ARTICLE

Cranial Computed Tomography Use Among Children With Minor Blunt Head Trauma

Association With Race/Ethnicity

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Objective: To determine if patient race/ethnicity is independently associated with cranial computed tomography (CT) use among children with minor blunt head trauma.

Design: Secondary analysis of a prospective cohort study.

Setting: Pediatric research network of 25 North American emergency departments.

Patients: In total, 42 412 children younger than 18 years were seen within 24 hours of minor blunt head trauma. Of these, 39 717 were of documented white non-Hispanic, black non-Hispanic, or Hispanic race/ethnicity. Using a previously validated clinical prediction rule, we classified each child's risk for clinically important traumatic brain injury to describe injury severity. Because no meaningful differences in cranial CT rates were observed between children of black non-Hispanic race/ethnicity vs Hispanic race/ethnicity, we combined these 2 groups.

Main Outcome Measure: Cranial CT use in the emergency department, stratified by race/ethnicity.

Results: In total, 13 793 children (34.7%) underwent cranial CT. The odds of undergoing cranial CT among children with minor blunt head trauma who were at higher risk for clinically important traumatic brain injury did not differ by race/ethnicity. In adjusted analyses, children of black non-Hispanic or Hispanic race/ethnicity had lower odds of undergoing cranial CT among those who were at intermediate risk (odds ratio, 0.84; 95% CI, 0.76-0.94) or lowest risk (odds ratio, 0.73; 95% CI, 0.66-0.81) for clinically important traumatic brain injury. Regardless of risk for clinically important traumatic brain injury, parental anxiety and request was commonly cited by physicians as an important influence for ordering cranial CT in children of white non-Hispanic race/ethnicity.

Conclusions: Disparities may arise from the overuse of cranial CT among patients of nonminority races/ethnicities. Further studies should focus on explaining how medically irrelevant factors, such as patient race/ethnicity, can affect physician decision making, resulting in exposure of children to unnecessary health care risks.

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Group Information: The Pediatric Emergency Care Applied Research Network group members are listed on page 737.

Racial/ethnic disparities affect health and health care among children across a wide variety of conditions.[1] Of greatest concern are potentially modifiable disparities affecting aspects of health care and resource allocation that adversely influence short- and long-term outcomes of medical treatment. Among children, disparities are observed in emergency care, including chronic disease management, behavioral health, opioid pain management, wait times, and the evaluation or management of potential abuse.[2-8] Multiple explanations for such disparities have been suggested. These include inaccurate and biased assessment of race/ethnicity or medical treatment and outcomes, confounding by socioeconomic status or site of care, and true differences in physician behavior or medical care influenced by patient race/ethnicity.[9,10] A controlled study[11] describing disparities in almost 9000 severity-adjusted pediatric hospitalizations demonstrated increased admissions among less seriously ill patients of white race/ethnicity rather than failure to admit more seriously ill patients of black or Hispanic race/ethnicity.

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Traumatic brain injury (TBI) is a leading source of pediatric morbidity and mortality in the United States, responsible for approximately 7400 deaths, 60 000 hospital admissions, and more than 600 000 emergency department (ED) visits annually.[12] Available evidence suggests that children of black race/ethnicity experience

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worse functional outcomes than children of white race/ethnicity following TBI, even after controlling for injury severity.[13,14] Therefore, it is important to identify and address any disparities in the evaluation and management of head trauma that may contribute to differential outcomes. In the present study, we focused on cranial computed tomography (CT) use for the evaluation of minor but nontrivial blunt head trauma in children. Cranial CT use may be especially relevant because it is the standard of care for emergency diagnosis of TBI, but irradiation is associated with increased long-term risk for malignant neoplasms, particularly in children.[15-17] This makes underuse or overuse of CT problematic and racial/ethnic disparities in judicious neuroimaging particularly troublesome. To date, the only available evidence concerning this issue was derived from a secondary analysis of head injuries from the National Hospital Ambulatory Medical Care Survey, which included 1256 ED visits among children younger than 20 years.[18] In that cohort, children of white race/ethnicity were 1.5 times more likely to undergo neuroimaging; however, the study was limited by its retrospective nature and use of proxy measures of injury severity in the analysis (triage status, associated injuries, and discharge status as admission vs transfer).

The objective of this study was to determine if patient race/ethnicity is independently associated with cranial CT use in the ED among children with minor blunt head trauma, after controlling for injury severity and hospital site of care. Determining the extent to which patient race/ethnicity independently influences the use of diagnostic imaging in head trauma is essential to ensure prudent and equitable care for all children.

METHODS

We performed a planned secondary analysis of a large prospective cohort study of children younger than 18 years with nontrivial minor blunt head trauma. The study was conducted between June 2004 and September 2006 in the EDs at 25 Pediatric Emergency Care Applied Research Network (PECARN) sites.[19] The study was approved by each participating site's institutional review board. The methods of the primary study[19] are described elsewhere, while the specific methods relevant to this secondary analysis are described herein.

INCLUSION AND EXCLUSION CRITERIA

We enrolled children with minor blunt head trauma, defined by a Glasgow Coma Scale (GCS) score of 14 or 15, who were seen at the ED within 24 hours of the traumatic event. Patients with trivial injury mechanisms, defined a priori as ground-level falls or as walking or running into stationary objects, and with no signs or symptoms of head trauma other than scalp abrasions or lacerations, were excluded from the study, as were patients with penetrating trauma, comorbidities (ventricular shunts or bleeding disorders), or previous neuroimaging, as well as those who left the ED against medical advice.

DATA COLLECTION

For all the enrolled patients, the treating physician completed a structured case report form. On the case report form, race/ethnicity was separated into the following categories: white, black, Asian, American Indian/Alaskan native, Pacific Islander, unknown, or other. The physician determined and recorded the patient's race/ethnicity. For those children with orders for cranial CT, the physician documented indications that were most important in influencing his or her decision, including the following: young age, seizure, amnesia, vomiting, headache, mechanism, scalp hematoma, loss of consciousness, decreased mental status, trauma team request, parent anxiety or request, referring physician request, neurological defect (other than mental status), and other.

When sufficient information was provided, we reclassified the "other" race/ethnicity field. Specifically, we categorized ethnicity as Hispanic, non-Hispanic, or unknown. Non-Hispanic and unknown ethnicities were considered non-Hispanic. This allowed us to combine race and ethnicity as white non-Hispanic, black non-Hispanic, or Hispanic (of any race). All individuals of race/ethnicity other than these 3 categories were excluded from the analysis because of insufficient numbers to adequately analyze these groups.

All 3 groups were described with respect to their sociodemographic and clinical characteristics. Initial analyses compared cranial CT use among the 3 separate groups. However, because no clinically meaningful differences in cranial CT rates were observed between children of black non-Hispanic race/ethnicity vs Hispanic race/ethnicity, we combined these 2 groups in subsequent analyses.

PECARN CLINICAL PREDICTION RULES

The previously validated PECARN clinical prediction rules for clinically important TBI (ciTBI) included 2 high-risk and 4 intermediate-risk clinical predictors for 2 age groups (<2 years and ≥2 years).[19] In the present analysis, risk for ciTBI was not assigned for patients who were missing either of the high-risk clinical predictors, even if all 4 intermediate-risk clinical predictors were negative. If the 2 high-risk clinical predictors were known and only one of the intermediate-risk clinical predictors was missing, we assumed that the missing intermediate-risk clinical predictor was negative. Patients in whom risk for ciTBI was missing were excluded from the multivariable logistic regression analysis. The clinical prediction rule suggested that children with minor blunt head trauma can be grouped into 3 categories of risk for ciTBI (lowest, intermediate, and higher), which can inform the decision to perform CT.[19] For children younger than 2 years in the present analysis, the categories of risk for ciTBI were defined as follows: lowest (having none of 6 PECARN clinical predictors), intermediate (having nonfrontal scalp hematoma, loss of consciousness for ≥5 seconds, or severe mechanism of injury or acting abnormally per parent observation), or higher (having altered mental status or palpable skull fracture). For children 2 years or older, the categories of risk for ciTBI were defined as follows: lowest (having none of 6 PECARN clinical predictors), intermediate (having any loss of consciousness, history of vomiting, severe mechanism of injury, or severe headache), or higher (having altered mental status or clinical signs of basilar skull fracture). All historical and clinical risk factors were defined a priori. Altered mental status was defined as a GCS score of less than 15 or as agitation, sleepiness, repetitive questioning, or slow responses to verbal communication. Severe mechanism of injury was defined as the head struck with a high-impact object, a motor vehicle crash with patient ejection, the death of another passenger or a rollover, a pedestrian or bicyclist without helmet struck by a motorized vehicle, or a fall (>0.9 m for children <2 years and >1.5 m for children ≥2 years).

STATISTICAL ANALYSIS

We described categorical data using counts, percentages, and 95% CIs wherever appropriate, and we described continuous data using

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Table 1. Characteristics of Children Enrolled in the Study

Variable	Overall (N=39 717)	Race/Ethnicity: White Non-Hispanic (n=19 122)	Black Non-Hispanic (n=15 425)	Hispanic (n=5170)
Age				
Median (IQR), y	5.7 (2.0-12.1)	5.8 (2.0-12.4)	6.3 (2.2-12.3)	4.2 (1.6-10.2)
≥2 y, %	75.1	75.3	76.9	69.1
Male sex, %	62.4	61.1	64.0	62.3
Principal language of parent or guardian not English, %	6.4	0.9	0.6	44.3
Glasgow Coma Scale score of 15, %	96.9	96.4	97.4	97.0
Isolated head injury, %	90.0	88.9	91.2	90.2
Risk for ciTBI, %				
Lowest	55.9	49.2	63.3	58.8
Intermediate	29.9	33.9	25.1	29.7
Higher	14.1	16.9	11.6	11.5
Emergency department disposition to home, %	90.6	89.6	92.0	90.6
Cranial computed tomography in the emergency department, %	34.7	41.8	26.9	32.0

Abbreviations: ciTBI, clinically important traumatic brain injury; IQR, interquartile range.

medians and interquartile ranges (25th to 75th percentiles). We defined the outcome of interest as whether cranial CT was performed in the ED. Using a χ^2 test of independence for each racial/ethnic group, we compared the following variables between children who did not undergo cranial CT in the ED vs those who did: age (<2 vs ≥2 years), sex, GCS score, head injury (isolated vs nonisolated), and risk for ciTBI. Using a χ^2 test of independence for each level of risk for ciTBI, we compared how often parental anxiety or request was reported by physicians to be one of the most important indications influencing their decision to order cranial CT, stratified by racial/ethnic group.

We performed multivariable logistic regression analysis to compare cranial CT rates in the ED between children of white non-Hispanic race/ethnicity vs the combined group of children of black non-Hispanic race/ethnicity and Hispanic race/ethnicity and used generalized estimating equations to adjust for potential clustering of cranial CT use within hospitals. We controlled for the following variables in the model: age group (<2 vs ≥2 years), sex, nonisolated head injury, race/ethnicity (reference group was white non-Hispanic), principal language of parent or guardian (English vs non-English), and risk for ciTBI per the PECARN clinical prediction rule (reference group was lowest risk). The interactions considered for the model were age group × risk for ciTBI, race/ethnicity × risk for ciTBI, race/ethnicity × age group, and race/ethnicity × nonisolated head injury. Given the large sample size, we selected a priori the interactions to include in the model selection. Because their associated *P* values were not significant on bivariable analysis, we excluded the following from the final model: sex, principal language of parent or guardian, race/ethnicity × age group, and race/ethnicity × nonisolated head injury. For the final model, we report adjusted odds ratios (95% CIs) (reference group was white non-Hispanic).

For all analyses, we defined a 2-tailed significance level of .05. Commercially available statistical software was used (SAS/STAT software, version 9.2; SAS Institute, Inc).

RESULTS

Of 42 412 children with minor blunt head trauma enrolled in the main study, 39 717 (93.6%) had documented white non-Hispanic, black non-Hispanic, or Hispanic race/ethnicity. Of these, 19 122 (48.1%) were of white non-Hispanic race/ethnicity, 15 425 (38.8%) were of black non-Hispanic race/ethnicity, and 5170 (13.0%) were of Hispanic race/ethnicity. Enrolled children had a median age of 5.7 years (interquartile range, 2.0-12.1 years), and 62.4% were male (**Table 1**). In total, 13 793 children (34.7%) underwent cranial CT in the ED, with rates of 41.8%, 26.9%, and 32.0%, respectively, for children of white non-Hispanic, black non-Hispanic, and Hispanic race/ethnicity. Across all sociodemographic and clinical characteristics, children of white non-Hispanic race/ethnicity were consistently more likely to undergo cranial CT in the ED than the combined group of children of black non-Hispanic or Hispanic race/ethnicity (**Table 2**). Regardless of race/ethnicity, cranial CT was more frequently obtained in the ED for children 2 years or older, those with a GCS score of 14, those with nonisolated head injury, and those with higher risk for ciTBI.

Based on an a priori hypothesis, we determined whether parental anxiety or request was an important influence on a physician's decision to order cranial CT, stratified by patient race/ethnicity and by patient risk for ciTBI (**Table 3**). At all levels of risk for ciTBI, parental anxiety or request was commonly cited by the physician as one of the most important influences in ordering cranial CT among children of white non-Hispanic race/ethnicity ($P < .001$). Parental anxiety/request was reportd as one of the most important influences in 11.4% of CTs ordered in white non-Hispanic children at lowest risk of ciTBI. At intermediate and higher levels of risk for ciTBI, parental anxiety or request was less commonly reported as an important influence. Conversely, in the combined group of children of black non-Hispanic or Hispanic race/ethnicity who had the lowest risk for ciTBI, parental anxiety or request was cited by the physician as one of the most important influences in ordering cranial CT among only 4.9% of patients, and this frequency tended to decrease as risk for ciTBI increased.

Controlling for relevant sociodemographic and clinical variables and for clustering by hospital site of care using generalized estimating equations, multivariable analyses demonstrated no significant differences by race/

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ethnicity in the odds of undergoing cranial CT in the ED among children at higher risk for ciTBI (odds ratio, 0.87; 95% CI, 0.73-1.04). In a multivariable model that excluded 681 patients (1.7%) because of missing data in 1 or more covariates, the odds of undergoing cranial CT was calculated by race/ethnicity while controlling for relevant sociodemographic and clinical variables as well as for clustering by hospital site of care using generalized estimating equations. These analyses found no signficant difference among children at higher risk for ciTBI (odds ratio, 0.87%; 95% CI, 0.73-1.04). Among those at intermediate risk for ciTBI, the combined group of children of black non-Hispanic or Hispanic race/ethnicity had lower odds of undergoing cranial CT in the ED (odds ratio, 0.84; 95% CI, 0.76-0.94). Among those at lowest risk for ciTBI, this effect was even more pronounced, with an odds ratio of 0.73 (95% CI, 0.66-0.81).

COMMENT

We analyzed prospectively collected data obtained from a large multisite study of children with nontrivial blunt head trauma and controlled for injury severity and clustering by hospital site of care. In this study, all children had minor blunt head trauma, and their risk for ciTBI could be described and stratified using validated indicators from the recently described PECARN clinical prediction rules.[19] Not surprisingly, we found that sociodemographic factors (older age among all race/ethnicity groups and male sex among children of black non-Hispanic race/ethnicity) and clinical factors (GCS score, nonisolated head injury, and injury severity) were associated with obtaining cranial CT in the ED. As anticipated, risk for ciTBI strongly influenced cranial CT use.

We found no significant disparities in cranial CT use related to race/ethnicity among children with higher risk for ciTBI after minor blunt head trauma. However, among children with the lowest risk or intermediate risk for ciTBI, racial/ethnic disparities were observed in cranial CT use, with children of white non-Hispanic race/ethnicity being more likely to undergo cranial CT. Our results suggest that physician decision making about emergency cranial CT use for minor blunt head trauma is influenced by patient or family race/ethnicity, particularly at the lowest level of injury severity, for which few children should undergo cranial CT, to avoid irradiation.[19] Notably, parental anxiety or request was cited as influencing clinical decision making more frequently among children of white non-Hispanic race/ethnicity, a phenomenon particularly common at the lowest level of injury severity. Therefore, racial/ethnic disparities became more pronounced as clinical indications for cranial CT use diminished.

Our results are consistent with the findings of previous studies[2,20,21] suggesting that racial/ethnic disparities occur in selected aspects of pediatric emergency care. By controlling for injury severity using prospectively collected sociodemographic and clinical data and by including patients from multiple hospital sites of care in the analyses, our results confirm and extend an earlier finding that children of white race/ethnicity are more likely to undergo neuroimaging following minor blunt head injury.[18] In addition, by specifically focusing on those at lower risk for ciTBI, we describe medical care in a group of children among whom physician decision making may be influenced by various factors other than the history and physical examination. Differences in cranial CT use are particularly important as the risks associated with irradiation become better understood.

The inverse "dose response" between risk for ciTBI and racial/ethnic differences in cranial CT use merits careful attention, particularly when considered in combination with the observed differences in parental anxiety or request influencing physician decision making. Although by no means definitive, our results are consistent with selected previous work on parental or patient

Table 2. Percentage of Children Undergoing Cranial Computed Tomography in the Emergency Department by Race/Ethnicity, Sociodemographics, and Clinical Characteristics

	Children, %[a]	
Variable	White Non-Hispanic Race/Ethnicity (n=7992)	Combined Group of Black Non-Hispanic Race/Ethnicity or Hispanic Race/Ethnicity (n=5801)
Age group, y		
<2	35.9	25.7
≥2	43.7	29.0
Sex		
Male	42.1	29.1
Female	41.4	26.5
Glasgow Coma Scale score		
14	92.4	85.8
15	39.9	26.6
Head injury		
Isolated	39.4	25.7
Nonisolated	61.4	53.2
Risk for ciTBI		
Lowest	16.9	9.7
Intermediate	57.1	49.4
Higher	84.1	79.8

Abbreviation: ciTBI, clinically important traumatic brain injury.
[a] $P<.001$ for all comparisons.

Table 3. Percentage of Patients for Whom Parental Anxiety or Request Was One of the Most Important Indications Influencing Physician Decision to Order Cranial Computed Tomography in the Emergency Department

	Patients, %[a]	
Risk for ciTBI	Children of White Non-Hispanic Race/Ethnicity (n=752)	Combined Group of Children of Black Non-Hispanic Race/Ethnicity or Hispanic Race/Ethnicity (n=286)
Lowest	11.4	4.9
Intermediate	8.0	4.7
Higher	9.1	3.8

Abbreviation: ciTBI, clinically important traumatic brain injury.
[a] $P<.001$ for all comparisons.

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preference and medical practice. In a study[22] of knowledge and attitudes among ED patients about the irradiation risk of CT, patients of white race/ethnicity and privately insured patients preferred "a more definitive test" at the expense of increased irradiation. In another area of discretionary physician decision making (the use of antibiotics in outpatient practice), perception of parental preference was the only factor significantly predicting the prescription of antimicrobial agents for presumed viral infections (increasing the probability of such prescriptions from 7% to 62%).[23] Our findings are also consistent with previous work suggesting that overadmission of low-acuity pediatric patients of white race/ethnicity rather than underadmission of higher-acuity pediatric patients of minority races/ethnicities accounts for observed disparities in ED discharge practices.[11]

Disparities in provision of health care can adversely affect the health of individual patients[24,25] and the cost of the medical care.[9,26,27] Our findings draw attention to the possibility that a potentially unnecessary intervention with known risks (cranial CT) is being provided disproportionately to a group of children (of white non-Hispanic race/ethnicity) and that such use may be influenced by parental preferences or assumptions about such preferences.

The results reported herein were obtained from the largest prospective study to date of cranial CT use in injured children. We analyzed data collected prospectively from pediatric patients seen at multiple sites and rigorously controlled for injury severity and for hospital site of care. Despite these strengths, our study is limited by the lack of insurance status or other measures of family socioeconomic status. In addition, because the role of parental anxiety or request was not obtained in children for whom the physician did not order cranial CT, we were unable to develop a statistical model to assess the independent contribution of such communication on cranial CT use. Finally, race/ethnicity was described by the physicians providing care rather than by the patients or parents themselves. Although this might constitute a weakness in other circumstances, we believe it is appropriate in the context of the present study because we are focusing on clinical decision making in which the perceived race/ethnicity of the patient is the salient issue.

Racial/ethnic disparities in multiple aspects of health care, including those reported herein, continue to be a source of substantial concern for various reasons. Disparities compromise equity and lead to failure to achieve consistently high levels of quality care in different populations regardless of patient characteristics. As demonstrated herein with cranial CT for pediatric patients with minor blunt head trauma, evidence suggests that such disparities may potentially arise from the overuse of care among patients of nonminority races/ethnicities. Such overuse not only exposes individual patients to avoidable risks (in this case, long-term irradiation hazards) but also unnecessarily increases the costs of health care at a time when financial restraint is increasingly emphasized. Most important, the results of this study provide tangible evidence that medically irrelevant factors can affect physician decision making.[11] Such disparities that arise in pediatric care may be particularly worrisome because any adverse sequelae can extend across a patient's lifetime. Further research is required to describe and address disparities in health care among children and adults. Even as such investigations are on-going, optimal care for all patients may be ensured by developing, implementing, and supporting sound clinical decision making based on strong empirical evidence.

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