, there was no significant difference between various racial and ethnic groups in mortality for pneumonia. With paediatric healthcare in the United States becoming increasingly regionalized and vulnerability to pneumonia highly dependent on age, the contribution of geography and age to mortality for paediatric CAP warrants investigation.

Added value of this study

This study demonstrates that the combination of age, geographic region, and race or ethnicity significantly delineates mortality for paediatric CAP. Specifically, children under one year of age have higher mortality, and this association is significantly amplified for Black children throughout the United States, Hispanic/Latino children in the Northeast, Midwest, and West, White children in the South and West, and children of Other race in all geographic regions.

Implications of all the available evidence

This study demonstrates significant racial and ethnic disparities in paediatric CAP, which are affected by age and geography. When considering the joint association of race or ethnicity, age, and geographic region, differences in healthcare delivery across racial and ethnic groups, inequities in neonatal outcomes, and regional variation in healthcare may contribute to disparities in mortality for paediatric CAP. These findings may be applicable to other countries with similar healthcare challenges. It should be acknowledged that the specific drivers of healthcare disparities, such as structural inequities and access to specialized paediatric care, may differ in other international contexts.

Introduction

Pneumonia is a leading cause of inpatient admissions for children in the United States (US), with approximately 35,000 children hospitalized each year, totaling US $1 billion annually in medical costs.[1,2] While advancements in medical care have improved the treatment and management of community-acquired pneumonia (CAP) in adults and children, racial disparities persist in the incidence and outcomes of CAP in adults.[3,4] Although previous studies have demonstrated racial and ethnic disparities in hospital admissions and procedures for children with CAP, there is limited literature regarding racial and ethnic disparities in mortality for paediatric CAP.[5,6]

Pervasive racial and ethnic disparities are a paramount concern across a spectrum of challenges affecting children.[7,8] Paediatric sepsis, primarily caused by CAP, has well-documented disparities in mortality in the United States.[9,10] In an effort to understand these disparities, age and geographic region were evaluated by Mitchell et al. and found to significantly modify the association between race and ethnicity and mortality for paediatric sepsis. Specifically, Black children in the South and West and neonates had higher mortality.[9] However, most studies provide only a limited analysis of potential mechanisms that lead to these racial disparities.[8]

Utilizing methods to assess effect modification can help discern the relationship between race, ethnicity, and mortality across age or geographic regions. However, these methods are limited in their ability to determine the combined effect of multiple exposures on an outcome, which may be more representative of plausible mechanisms. Joint exposure modeling presents a novel opportunity to examine which subgroups are most affected by mortality related to paediatric CAP. As such, utilizing a joint exposure variable of race or ethnicity, age, and geographic region in a large paediatric database to identify potential interventions to improve CAP outcomes, we aimed to examine the collective association of race/ethnicity, age, and geographic region on mortality for paediatric CAP. We

hypothesized that age and geographic region could further delineate racial and ethnic disparities in paediatric CAP.

Methods

Study design and participants

This was a retrospective cohort study from the Public Health Information System (PHIS) database. PHIS is an administrative database containing clinical and resource utilization data for inpatient, ambulatory surgery, emergency department, and observation unit encounters for more than 49 tertiary-care paediatric hospitals affiliated with the Children's Hospital Association in the United States.[11] Data are de-identified at admission and subjected to various liability and validity checks before inclusion in the database. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline for observational studies.[12] The study was deemed exempt by the Children's Hospital of Philadelphia Institutional Review Board (IRB-20-017696) due to the use of de-identified data from the PHIS database which does not include personal identifiers. As such, there is minimal risk to patient privacy or safety.

The study cohort comprised patients less than 18 years old who were admitted to an inpatient or observational unit between 2016 and 2021 with a diagnosis of CAP. CAP was defined by the International Classification of Diseases (ICD), Tenth Revision, and Clinical Modification codes to identify patients admitted with common causes of bacterial CAP (primary or secondary ICD 10 codes J13–J18). Patients were excluded if both race and ethnicity were missing from the database. We also excluded patients with encounters in the emergency department, clinic, ambulatory surgery, or classified as "other" encounter. Additionally, patients with disposition status missing or transferred while inpatient were excluded.

Variables

The primary exposures for this study were hospital-reported race or ethnicity, geographic region, and age, analyzed as a joint exposure variable. Race and ethnicity were combined into Black, Hispanic/Latino, Other, and White to facilitate comparisons with other large US databases and protect against smaller sub-cohorts. Race and ethnicity were recorded separately in PHIS, with race recorded as Black, Other (Asian, Pacific Islander, American Indian, or Other race), or White. Ethnicity was recorded as Hispanic/Latino or Not Hispanic/Latino. For the purposes of this analysis, race and ethnicity were combined such that all subjects with Hispanic/Latino ethnicity classified as such, regardless of recorded race.[13] Geographic regions were reported as Northeast, South, Midwest, or West based on hospital location. We reported age as less than 1 year and 1–18 years. Patient characteristics included in the multivariable analysis were sex, primary insurance payer, median household income quartile, urban identification, and the presence of a complex chronic condition (CCC). The primary insurance payer was defined as commercial, government (Medicaid or Medicare), or other (self-pay or charity care). Median household income quartiles were defined utilizing patient ZIP code according to the median household income in 2019.[2,14] The first quartile included all patients with a household income of less than $48,000; second quartile $48,000–$60,999; third quartile $61,000–$81,999; fourth quartile more than $81,999. Urban identification was pre-defined in the PHIS database as a dichotomized variable of urban or not urban. CCC was defined in the PHIS database in accordance with the CCC version 2 classification system.[15]

Outcome

The primary outcome was death from any cause prior to hospital discharge.

Data analysis

Assuming a paediatric CAP mortality rate of less than 1% to detect a 1.25 times odds of death (informed by racial and ethnic differences in paediatric sepsis)[8] in Black and Hispanic/Latino children compared to White children with 80% power and 0.05 significance for a 2-sided t-test, a sample size of 29,100 patients from a subgroup of the joint exposure variable (e.g., Black children <1 year old from the South) was required. Patient characteristics were evaluated using Chi-square tests for categorical variables and Student's t-tests for continuous variables.

We a priori conducted a multivariable logistic regression analysis adjusting for age, sex, primary insurance payer, median household income quartile, urban identification, and CCC to analyze the association of race or ethnicity with mortality for paediatric CAP based on previous studies demonstrating racial, ethnic, or socioeconomic disparities in sepsis mortality.[8–10] Given the contribution of age and geography to sepsis outcomes (a diagnosis related to CAP), a joint exposure variable was created utilizing race or ethnicity, age, and geographic region to analyze the combined effects of age and geography on potential racial or ethnic disparities in mortality for paediatric CAP.

For all regressions, we evaluated age as <1 year and ≥1 year, given the differences in maternal health, access to neonatal intensive care, and healthcare delivery between these two age groups. Joint exposure modeling has been utilized previously to analyze the combined effects of two or more exposure variables on an outcome of interest.[16,17] For the joint exposure multivariable logistic regression analysis, we adjusted for sex, primary insurance payer, median household income quartile, urban identification, and the presence of a CCC

(Supplemental Figs. S2 and S3). We additionally clustered by hospital as a random effect to account for the inherent dependencies and variations within hospitals while simultaneously analyzing the overall relationships between exposure groups for all analyses. The reference group was White children <1 in the Northeast given the known racial and ethnic differences in mortality for paediatric sepsis in all regions except the Northeast.[9]

We also assessed the association of the joint exposure of race or ethnicity and geography stratified by < 1 year and ≥1 year. Confounder adjusted predicted mortalities of subjects are additionally presented utilizing this stratification. As children with CCC are at particular risk for poor outcomes, we performed an analysis restricted to these subjects. Joint exposure regression results are presented as adjusted odds ratios (aOR) with 95% confidence intervals (CI) and correlate to within-hospital effects. Predicted mortality is presented as percentages with 95% CI and correlate to within-hospital effects. All analyses were performed using Stata version 17.0 (College Station, TX: StataCorp LLC).

Role of funding source

The funding source had no role in the study design, data collection, data analysis, data interpretation, or manuscript preparation. The researchers maintained complete independence in conducting the study and reporting its findings.

Results

Patient characteristics

Cohort demographics are shown in Table 1. Among 4,626,887 patients at 47 hospitals, 783,981 children (median age 4 years [IQR 1–9 years], 45.9% female) met the inclusion criteria for CAP (Fig. 1). The 1–18 year age group (83.0%) comprised the largest age group. White children constituted 45.0% of the cohort, Black children 21.8%, Hispanic/Latino children 15.6%, and children of Other race 17.5%. Most encounters occurred in the South (39.8%) and urban areas (86.0%). Most children were in the lowest household income quartile (65.5%), utilized government insurance (63.6%), and were classified as having a CCC (69.2%). There is a similar distribution of demographics of children with a CCC as compared to all children in the inclusion cohort.

Among children with CAP, 6827 (0.9%) did not survive to hospital discharge. Of those children who did not survive to hospital discharge, 1767 (25.9%) were less than 1 year of age, 2920 (42.8%) were White, 1331 (19.5%) were Black, 1236 (18.1%) were Hispanic/Latino, 1340 (19.6%) were Other race, and 2866 (42%) were in the South.

Multivariable logistic regression outcomes

On multivariable logistic regression analyzing the association of race or ethnicity with mortality, Hispanic/Latino children (aOR 1.21, 95% CI 1.13–1.30) and children of Other race (aOR 1.22, 95% CI 1.13–1.31) had a higher odds of mortality as compared to White children (Table 2, Fig. 2). There was no significant difference in survival rates for Black children as compared to White children (aOR 1.01, 95% CI 0.94–1.08).

Joint exposure modeling outcomes

On multivariable logistic regression analyzing the joint association of race or ethnicity, age, and geographic region with mortality, children <1 year of age in all geographic regions and children <1 year of age in all racial and ethnic groups had a higher odds of mortality compared to White children <1 year of age in the Northeast (Table 3 and Fig. 3). Particularly, Hispanic/Latino children in the Northeast (aOR 2.36, 95% CI 1.08–5.15), Hispanic/Latino children in the Midwest (aOR 2.16, 95% CI 1.26–3.70), Black children in the South (aOR 2.35, 95% CI 1.52–3.63), and Black children in the West (aOR 2.47, 95% CI 1.35–4.49) had the highest odds of mortality in each geographic region as compared to White children <1 year of age in the Northeast. There was no significant association between the joint association of race or ethnicity, age 1–18 years of age, and geographic region with mortality. Joint associations across all groups are illustrated in Fig. 3. Predicted probabilities of mortality were similar to results of the joint exposure logistic regression with the highest mortality among Hispanic/Latino and Black children <1 in all regions and Hispanic/Latino children 1–18 years of age in all regions (Table 4, Figs. 4 and 5). Results were additionally similar when we restricted the analysis to children with a CCC (Supplemental Fig. S1 and Table S2) and when stratified by age with a joint exposure of race/ethnicity and geographic region (Supplemental Figs. S2 and S3 and Table S3).

Discussion

In this large, retrospective cohort study analyzing the joint association of race or ethnicity, age, and geographic region with mortality, we found evidence of significant disparities in mortality for paediatric CAP, particularly for children who are less than 1 year of age. This association was amplified for Black children <1 year throughout the United States, Hispanic/Latino children <1 year in the Northeast, Midwest, and West, White children <1 year in the South and West, and children of Other race <1 year in all geographic regions, compared to White children <1 in the Northeast.

Racial and ethnic disparities in paediatric critical care, particularly for respiratory illnesses, have been documented.[8,18,19] Furthermore, racial and ethnic disparities in the incidence and outcomes of CAP exist in adult literature, in addition to racial and ethnic disparities in antibiotic use for respiratory viral illnesses in children.[3–5] Moreover, racial and ethnic disparities in

outcomes based on geographic region exist for paediatric sepsis.[9] Our study expands on previous literature by highlighting the contribution of age and geographic region to racial and ethnic disparities in outcomes for paediatric CAP. The magnification of mortality for paediatric CAP via younger age and geographic region further highlights the complexities of structural inequities in paediatric inpatient care, specifically for paediatric CAP.[8,9] Given previous literature highlighting modes of structural inequity in paediatric healthcare, our results suggest that differences in healthcare delivery across racial and ethnic groups, inequities in neonatal outcomes continuing to affect mortality up to 1 year of age, and regional variation in healthcare may contribute to disparities in mortality for paediatric CAP. Moving forward, precisely tailoring healthcare delivery to vulnerable populations based on these disparities may be paramount in preventing child health inequities.[20]

Racial and ethnic disparities in paediatric critical care have been established in previous literature.[8] Factors likely contributing to these disparities include differences in access to care, comorbidities, severity of illness, prehospital interventions, timing of presentation to care, hospital quality, healthcare delivery, interpretation services for families with limited English proficiency, the family experience at bedside, and implicit bias.[21–27] To date, there has been a limited analysis of factors contributing to mortality for paediatric CAP. However, a previous study of emergency departments at academic children's hospitals showed that White children were more likely to receive antibiotics for viral acute respiratory tract infections than Black children, Hispanic/Latino children, and children of Other race.[5] This paradoxical "reverse disparity" is concerning as children were prescribed inappropriate antibiotics for a respiratory viral illness. This discrepancy is particularly striking, considering that pediatricians and teaching hospitals have lower antibiotic prescription rates for viral illnesses as compared to other specialties and non-teaching hospitals.[28,29] These differences in prescribing practices may be due to provider bias in predicting family expectations for an antibiotic prescription across racial and ethnic groups.[30] While children with CAP, as defined in our study, should receive (at least initial) antibiotics by definition, when considering provider implicit bias and practice variations, it is plausible that differential antibiotic prescribing, the existence of institutional CAP protocols, or adherence to such protocols, may mediate disparities in paediatric CAP.[5] Future studies should better elucidate the association between race and ethnicity, age, geographic region, and mortality for paediatric CAP by evaluating modifiable mechanisms, including differences in antibiotic administration, availability of interpretation services, the existence of hospital protocols for managing CAP, criteria for escalation of care, overall hospital payor mix as a marker of quality, and bias in clinical decision-making.

	Survive to Hospital Discharge		Total (N = 783,981)	p-value
	Yes (N = 777,154)	No (N = 6827)		
Sex, n (%)				0.007
Male	419,982 (54.0)	3576 (52.4)	423,558 (54.0)	
Female	356,958 (45.9)	3245 (47.5)	360,203 (45.9)	
Missing	214 (0.03)	6 (0.10)	220 (0.03)	
Age in years (IQR)	4 (1–9)	5 (0–12)	4 (1–9)	<0.001
Age group, n (%)				<0.001
Less than 1 year	131,675 (16.9)	1767 (25.9)	133,442 (17.0)	
1–18 years	645,479 (83.1)	5060 (74.1)	650,539 (83.0)	
Race/ethnicity, n (%)				<0.001
White	350,256 (45.1)	2920 (42.8)	353,176 (45.0)	
Black	169,637 (21.8)	1331 (19.5)	170,968 (21.8)	
Hispanic/Latino	121,035 (15.6)	1236 (18.1)	122,271 (15.6)	
Other	136,226 (17.5)	1340 (19.6)	137,566 (17.5)	
Geographic region, n (%)				<0.001
Northeast	87,255 (11.2)	645 (9.4)	87,900 (11.2)	
South	309,047 (39.8)	2866 (42.0)	311,913 (39.8)	
Midwest	237,392 (30.5)	1801 (26.4)	239,193 (30.5)	
West	143,460 (18.5)	1515 (22.2)	144,975 (18.5)	
Urban identification, n (%)				<0.001
Rural	97,006 (12.5)	1098 (16.1)	98,104 (12.5)	
Urban	668,587 (86.0)	5598 (82.0)	674,185 (86.0)	
Missing	11,561 (1.5)	131 (1.9)	11,692 (1.5)	
Household income quartiles, n (%)				0.002
0–47,999	508,672 (65.5)	4586 (67.2)	513,258 (65.5)	
48,000–60,999	141,722 (18.2)	1196 (17.5)	142,918 (18.2)	
61,000–81,999	86,529 (11.1)	676 (9.9)	87,205 (11.1)	
≥82,000	23,465 (3.0)	200 (2.9)	23,665 (3.0)	
Missing	16,766 (2.2)	169 (2.5)	16,935 (2.2)	
Insurance type, n (%)				<0.001
Commercial	255,393 (32.9)	2117 (31.0)	257,510 (32.8)	
Government	494,167 (63.6)	4437 (65.0)	498,604 (63.6)	
Other	18,866 (2.4)	196 (2.9)	19,062 (2.4)	
Missing	8728 (1.1)	77 (1.1)	8805 (1.1)	
Complex chronic condition, n (%)				<0.001
Absent	241,216 (31.0)	106 (1.6)	241,322 (30.8)	
Present	535,938 (69.0)	6721 (98.4)	542,659 (69.2)	

Table 1: **Cohort demographics.**

Complex chronic conditions in infancy may manifest in the neonatal period due to sequelae of prematurity. Specifically, the development of bronchopulmonary dysplasia as a neonate places children at increased risk for recurrent CAP, additional comorbidities, and mortality.[31] While two previous studies have shown that children born to White mothers have increased odds of developing bronchopulmonary dysplasia as compared to children born to non-White and Black mothers, the studies also demonstrated that children born to White mothers have a decreased likelihood of respiratory

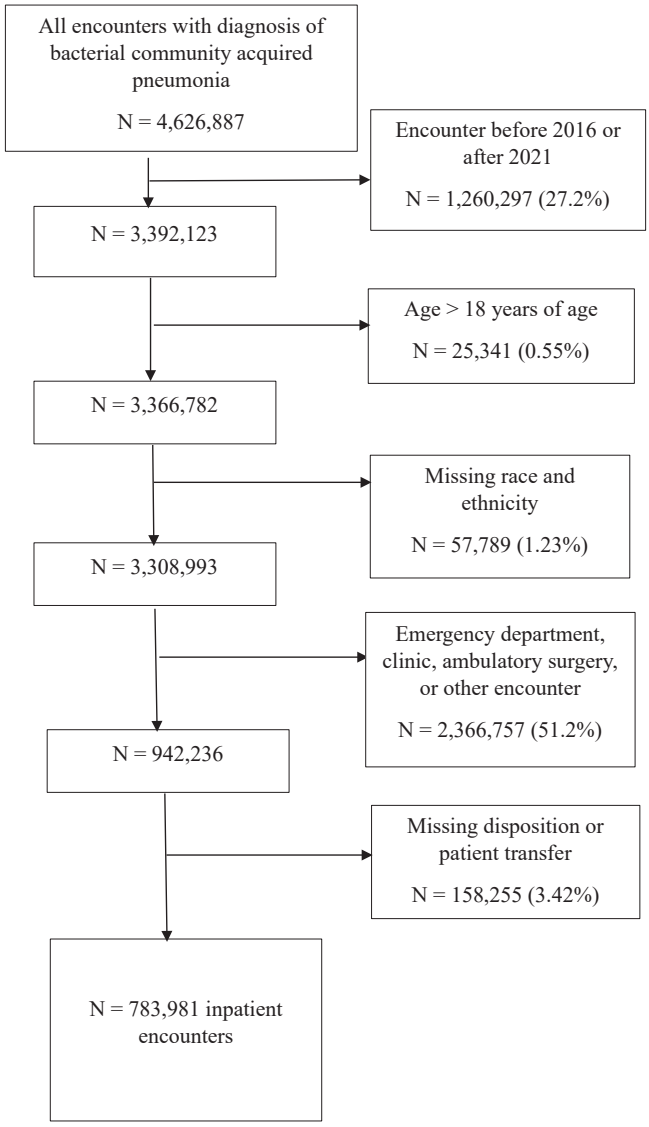

Fig. 1: **CONSORT diagram**.

comorbidities in the first 2 years of life.[32,33] Moreover, another study that adjusted for hospital site and had no differences in overall bronchopulmonary dysplasia disease severity between racial groups identified racial differences in mortality during the initial birth hospitalization.[34] Neonates born to Black mothers had higher mortality and increased length of stay than neonates born to White mothers. We hypothesize that these racial disparities in bronchopulmonary dysplasia risk as a neonate and respiratory comorbidities later in life may result in increased mortality for CAP for non-White infants. However, given that Black children have lower rates of bronchopulmonary dysplasia (possibly due to higher mortality precluding development of bronchopulmonary dysplasia), but higher mortality associated with bronchopulmonary dysplasia, it is critical to consider other aspects of care, including the experience of Black families, perinatal care for Black women,

Race/Ethnicity	aOR (95% CI)
White	Reference
Black	1.01 (0.94–1.08)
Hispanic/Latino	1.21 (1.13–1.30)
Other	1.22 (1.13–1.31)

Model adjusts for sex, age, geographic region, primary insurance payer, median household income quartile, urban identification, and the presence of a complex chronic condition. aOR = adjusted odds ratio, CI = confidence interval.

Table 2: **Association of race/ethnicity with all-cause mortality.**

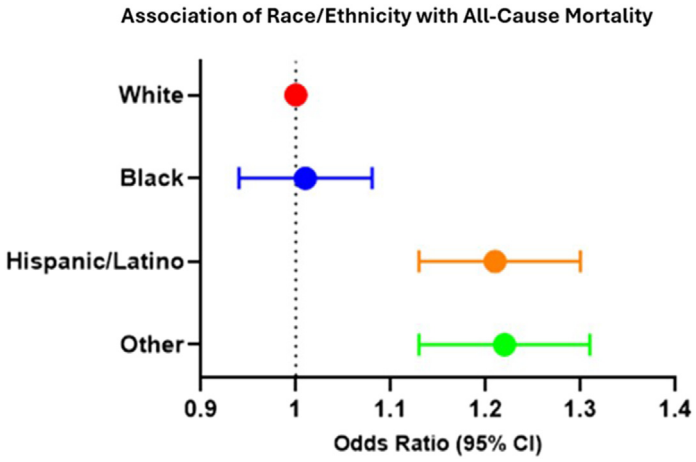

Fig. 2: Association of race or ethnicity with all-cause mortality.

provider communication, and bias in the intensive care setting as these drivers likely magnify disparities in bronchopulmonary dysplasia-related outcomes.[35,36] These factors are particularly contributory given that our study did not identify CCCs as an effect modifier of mortality. While the previously mentioned studies specifically emphasize disparities between Black and White mothers, similar drivers of disparities likely apply to other racial and ethnic groups. This notion is especially plausible when considering adverse outcomes related to language disconcordance.[21] The interplay of disparities in neonatal outcomes with differences in healthcare delivery continues to highlight the complexity of disentangling drivers of disparate outcomes. Given the disparities in preterm birth and bronchopulmonary dysplasia in historically marginalized racial and ethnic communities, the implementation of community-based interventions to enhance access to prenatal and infant care is essential to reducing disparities in maternal and infant health outcomes. Community health worker programs, mobile health units, and structured group prenatal care models provide culturally competent care, facilitate navigation of healthcare barriers, and promote health literacy to enhance access to prenatal and infant care.[37–40] These approaches address both immediate healthcare access needs and underlying social determinants of health, ultimately advancing maternal health and reducing racial and ethnic disparities in preterm birth and bronchopulmonary dysplasia outcomes.

Geography has been shown to magnify existing disparities in outcomes in paediatric critical care. A previous study of a large, nationally representative registry demonstrated that racial disparities in sepsis mortality are further amplified in the South and West.[9] Moreover, it has been shown that distance to paediatric intensive care services increases with poverty.[27] While our study did not examine markers of socioeconomic status as the primary exposure, we expand upon previous literature showing that geographic region plays an important role in driving mortality for CAP. The implications for regional variation in outcomes are critical, as the utilization of paediatric intensive care unit services is increasing and becoming more regionalized.[41] Moreover, children who require transfer for critical services

Less than 1 Year of Age		1–18 Years of Age	
	aOR (95% CI)		aOR (95% CI)
Northeast		**Northeast**	
White	Reference	White	0.87 (0.62–1.22)
Black	2.31 (1.46–3.66)	Black	0.68 (0.46–1.00)
Hispanic/Latino	2.36 (1.08–5.15)	Hispanic/Latino	1.48 (0.92–2.37)
Other	1.96 (1.24–3.11)	Other	0.74 (0.51–1.07)
South		**South**	
White	1.87 (1.21–2.88)	White	0.76 (0.50–1.16)
Black	2.35 (1.52–3.63)	Black	0.80 (0.52–1.23)
Hispanic/Latino	1.55 (0.99–2.44)	Hispanic/Latino	0.94 (0.61–1.44)
Other	2.31 (1.45–3.66)	Other	1.11 (0.72–1.71)
Midwest		**Midwest**	
White	1.40 (0.90–2.17)	White	0.74 (0.48–1.13)
Black	1.75 (1.11–2.77)	Black	0.69 (0.45–1.07)
Hispanic/Latino	2.16 (1.26–3.70)	Hispanic/Latino	0.96 (0.60–1.54)
Other	1.78 (1.09–2.89)	Other	0.88 (0.56–1.38)
West		**West**	
White	2.32 (1.46–3.66)	White	1.01 (0.65–1.58)
Black	2.47 (1.35–4.49)	Black	0.70 (0.41–1.17)
Hispanic/Latino	1.90 (1.17–3.09)	Hispanic/Latino	1.05 (0.67–1.64)
Other	1.79 (1.12–2.86)	Other	1.16 (0.74–1.81)

Model adjusts for sex, primary insurance payer, median household income quartile, urban identification, and the presence of a complex chronic condition. aOR = adjusted odds ratio, CI = confidence interval.

Table 3: **Joint associations of age, region, and race or ethnicity with all-cause mortality.**

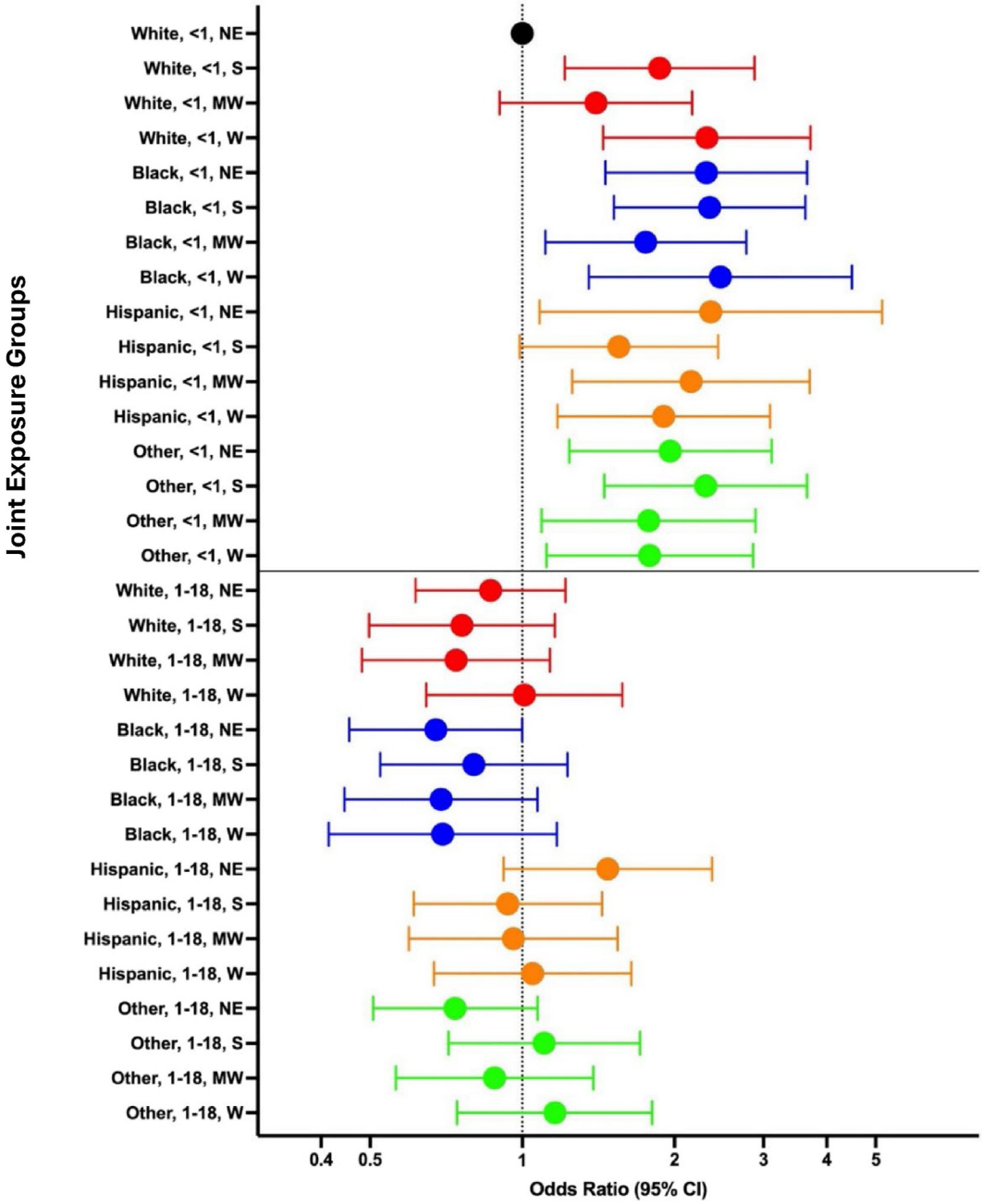

***Fig. 3*: Joint association of age, region, race or ethnicity with all-cause mortality.** NE = Northeast, S = South, MW = Midwest, W = West.

have higher mortality and delayed definitive treatment.[42] When considering the impact of regional care in more rural areas, typically concentrated in the South and West, critical care for paediatric CAP may be delayed and contribute to increased mortality in these regions. Additionally, non-paediatric emergency medicine providers, often the providers transferring the patient to a paediatric intensive care unit, may be less comfortable with managing paediatric patients.[43] This is especially true for infants who sustain higher mortality in our study. Lastly, disparities in care may be related to differences in hospital quality. Previous studies have demonstrated that hospital characteristics contribute to variable outcomes across racial and ethnic groups, with

Black patients racially segregated and concentrated at lower-quality hospitals.[44,45] Racial segregation impacts many components of health (access to medical care, nutrition, emotional well-being, education, environment, and economic stability) in addition to health care delivery.[46] In a study by Horbar and colleagues, the authors identified significant racial and ethnic segregation across neonatal intensive care units, with large differences in neonatal intensive care unit quality across geographic regions and Black infants receiving care at lower-quality neonatal intensive care units.[45] Future studies should examine the characteristics of high-performing centers that better mitigate disparities in outcomes for paediatric CAP. Additionally, future policy implications should prioritize paediatric healthcare in underserved regions, continued education for non-paediatric emergency medicine providers, and equitable care across paediatric hospitals.

Our study should be interpreted in the context of its limitations. We constructed our age groupings on the presumption that maternal factors may continue to drive disparities in infancy. However, a different age grouping could result in a different conclusion for this study, and future studies should elucidate between children in the neonatal intensive care unit with CAP and children primarily admitted from home with CAP, as the joint association in this study may partially be driven by healthcare delivery and medical complexity in the neonatal intensive care unit population. We also did not impute data for patients with missing insurance status, urban designation, or geography. This data had <3% missingness and should not significantly bias the results. Additionally, the "Other" race group represents a heterogeneous population of children. As such, conclusions on granular factors contributing to disparate outcomes for this racial group are difficult to discern. We used the definition of a CCC in the PHIS database, and this definition may not fully account for the granularity of medical complexity seen in paediatric health.[15] We also did not evaluate markers or composite indices of socioeconomic status as the primary exposure since we aimed to build upon previous literature that noted geographic variations in outcomes across racial and ethnic groups. We were limited by the data available in PHIS, and notable variables that were not recorded in this deidentified dataset include the primary language of the patient, perinatal care, distance to care, duration of symptoms before presentation, pre-encounter medical contact, provider variability in care, and specific cause of death. Future studies should evaluate these granular factors to better understand mechanisms associated with mortality for children with CAP. Additionally, we did not incorporate community consultation in the research design. Future studies incorporating community input could better align findings with community-specific needs and enhance the relevance and potential impact of interventions. PHIS is entirely composed of tertiary children's hospitals, which likely have more consistent and well-developed paediatric resources compared to community hospitals. While our findings may not be fully explained by differential hospital quality, these tertiary hospital settings may not fully capture the variability and systemic inequities present in broader paediatric pneumonia admissions across tertiary children's hospitals. Given complex correction methods for the various subgroups in our study, we did not apply formal correction methods for our power calculation. However, our power calculation was constructed on the premise that age and geography are effect modifiers for racial and ethnic disparities in mortality for CAP. As such, we mirrored previous studies that were adequately powered to detect racial and ethnic differences in mortality. Given that ethnicity was reported if both race and ethnicity were recorded in PHIS, we are limited in assessing the full diversity of our inclusion cohort. However, an additional 3% of the cohort had missing ethnicity data, and we prioritized including all individuals with a race or ethnicity flag reported to ensure we were adequately powered to detect racial and ethnic differences in mortality. Lastly, while race and ethnicity are presumed to be self-identified, there is potential for exposure misclassification as this is a large administrative database of hospital reported data.

Less than 1 year of age		1–18 years of age	
	Predicted probability of mortality [%] (95% CI)		Predicted probability of mortality [%] (95% CI)
Northeast		**Northeast**	
White	0.83 (0.44–1.23)	White	0.78 (0.59–0.97)
Black	1.84 (0.99–2.69)	Black	0.61 (0.42–0.80)
Hispanic/Latino	1.74 (0.41–3.08)	Hispanic/Latino	1.36 (0.82–1.89)
Other	1.61 (0.87–2.35)	Other	0.67 (0.48–0.86)
South		**South**	
White	1.38 (1.06–1.71)	White	0.71 (0.60–0.81)
Black	1.72 (1.31–2.14)	Black	0.74 (0.63–0.86)
Hispanic/Latino	1.13 (0.82–1.44)	Hispanic/Latino	0.89 (0.74–1.03)
Other	1.91 (1.38–2.45)	Other	0.97 (0.79–1.14)
Midwest		**Midwest**	
White	0.99 (0.74–1.25)	White	0.71 (0.60–0.82)
Black	1.38 (0.99–1.76)	Black	0.64 (0.52–0.75)
Hispanic/Latino	1.69 (1.02–2.37)	Hispanic/Latino	0.88 (0.65–1.10)
Other	1.37 (0.91–1.82)	Other	0.81 (0.64–0.98)
West		**West**	
White	1.84 (1.24–2.45)	White	0.92 (0.74–1.10)
Black	1.92 (1.00–2.84)	Black	0.64 (0.43–0.85)
Hispanic/Latino	1.48 (0.97–1.99)	Hispanic/Latino	0.96 (0.77–1.16)
Other	1.33 (0.89–1.76)	Other	1.08 (0.87–1.29)

Model adjusts for sex, primary insurance payer, median household income quartile, and urban identification. CI = confidence interval.

Table 4: **Predicted probability of all cause in-hospital mortality.**

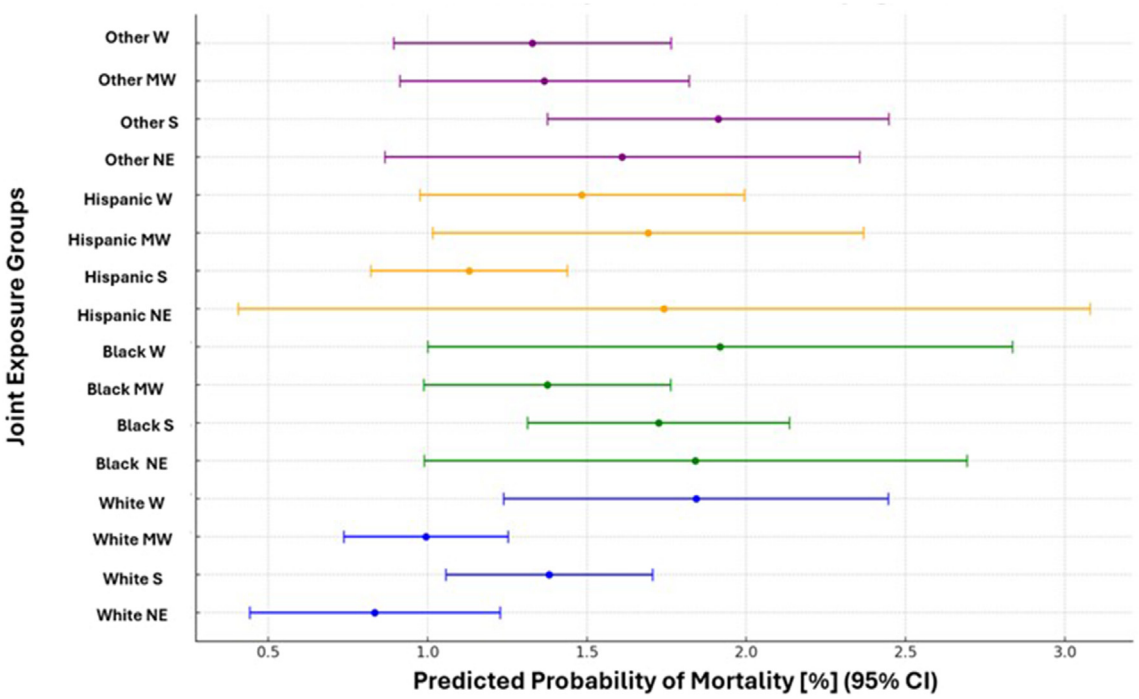

Fig. 4: **Predicted probability of all-cause mortality age < 1 year.** NE = Northeast, S = South, MW = Midwest, W = West.

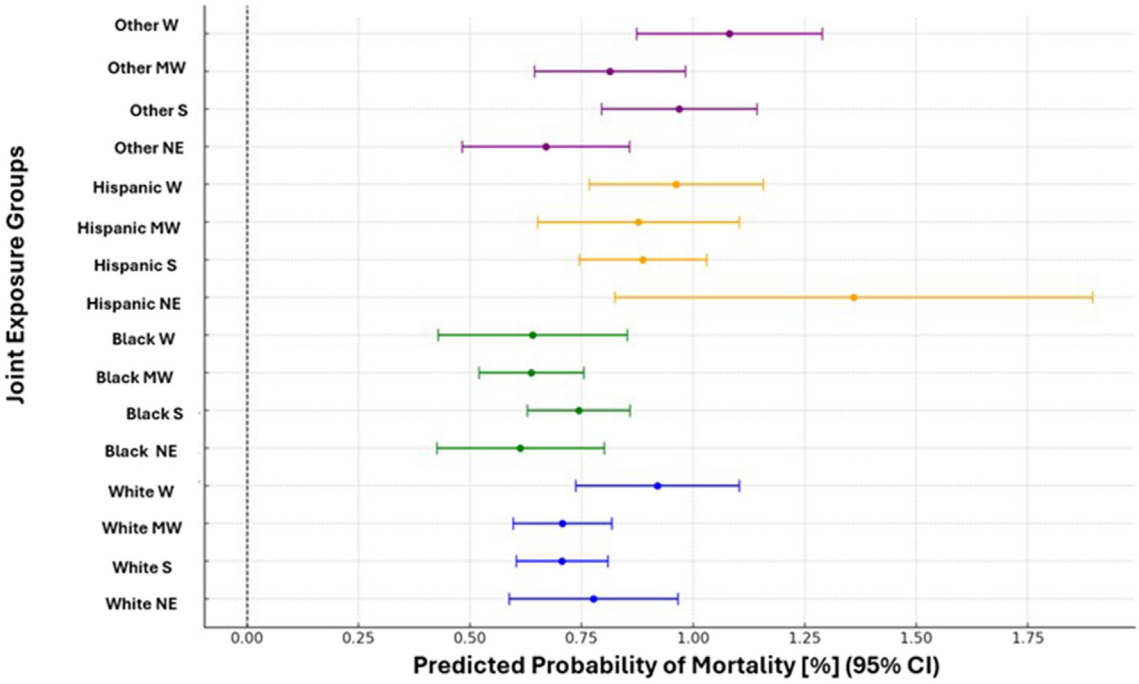

Fig. 5: **Predicted probability of all-cause mortality age 1–18 years.** NE = Northeast, S = South, MW = Midwest, W = West.

Conclusion

We found evidence of racial and ethnic disparities in mortality for hospitalized children with CAP. Joint associations of age and geographic region may partially inform mechanisms underlying these racial disparities. Future work should incorporate community engagement with maternal and infant care, in addition to evaluating the contribution of healthcare delivery and hospital variation in clarifying the mechanism for racial and ethnic disparities for paediatric CAP.

Contributors

Dr. Cody-Aaron Gathers conceptualized and designed the study, assisted in data handling, performed the data analysis, drafted the initial manuscript, and critically reviewed and revised the manuscript.

Dr. Nadir Yehya conceptualized and designed the study, and critically reviewed and revised the manuscript.

Dr. Anireddy Reddy critically reviewed and revised the manuscript.

Dr. Paula M. Magee critically reviewed and revised the manuscript.

Dr. Vanessa Denny critically reviewed and revised the manuscript.

Dr. Michelle Mayeda critically reviewed and revised the manuscript.

Dr. Amanda O'Halloran critically reviewed and revised the manuscript.

Dr. Sanjiv Mehta critically reviewed and revised the manuscript.

Dr. Stephanie Wanamaker critically reviewed and revised the manuscript.

Dr. Jessica Fowler critically reviewed and revised the manuscript.

Dr. Garrett Keim conceptualized and designed the study, assisted in data handling, performed the data analysis, critically reviewed and revised the manuscript, and supervised the study.

All authors had full access to the data.

All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

Data sharing statement

This paper uses publicly accessible data from the PHIS database (https://www.childrenshospitals.org/content/analytics/product-program/pediatric-health-information-system).

Declaration of interests

This work was published as an abstract in Critical Care Medicine (https://doi.org/10.1097/01.ccm.0000906764.65803.69) and presented at the 2023 Society of Critical Care Medicine Annual Congress.

Acknowledgements

We thank the PHIS database for the data.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lana.2025.101001.

References

1 McDermott KW, Roemer M. *Most frequent principal diagnoses for inpatient stays in U.S. Hospitals, 2018*. Rockville MD: Agency for Healthcare Research and Quality; 2021. www.hcup-us.ahrq.gov/reports/statbriefs/sb277-Top-Reasons-Hospital-Stays-2018.pdf. Accessed August 20, 2023.
2 Agency for Healthcare Research and Quality. Healthcare cost and utilization project (HCUP) fast stats—national hospital utilization & costs. https://datatools.ahrq.gov/hcup-fast-stats/. Accessed August 20, 2023.
3 Burton DC, Flannery B, Bennett NM, et al. Socioeconomic and racial/ethnic disparities in the incidence of bacteremic pneumonia among US adults. *Am J Public Health*. 2010;100(10):1904–1911. https://doi.org/10.2105/AJPH.2009.181313.
4 Flory JH, Joffe M, Fishman NO, Edelstein PH, Metlay JP. Socioeconomic risk factors for bacteraemic pneumococcal pneumonia in adults. *Epidemiol Infect*. 2009;137(5):717–726. https://doi.org/10.1017/S0950268808001489.
5 Goyal MK, Johnson TJ, Chamberlain JM, et al. Racial and ethnic differences in antibiotic use for viral illness in emergency departments. *Pediatrics*. 2017;140(4):e20170203. https://doi.org/10.1542/peds.2017-0203.
6 Washington EL, Shen JJ, Bell R, Coleman C, Shi L. Patterns of hospital-based pediatric care across diverse ethnicities: the case of pneumonia. *J Health Care Poor Underserved*. 2004;15(3):462–473. https://doi.org/10.1353/hpu.2004.0050.
7 Flores G, THE COMMITTEE ON PEDIATRIC RESEARCH. Racial and ethnic disparities in the health and health care of children. *Pediatrics*. 2010;125(4):e979–e1020. https://doi.org/10.1542/peds.2010-0188.
8 Mitchell HK, Reddy A, Perry MA, Gathers CA, Fowler JC, Yehya N. Racial, ethnic, and socioeconomic disparities in paediatric critical care in the USA. *Lancet Child Adolesc Health*. 2021;5(10):739–750. https://doi.org/10.1016/S2352-4642(21)00161-9.
9 Mitchell HK, Reddy A, Montoya-Williams D, Harhay M, Fowler JC, Yehya N. Hospital outcomes for children with severe sepsis in the USA by race or ethnicity and insurance status: a population-based, retrospective cohort study. *Lancet Child Adolesc Health*. 2021;5(2):103–112. https://doi.org/10.1016/S2352-4642(20)30341-2.
10 Reddy AR, Badolato GM, Chamberlain JM, Goyal MK. Disparities associated with sepsis mortality in critically ill children. *J Pediatr Intensive Care*. 2020;11(2):147–152. https://doi.org/10.1055/s-0040-1721730.
11 Leverage clinical and resource utilization data. https://www.childrenshospitals.org/content/analytics/product-program/pediatric-health-information-system. Accessed May 30, 2024.
12 Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. 2008;61(4):344–349. https://doi.org/10.1016/j.jclinepi.2007.11.008.
13 Federal Register. Revisions to OMB's statistical policy directive No. 15: standards for maintaining, collecting, and presenting federal data on race and ethnicity. https://www.federalregister.gov/documents/2024/03/29/2024-06469/revisions-to-ombs-statistical-policy-directive-no-15-standards-for-maintaining-collecting-and. Accessed June 14, 2024.
14 Healthcare cost and utilization project (HCUP) NIS notes. https://hcup-us.ahrq.gov/db/vars/zipinc_qrtl/nisnote.jsp. Accessed November 21, 2023.
15 Feudtner C, Feinstein JA, Zhong W, Hall M, Dai D. Pediatric complex chronic conditions classification system version 2: updated for ICD-10 and complex medical technology dependence and transplantation. *BMC Pediatr*. 2014;14(1):199. https://doi.org/10.1186/1471-2431-14-199.
16 Sangaramoorthy M, Shariff-Marco S, Conroy SM, et al. Joint associations of race, ethnicity, and socioeconomic status with mortality in the multiethnic cohort study. *JAMA Netw Open*. 2022;5(4):e226370. https://doi.org/10.1001/jamanetworkopen.2022.6370.
17 Huang W, Zhou Y, Chen X, et al. Individual and joint associations of long-term exposure to air pollutants and cardiopulmonary mortality: a 22-year cohort study in Northern China. *Lancet Reg Health West Pac*. 2023;36:100776. https://doi.org/10.1016/j.lanwpc.2023.100776.
18 Silber JH, Rosenbaum PR, Calhoun SR, et al. Racial disparities in medicaid asthma hospitalizations. *Pediatrics*. 2017;139(1):e20161221. https://doi.org/10.1542/peds.2016-1221.
19 Mpody C, Kemper AR, Aldrink JH, Michalsky MP, Tobias JD, Nafiu OO. Trends and economic implications of disparities in postoperative pneumonia. *Pediatrics*. 2023;151(5):e2022058774. https://doi.org/10.1542/peds.2022-058774.
20 Goldfeld S, Gray S, Azpitarte F, et al. Driving precision policy responses to child health and developmental inequities. *Health Equity*. 2019;3(1):489–494. https://doi.org/10.1089/heq.2019.0045.
21 Khan A, Yin HS, Brach C, et al. Association between parent comfort with English and adverse events among hospitalized children. *JAMA Pediatr*. 2020;174(12):e203215. https://doi.org/10.1001/jamapediatrics.2020.3215.
22 Lopez AM, Tilford JM, Anand KJS, et al. Variation in pediatric intensive care therapies and outcomes by race, gender, and insurance status*. *Pediatr Crit Care Med*. 2006;7(1):2–6. https://doi.org/10.1097/01.PCC.0000192319.55850.81.
23 Purcell LN, Hayes-Jordan A. Racial and ethnic disparities in access and outcomes in children's health care. *Surgery*. 2021;169(6):1288–1289. https://doi.org/10.1016/j.surg.2021.01.020.

24 Kenyon CC, Melvin PR, Chiang VW, Elliott MN, Schuster MA, Berry JG. Rehospitalization for childhood asthma: timing, variation, and opportunities for intervention. *J Pediatr*. 2014;164(2):300–305. https://doi.org/10.1016/j.jpeds.2013.10.003.

25 Smith MB, Dervan LA, Watson RS, et al. Family presence at the PICU bedside: a single-center retrospective cohort study*. *Pediatr Crit Care Med*. 2023;24(12):1053–1062. https://doi.org/10.1097/PCC.0000000000003334.

26 Dehon E, Weiss N, Jones J, Faulconer W, Hinton E, Sterling S. A systematic Review of the impact of physician implicit racial bias on clinical decision making. Choo EK, ed *Acad Emerg Med*. 2017;24(8):895–904. https://doi.org/10.1111/acem.13214.

27 Brown LE, França UL, McManus ML. Socioeconomic disadvantage and distance to pediatric critical care*. *Pediatr Crit Care Med*. 2021;22(12):1033–1041. https://doi.org/10.1097/PCC.0000000000002807.

28 Nadeem Ahmed M, Muyot MM, Begum S, Smith P, Little C, Windemuller FJ. Antibiotic prescription pattern for viral respiratory illness in emergency room and ambulatory care settings. *Clin Pediatr (Phila)*. 2010;49(6):542–547. https://doi.org/10.1177/0009922809357786.

29 Yaeger JP, Temte JL, Hanrahan LP, Martinez-Donate P. Roles of clinician, patient, and community characteristics in the management of pediatric upper respiratory tract infections. *Ann Fam Med*. 2015;13(6):529–536. https://doi.org/10.1370/afm.1856.

30 Mangione-Smith R, Elliott MN, Stivers T, McDonald L, Heritage J, McGlynn EA. Racial/ethnic variation in parent expectations for antibiotics: implications for public health campaigns. *Pediatrics*. 2004;113(5):e385–e394. https://doi.org/10.1542/peds.113.5.e385.

31 Jensen EA, Edwards EM, Greenberg LT, Soll RF, Ehret DEY, Horbar JD. Severity of bronchopulmonary dysplasia among very preterm infants in the United States. *Pediatrics*. 2021;148(1):e2020030007. https://doi.org/10.1542/peds.2020-030007.

32 Morrow LA, Wagner BD, Ingram DA, et al. Antenatal determinants of bronchopulmonary dysplasia and late respiratory disease in preterm infants. *Am J Respir Crit Care Med*. 2017;196(3):364–374. https://doi.org/10.1164/rccm.201612-2414OC.

33 Ryan RM, Feng R, Bazacliu C, et al. Black race is associated with a lower risk of bronchopulmonary dysplasia. *J Pediatr*. 2019;207:130–135.e2. https://doi.org/10.1016/j.jpeds.2018.11.025.

34 Lewis TR, Kielt MJ, Walker VP, et al. Association of racial disparities with in-hospital outcomes in severe bronchopulmonary dysplasia. *JAMA Pediatr*. 2022;176(9):852–859. https://doi.org/10.1001/jamapediatrics.2022.2663.

35 McLemore MR, Altman MR, Cooper N, Williams S, Rand L, Franck L. Health care experiences of pregnant, birthing and postnatal women of color at risk for preterm birth. *Soc Sci Med*. 2018;201:127–135. https://doi.org/10.1016/j.socscimed.2018.02.013.

36 Profit J, Gould JB, Bennett M, et al. Racial/ethnic disparity in NICU quality of care delivery. *Pediatrics*. 2017;140(3):e20170918. https://doi.org/10.1542/peds.2017-0918.

37 Yelland J, Riggs E, Szwarc J, et al. Bridging the Gap: using an interrupted time series design to evaluate systems reform addressing refugee maternal and child health inequalities. *Implement Sci*. 2015;10(1):62. https://doi.org/10.1186/s13012-015-0251-z.

38 Yelland J, Mensah F, Riggs E, et al. Evaluation of systems reform in public hospitals, Victoria, Australia, to improve access to antenatal care for women of refugee background: an interrupted time series design. *PLoS Med*. 2020;17(7):e1003089. https://doi.org/10.1371/journal.pmed.1003089.

39 Byerley BM, Haas DM. A systematic overview of the literature regarding group prenatal care for high-risk pregnant women. *BMC Pregnancy Childbirth*. 2017;17(1):329. https://doi.org/10.1186/s12884-017-1522-2.

40 Scharff D, Enard KR, Tao D, Strand G, Yakubu R, Cope V. Community health worker impact on knowledge, antenatal care, and birth outcomes: a systematic Review. *Matern Child Health J*. 2022;26(1):79–101. https://doi.org/10.1007/s10995-021-03299-w.

41 Killien EY, Keller MR, Watson RS, Hartman ME. Epidemiology of intensive care admissions for children in the US from 2001 to 2019. *JAMA Pediatr*. 2023;177(5):506–515. https://doi.org/10.1001/jamapediatrics.2023.0184.

42 Odetola FO, Gebremariam A. Transfer hospitalizations for pediatric severe sepsis or septic shock: resource use and outcomes. *BMC Pediatr*. 2019;19(1):196. https://doi.org/10.1186/s12887-019-1577-5.

43 Jain PN, Choi J, Katyal C. Pediatric care in the nonpediatric emergency department: provider perspectives. *Hosp Pediatr*. 2019;9(3):216–219. https://doi.org/10.1542/hpeds.2018-0133.

44 Jones JM, Fingar KR, Miller MA, et al. Racial disparities in sepsis-related in-hospital mortality: using a broad case capture method and multivariate controls for clinical and hospital variables, 2004–2013. *Crit Care Med*. 2017;45(12):e1209–e1217. https://doi.org/10.1097/CCM.0000000000002699.

45 Horbar JD, Edwards EM, Greenberg LT, et al. Racial segregation and inequality in the neonatal intensive care unit for very low-birthweight and very preterm infants. *JAMA Pediatr*. 2019;173(5):455. https://doi.org/10.1001/jamapediatrics.2019.0241.

46 Trent M, Dooley DG, Dougé J, et al. The impact of racism on child and adolescent health. *Pediatrics*. 2019;144(2):e20191765. https://doi.org/10.1542/peds.2019-1765.