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# Racial disparities and the acute management of severe blunt traumatic brain injury

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## ABSTRACT

**Background** Traumatic brain injury (TBI) is a significant source of morbidity and mortality. In patients with TBI, racial disparities have been shown to exist in patient outcomes. Identifying where disparities occur along the patient continuum of care will allow for targeted interventions. This study evaluated if racial disparity exists for neuromonitoring and neurointervention rates in patients with severe TBI due to blunt injury.

**Methods** The National Trauma Data Bank was used to identify patients aged 18 to 55 years old from 2007 through 2016 with a blunt injury, an initial Glasgow Coma Scale score of 3 to 8, a head Abbreviated Injury Scale score of 3 to 5, and all other anatomic Abbreviated Injury Scale scores less than 3. Coarsened exact matching (CEM) was used to balance covariates between white and non-white patients. Rates of neuromonitoring and neurosurgical interventions were compared between groups. Secondary outcomes were days spent in the intensive care unit (ICU), total hospital length of stay (LOS), and mortality.

**Results** A total of 3692 patients with severe isolated TBI due to blunt injury were identified. After applying CEM, 1064 patients were analyzed (644 white, 420 non-white). No differences were observed between white and non-white patient groups for neuromonitoring, neurointervention, mortality, or ICU LOS. White patients had a shorter hospital LOS (8 days vs. 9 days, $p<0.05$) than non-white patients.

**Discussion** For severe isolated blunt TBI, neuromonitoring, neurointervention, and mortality rates were similar for white and non-white patients. Although racial disparities in patient outcomes exist, these differences do not seem to be due to neuromonitoring and neurointervention rates for management of TBI.

**Level of evidence** Level III.

## BACKGROUND

Traumatic brain injury (TBI) is a significant source of morbidity and mortality in the USA and led to over 2.8 million emergency department visits in 2013 alone.[1] Outcomes after TBI can vary, and although multiple factors impact any one patient's ability of recovering after traumatic injury, prior studies have implicated a patient's race as one important determinant of disparity; this has been demonstrated in several facets of medicine, including general surgery, oncology, and infectious disease.[2–11] Although it is clear that racial disparities exist in patient outcomes after trauma, it is less clear where along the continuum of care these disparities are introduced.

Numerous studies have examined the initial triage and workup of trauma patients to assess whether this may reveal a source of disparity. When investigating the initial assessment and management of trauma patients in emergency departments nationwide, Shafi and Gentilello[12] found no differences based on race. In contrast, Bolorunduro *et al*[13] observed that in patients with pelvic fractures, fewer diagnostic studies are performed in uninsured patients, a group disproportionately represented by minorities. With regard to TBI specifically, Wall *et al*[14] found no differences in the rate of initial head CT imaging after blunt trauma in a single-center analysis. However, another study done by Natale *et al*[15] found that white pediatric patients underwent CTs more often than children of other races as part of their TBI management. Although numerous studies have shown worse outcomes for non-white patients after a TBI, no study has identified where along the pathway of care these disparities occur.[8–11] Identifying the source of these disparities is a crucial investigatory step that will allow for targeted interventions to reduce disparities in care and improve patient outcomes. The acute operative management of blunt TBI is a small but important component along this pathway and merits evaluation as a potential source of disparity.

The objective of this study was to determine if racial disparities are present during the acute care of white versus non-white patients with severe isolated TBI after blunt trauma by comparing rates of neuromonitoring procedures (intracranial pressure monitoring, external ventricular drain placement, or intracranial oxygen monitoring) and neurointerventions (craniotomy, craniectomy, and burr hole). Mortality, hospital length of stay (LOS), and intensive care unit (ICU) LOS were also evaluated.

## METHODS

After approval, a retrospective analysis of the National Trauma Data Bank (NTDB) was performed. Adult trauma patients aged 18 to 55 years old presenting to level 1 and 2 trauma centers between the years 2007 and 2016 were included. Patients were identified with severe TBI by an initial Glasgow Coma Scale (GCS) score of 3 to 8 and a head Abbreviated Injury Scale (AIS) score of 3 to 5. Patients were excluded if they had non-blunt mechanism of injury, died in less than 24 hours from admission, had any non-head AIS score greater than or equal to 3, or had missing race, mortality, or procedure data. Patient age, comorbidities, mortality, hospital LOS, and ICU

LOS were analyzed. International Statistical Classification of Diseases and Related Health Problems (ICD-9) codes were used to identify neuromonitoring (ICD-9 codes 01.10, 01.16, and 02.21) and neurosurgical intervention procedures (craniotomy: ICD-9 codes 1.09, 1.23, 1.24, and 1.26; craniectomy: ICD-9 code 1.25; burr hole: ICD-9 code 1.28).

## Statistical analysis

Statistical analysis was performed using R (V.3.5.0). Patient demographic information, clinically related variables, and outcomes were summarized using descriptive statistics. For categorical variables, their counts and corresponding percentages were calculated. For numerical variables, their distributions were first examined by conducting a Shapiro-Wilk normality test. As none of the numerical data were normally distributed, their median and IQR were chosen as summary statistics. A two-sided Wilcoxon rank-sum test was used to test significance in continuous variables, and a two-sided $\chi^2$ test or two-sided Fisher's exact test was used to test significance in categorical variables.

The baseline covariates were defined as age, sex, GCS score, AIS score, systolic blood pressure (SBP), respiratory rate (RR), and insurance status. Patients identified in the NTDB as uninsured or self-pay were defined as "Uninsured" for our analysis; otherwise patients with any identified insurance coverage were considered "Insured." To account for heterogeneity between the baseline covariates of white and non-white patients, statistical matching using coarsened exact matching (CEM) was conducted. Prior to matching, missing data were imputed for the following variables: SBP, RR, and insurance status; the proportions of missing data that were imputed were 1%, 11%, and 18%, respectively. To address the possibility that patients may cluster around hospitals in a disproportionate and heterogeneous manner, and that the performance of a hospital system's TBI care may unduly influence patient outcomes, we included "Hospital" as random effect in our models. Each model included the following covariates as fixed effects: age, sex, race, GCS score, AIS score, SBP, RR, insurance status, alcoholism, smoking status, cardiac comorbidity, and respiratory disease. Clinical outcomes of interest included rates of neuromonitoring, neurointerventions, mortality, hospital LOS, and ICU LOS. Generalized linear mixed models were then performed for each of these five clinical outcomes. Within this matched data set, patients were disaggregated into their individual NTDB race categories (ie, white, American Indian, Asian, black or African–American, and Other). Rates of neuromonitoring, neurointervention, and mortality were then compared among the disaggregated racial groups using Fisher's exact test; if the overall p value was below 0.05, pairwise comparisons were performed between each individual non-white group and the white population. Due to the multiple comparisons required for the pairwise analyses, the significance levels were held to a Bonferroni-corrected p value of <0.0125.

## RESULTS

We identified 3692 total patients from the NTDB who met our inclusion criteria, of whom 2639 were white patients and 1053 were non-white patients. In the unmatched data, both groups were predominantly male, although the percentage of males was higher in the non-white group (82% vs. 79%; p=0.04). Non-white patients were typically younger (median age=33 years, IQR=24–45 years vs. median=36 years, IQR=25–47 years; p=0.002) and more likely to be uninsured (33% vs. 22%, p<0.001). White patients were found to have higher incidences of alcoholism (23% vs. 19%; p=0.04) and smoking history (8% vs. 5%; p=0.003). There were no significant differences in rates of neuromonitoring (12% vs. 11%; p=0.39), neurointerventions (22% in both groups; p=0.67), Injury Severity Score (median=21, IQR=16–26 vs. median=20, IQR=16–25; p=0.67), ICU LOS (median=5 days, IQR=2–12 days in both groups; p=0.53), or mortality (17% vs. 15%; p=0.28). White patients had a shorter hospital LOS (median=9 days vs. median=10 days; p=0.07). Table 1 summarizes unmatched patient characteristics and injury data for both patient populations.

**Table 1** Non-matched patient characteristics and injury data

| Characteristics | White (n=2639) | Non-white (n=1053) | P value |
|---|---|---|---|
| Age, years* | 36 (25–47) | 33 (24–45) | 0.002 |
| Sex, male (%) | 2078 (79) | 862 (82) | 0.04 |
| Uninsured, number of patients with insurance data (%) | 486, 2162 (22) | 290, 875 (33) | <0.001 |
| SBP, mm Hg* | 140 (124–158) | 140 (122–160) | 0.69 |
| RR, bpm* | 15 (0–18) | 16 (12–20) | <0.001 |
| GCS score* | 3 (3–5) | 3 (3–6) | 0.01 |
| ISS* | 21 (16–26) | 20 (16–25) | 0.67 |
| Alcohol use disorder (%) | 598 (23) | 205 (19) | 0.04 |
| Congestive heart failure (%) | 22 (0.8) | 9 (0.9) | >0.99 |
| Smoker (%) | 220 (8) | 57 (5) | 0.003 |
| Cerebrovascular accident (%) | 39 (1) | 18 (2) | 0.71 |
| Diabetes (%) | 81 (3) | 36 (3) | 0.66 |
| Angina within 30 days (%) | 0 (0) | 1 (<0.1) | 0.29 |
| History of myocardial infarction (%) | 16 (0.6) | 5 (0.5) | 0.81 |
| History of chronic obstructive pulmonary disease (%) | 69 (3) | 25 (2) | 0.76 |
| Dementia (%) | 1 (<0.1) | 1 (<0.1) | 0.49 |
| Hospital LOS, days* | 9 (4–19) | 10 (5–21) | 0.07 |
| ICU LOS, days* | 5 (2–12) | 5 (2–12) | 0.53 |
| Neuromonitoring (%) | 309 (12) | 112 (11) | 0.39 |
| Neurointervention (%) | 570 (22) | 235 (22) | 0.67 |
| Mortality (%) | 436 (17) | 158 (15) | 0.28 |

*Median values with (IQR).
bpm, breaths per minute; GCS, Glasgow Coma Scale; ICU, intensive care unit; ISS, Injury Severity Score; LOS, length of stay; RR, respiratory rate; SBP, systolic blood pressure.

After applying CEM, 644 white patients and 420 non-white patients were retained. Generalized linear models of these matched data showed no significant differences in neuromonitoring (11% vs. 10%; p=0.99), neurointerventions (21% vs. 22%; p=0.90), or mortality (18% vs. 17%; p=0.48). White patients had a shorter hospital LOS (median=8 days, IQR=4–17 days vs. median=9 days, IQR=5–21 days; p<0.001), but similar ICU LOS (median=5 days, IQR=2–11.5 days vs. median=5 days, IQR=2–12 days; p=0.26). Table 2 summarizes the results of the analysis of the matched data.

The matched non-white patient data were then disaggregated into their individual NTDB-defined racial categories. Among the 420 non-white patients, 28 were American Indians, 18 were Asians, 143 were black or African–Americans, and 231 were reported as "Other" (table 3). Fisher's exact test was used to

**Table 2** Multivariate outcomes of matched patients

| Outcome | White (n=644) | Non-white (n=420) | OR (95% CI) | P value |
|---|---|---|---|---|
| Hospital LOS, days* | 8 (4–17) | 9 (5–21) | | <0.001 |
| ICU LOS, days* | 5 (2–11.5) | 5 (2–12) | | 0.26 |
| Neuromonitoring (%) | 72 (11) | 42 (10) | 1.00 (0.63 to 1.59) | 0.99 |
| Neurointervention (%) | 135 (21) | 92 (22) | 0.98 (0.69 to 1.38) | 0.90 |
| Mortality (%) | 114 (18) | 72 (17) | 0.88 (0.61 to 1.26) | 0.48 |

*Median values with (IQR).
ICU, intensive care unit; LOS, length of stay.

compare outcome measures in the disaggregated groups, and we found rates were similar for neuromonitoring (p=0.56), mortality (p=0.98), but not for neurointervention (p=0.02). To determine whether this difference in neurointerventions could be attributed to any specific racial group, pairwise comparisons of the rates of neurointerventions in individual non-white groups were performed against the white group; these pairwise comparisons showed no significant differences in neurointervention rates when a Bonferroni-corrected p value of <0.0125 was applied. Tables 3 and 4 summarize these comparisons.

## DISCUSSION

In a retrospective matched analysis of the NTDB, we found no differences based on race for neuromonitoring, neurosurgical intervention, or mortality rates in adult patients with severe isolated TBI after blunt trauma. Initial analysis of the unmatched data showed non-white patients had higher rates of uninsurance, congestive heart failure, and smoking; despite these differences, the rates of neuromonitoring, neurointerventions, and mortality did not vary between these groups. It is important to note, however, the dangers of drawing conclusions from studies using unmatched data, as the results may be unduly influenced by the analysis of raw, unmatched, and heterogeneous patient groups. A review of nearly 100 publications that used NTDB data to study mortality as an outcome found that 43% of these studies failed to adjust for at least one of five essential covariates (age, sex, any type of anatomic severity, any type of physiologic severity, and mechanism of injury) known to impact survival.[16] By employing CEM, this study was able to control for confounding patient variables.

The type and quality of care provided by a health system can vary significantly, and thus can have undue influence on patient outcomes. This is particularly true if underperforming trauma centers are treating disproportionally high numbers of non-white patients. If patients of certain racial backgrounds cluster around hospitals in a non-uniform manner, the performance of certain hospitals could skew the outcome data for that racial group. By accounting for patient clustering using generalized linear mixed models, we were able to minimize the effects of an additional confounder that can make interpretation of disparate outcomes difficult.

After imputing missing variables, applying CEM, and accounting for patient clustering, we found no statistically significant differences in rates of neuromonitoring, neurosurgical interventions, ICU LOS, or mortality between white and non-white groups after blunt TBI. When comparing individual racial groups, we similarly found no differences in the rates of these procedures and outcomes. Notably, however, a slightly longer hospital LOS was observed for non-white patients. It is unclear from our analysis why this difference in LOS exists or what clinical impact it has on a patient's overall outcome. Although patients were matched for insurance status in our analysis of the acute management of blunt TBI, this represents only one phase of care. It is possible that insurance coverage or other socioeconomic factors affect other phases of care that result in a slightly longer hospital LOS. Patients with any type of insurance coverage were aggregated and considered as "Insured." Not all insurances are alike, however, and the type of postinjury support services covered by these insurance plans can differ significantly. Furthermore, the proportion of patients who were initially uninsured but gained insurance while recovering from their injuries in the hospital is unknown. We were unable to account for these insurance variables in our analysis, and so the impact these factors have on the outcomes after blunt TBI is unclear. This is

**Table 3** Outcomes of matched patients by specific race categories

| | Yes (%) | P value |
|---|---|---|
| Neuromonitoring | | 0.56 |
| White (n=644) | 72 (11) | |
| American Indian (n=28) | 3 (11) | |
| Asian (n=18) | 1 (6) | |
| Black or African–American (n=143) | 10 (7) | |
| Other (n=231) | 28 (12) | |
| Neurointervention | | 0.02 |
| White (n=644) | 135 (21) | |
| American Indian (n=28) | 7 (25) | |
| Asian (n=18) | 7 (39) | |
| Black or African–American (n=143) | 19 (13) | |
| Other (n=231) | 59 (26) | |
| Mortality | | 0.98 |
| White (n=644) | 114 (18) | |
| American Indian (n=28) | 4 (14) | |
| Asian (n=18) | 3 (17) | |
| Black or African–American (n=143) | 27 (19) | |
| Other (n=231) | 38 (16) | |

**Table 4** Pairwise comparison of white versus individual non-white races

| | OR (95% CI) | P value* |
|---|---|---|
| **Neurointervention** | | |
| White | 1.00 (reference) | |
| American Indian | 1.26 (0.52 to 3.02) | 0.61 |
| Asian | 2.40 (0.91 to 6.31) | 0.07 |
| Black or African–American | 0.58 (0.34 to 0.97) | 0.04 |
| Other | 1.29 (0.91 to 1.84) | 0.15 |

*Bonferroni-corrected significance threshold p value <0.0125.

a limitation in our study, and a dedicated study is warranted to better examine this finding.

There are several other important limitations to this study, including its vulnerability to potential coding errors inherent to the nature of retrospective database analyses. Although we found no differences in the rates of neuromonitoring or neurointerventions, there are other very important clinical factors such as monitoring for changes in neurologic examination, accurate diagnosis when changes occur, the timeliness of any indicated interventions, or the appropriateness of said interventions for the underlying condition that are, as of now, not possible to analyze via a retrospective analysis of the NTDB. These granular details may impact the outcomes after blunt TBI, but we are unable to account for these factors in our analysis; targeted study of these relevant factors is warranted. Patients missing information on race, mortality, or procedure information were excluded from analysis and these data were not imputed. This may have excluded patients from specific racial backgrounds or from centers without resources to maintain high-quality data reporting. It was thought these elements were critical to the analysis and that imputation would be inappropriate.

Nearly a fifth of the patients included in the subset analysis of individual races were categorized as "Other." To what extent these patients represent Hispanic patients (for whom there exists no defined NTDB race category and only Ethnicity data are listed), patients with multiple racial backgrounds, those who were miscategorized, or those choosing not to identify with any specific category is unknown; regardless, this represents a significant portion of the non-white cohort, and the impact of this ill-defined category on the results of the study is difficult to ascertain. Lastly, although we detected a prima facie association between race and rates of neurointervention (table 3), subsequent pairwise comparison of individual racial categories did not show a difference meeting our Bonferroni-corrected significance threshold (table 4). We thought this statistical approach was appropriately conservative, but this runs the risk of committing a type II statistical error; clearly a dedicated study is warranted to investigate this further.

In summary, when comparing white and non-white patients with a severe TBI, no significant differences were observed in the rates of neuromonitoring, neurointervention, or mortality. The authors are careful to point out that they do not deny that racial disparities exist in patient outcomes after trauma. Rather, the results of the analysis suggest that these disparities are not due to differences in the acute management of patients with blunt TBI. Future studies should investigate other components of the treatment pathway in patients with TBI to better delineate where disparities are introduced so appropriate adjustments can be employed.

**Contributors** Study design: ZD, SK, JG, AJ, JL, RS. Literature search: ZD, JG, SK, RS, JL, IZ. Data collection: JL, JG. Data analysis: JL, ZD, JG, AJ, SK, RS. Writing: ZD, JG, JL, AJ, RS, IZ. Critical revision: AJ, RS, JL, SK, IZ.

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**Competing interests** None declared.

**Patient consent for publication** Not required.

**Ethics approval** This study was approved by the institutional review board at Santa Barbara Cottage Hospital and a waiver of informed consent was granted.

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**Data availability statement** Data are available in a public, open access repository.



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