Association Between Race and Age in Survival After Trauma

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IMPORTANCE Racial disparities in survival after trauma are well described for patients younger than 65 years. Similar information among older patients is lacking because existing trauma databases do not include important patient comorbidity information.

OBJECTIVE To determine whether racial disparities in trauma survival persist in patients 65 years or older.

DESIGN, SETTING, AND PARTICIPANTS Trauma patients were identified from the Nationwide Inpatient Sample (January 1, 2003, through December 30, 2010) using International Classification of Diseases, Ninth Revision, Clinical Modification diagnosis codes. Injury severity was ascertained by applying the Trauma Mortality Prediction Model, and patient comorbidities were quantified using the Charlson Comorbidity Index.

MAIN OUTCOMES AND MEASURES In-hospital mortality after trauma for blacks vs whites for younger (16-64 years of age) and older (80 years of age) patients was compared using 3 different statistical methods: univariable logistic regression, multivariable logistic regression with and without clustering for hospital effects, and coarsened exact matching. Model covariates included age, sex, insurance status, type and intent of injury, injury severity, head injury severity, and Charlson Comorbidity Index.

RESULTS A total of 1,073,195 patients were included (502,167 patients 16-64 years of age and 571,028 patients 80 years of age). Most older patients were white (547,325 [95.8%]), female (406,158 [71.1%]), and insured (567,361 [99.4%]) and had Charlson Comorbidity Index scores of 1 or higher (323,741 [56.7%]). The unadjusted odds ratios (ORs) for death in blacks vs whites were 1.35 (95% CI, 1.28-1.42) for patients 16 to 64 years of age and 1.00 (95% CI, 0.93-1.08) for patients 65 years or older. After risk adjustment, racial disparities in survival persisted in the younger black group (OR, 1.21; 95% CI, 1.13-1.30) but were reversed in the older group (OR, 0.83; 95% CI, 0.76-0.90). This finding was consistent across all 3 statistical methods.

CONCLUSIONS AND RELEVANCE Different racial disparities in survival after trauma exist between white and black patients depending on their age group. Although younger white patients have better outcomes after trauma than younger black patients, older black patients have better outcomes than older white patients. Exploration of this paradoxical finding may lead to a better understanding of the mechanisms that cause disparities in trauma outcomes.

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Disparities in survival after traumatic injury among minority and uninsured patients have been well described for those younger than 65 years. Despite the recent demonstration of racial disparities after trauma among younger patients, information regarding the effect of race on trauma outcomes among older patients is lacking.

Most authors choose to exclude older patients from analysis because of the lack of important comorbidity data in existing trauma databases. Comorbid conditions significantly affect trauma outcomes. Data from the Healthcare Cost and Utilization Project have demonstrated that patient comorbidities may have an interaction with race and socioeconomic status in posttraumatic mortality as well. Trauma-specific databases, such as the National Trauma Data Bank, are unable to collect adequate measures of patients’ preinjury health status, so existing analyses that compare racial disparities after trauma among older patients have limited applicability to older patients who commonly have significant comorbidities.

The objective of the current study was to determine whether the previously described racial disparities in outcomes after trauma continue to persist among older trauma patients. Using an approach that allows for the incorporation of patient comorbidity information with traumatic injury severity information, we assessed in-hospital mortality in white vs black patients after trauma using 3 different statistical methods. We hypothesized that racial disparities may not be present in patients 65 years or older because of better access to preinjury medical care (ie, Medicare).

Methods

Informed consent was not obtained because of the anonymous nature of the Nationwide Inpatient Sample (NIS) data set. After receiving approval from the Johns Hopkins Medicine Institutional Review Board, trauma patients were identified from the NIS from January 1, 2003, through December 30, 2010, using International Classification of Diseases, Ninth Revision, Clinical Modification diagnosis codes 800 through 959. Patients with late effects of injury (codes 905-909), superficial injuries (codes 910-924), and foreign bodies (codes 930-939) were excluded in an attempt to mimic as closely as possible the National Trauma Data Bank’s definition of a trauma admission. The NIS is a national US data set that represents a 20% sample of patients discharged from community hospitals in participating states, but its use in studying trauma has been limited because of a lack of recorded injury severity indexes. The ICD Programs for Injury Categorization (ICDPIC) was used to generate the Injury Severity Score and Trauma Mortality Prediction Model score as measures of injury severity for each trauma patient in the NIS. White and black patients 16 years or older with blunt or penetrating injuries were included. Patients of other races were excluded because accounts of racial disparities in these groups are conflicting and less consistently described than for blacks vs whites. Patients from the 12 states that do not reliably report race data (≥40% missing) were excluded (ie, Georgia, Illinois, Kentucky, Minnesota, Montana, Nebraska, Nevada, North Carolina, Ohio, Oregon, Washington, and West Virginia). Patients who were transferred into or out of another acute care facility in the NIS were also excluded (n = 50 847) because their ultimate in-hospital survival could not be accurately ascertained. For the final sample, missing data were less than 0.5% overall.

Demographic data, including race, age, sex, insurance status, mechanism of injury, intent of injury, and head injury severity, were abstracted from the records. To risk-adjust patients based on their comorbid conditions, we used a commercially available software program to generate the Charlson Comorbidity Index (CCI) from diagnosis codes specific to each patient within the data set.

Three different statistical methods were used to determine the independent effect of race on the main outcome measure of in-hospital mortality after trauma among younger (16-64 years of age) and older (≥65 years of age) patients: univariable logistic regression, multivariable logistic regression with and without clustering for hospital effects, and coarsened exact matching (CEM). Clustering patients by hospitals produces more reliable 95% CIs by taking into account the interfacility correlation of patient outcomes (ie, patient outcomes are more likely to be similar within rather than across hospitals). Coarsened exact matching is a statistical means of matching patients that aims to reduce the imbalance in covariates between 2 groups using monotonic imbalance bounding. Unlike traditional patient matching, CEM uses broader categorical bins that allow for matching based on the reasonable assumption that patients within those bins will behave similarly. This technique efficiently matches patients in large data sets and allows for a greater number of successfully matched patients while still bounding the degree of model dependence and the mean treatment estimation error.

Multivariable regression and CEM covariates were chosen based on the 5 minimum covariates that are considered to be essential when performing a risk-adjusted analysis of trauma mortality outcomes, including age, sex, insurance status, type of injury (blunt vs penetrating), intent of injury, injury severity (Trauma Mortality Prediction Model), head injury severity, and CCI score. A complete description of the statistical methods, including model diagnostics and covariate definitions, is included in the eAppendix and eFigure in the Supplement.

All statistical analyses were performed using STATA/MP statistical software, version 11.0 (StataCorp). Statistical significance was defined as P ≤ .05.

Results

During the 8 years studied, 1 073 195 patients met the inclusion criteria (502 167 patients 16-64 years of age and 571 028 patients ≥65 years of age) (Table 1). Most older patients were white (547 325 [95.8%]), female (406 158 [71.1%]), and had insurance (567 361 [99.4%]). The CCI scores were 1 or higher in 323 741 (56.7%) of the older patients. Most of these patients sustained blunt (568 485 [99.6%]) or unintentional (569 324 [99.7%]) trauma, resulting in Injury Severity Scores of 9 or higher (352 151 [61.7%]).
Notable findings in the demographics of the older vs younger patients included a lower proportion of males (164,833 [28.9%] vs 337,195 [67.2%]), higher rate of insurance (567,361 [99.4%] vs 413,650 [82.4%]), and higher mortality (19,697 [3.4%] vs 8,837 [1.8%]) in the older population. Younger patients also tended to be much healthier, with most having no reported comorbid conditions (400,434 [79.7%] vs 247,287 [43.3%] in the older population).

Coarsened exact matching was successfully used in both the younger and older patient cohorts. In both age groups, the multivariable \( L_1 \) distance (a multivariate measure of imbalance ranging from 1 for complete separation to 0 for perfect global match that is calculated based on the differences of all model covariates for the case vs control groups) decreased substantially after matching (0.17 vs 0.39 and 0.18 vs 0.28 for younger and older patients, respectively) (see eAppendix in the Supplement for details). There were also few unmatched patients in each group (Table 2).

The unadjusted odds ratios (ORs) for death in blacks vs whites were 1.35 (95% CI, 1.28-1.42) for patients younger than 65 years and 1.00 (95% CI, 0.93-1.08) for patients 65 years or older. After CEM, racial disparities in survival persisted in the younger black group (OR, 1.21; 95% CI, 1.13-1.30) but were reversed in the older group (OR, 0.83; 95% CI, 0.76-0.90). These findings were consistent with multivariable regression analysis (OR, 1.21; 95% CI, 1.13-1.29 vs OR, 0.83; 95% CI, 0.77-0.90) (Figure).

Discussion

In this study that risk-adjusts for both patient-specific comorbidity data and injury severity information, differential racial disparities in survival after trauma exist between white and black patients depending on their age group. For patients younger than 65 years, white patients have better outcomes after trauma than black patients. However, among older patients, black patients have better outcomes than similarly injured, matched white patients.

The paradox of the racial disparity findings that we report was initially surprising. However, previous literature reporting outcomes associated with race and age have reported similarly paradoxical findings in nontrauma populations.26 In an analysis of more than 1 million patients undergoing dialysis, black patients were found to have a lower risk of death than white patients but only in older adults; for patients younger than 50 years, black patients had a higher incidence of mortality than white patients.26 One commonly posited explanation for these age-dependent racial disparities is the availability of Medicare, and, consequently, better access to pressor care, in the older population. This phenomenon has been recently reported in a study of 541,471 trauma patients from the National Trauma Data Bank by Singer et al.27 That study found that older trauma patients are 4 times more likely to be insured than young patients and that insurance- and race-related disparities in mortality after blunt trauma are reduced in the population 65 years or older. The findings of the study by Singer et al are limited by the inclusion of only patients with blunt trauma, as well as its inability to account for

### Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>&lt;65 Years Old (n = 502,167)</th>
<th>≥65 Years Old (n = 571,028)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-25</td>
<td>108,101 (21.5)</td>
<td>NA</td>
</tr>
<tr>
<td>26-35</td>
<td>81,860 (16.3)</td>
<td>NA</td>
</tr>
<tr>
<td>36-45</td>
<td>93,695 (18.7)</td>
<td>NA</td>
</tr>
<tr>
<td>46-55</td>
<td>117,357 (23.4)</td>
<td>NA</td>
</tr>
<tr>
<td>56-64</td>
<td>101,154 (20.1)</td>
<td>NA</td>
</tr>
<tr>
<td>65-75</td>
<td>NA</td>
<td>139,392 (24.4)</td>
</tr>
<tr>
<td>76-85</td>
<td>NA</td>
<td>237,247 (41.2)</td>
</tr>
<tr>
<td>≥86</td>
<td>NA</td>
<td>194,389 (34.0)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>337,195 (67.2)</td>
<td>164,833 (28.9)</td>
</tr>
<tr>
<td>Female</td>
<td>174,886 (34.8)</td>
<td>406,158 (71.1)</td>
</tr>
<tr>
<td>Missing</td>
<td>86 (0.2)</td>
<td>37 (0.01)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>413,072 (82.3)</td>
<td>547,325 (95.8)</td>
</tr>
<tr>
<td>Black</td>
<td>89,095 (17.7)</td>
<td>23,703 (4.2)</td>
</tr>
<tr>
<td>Insured</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>413,650 (82.4)</td>
<td>567,361 (99.4)</td>
</tr>
<tr>
<td>No</td>
<td>86,221 (17.2)</td>
<td>30,765 (0.5)</td>
</tr>
<tr>
<td>Missing</td>
<td>2296 (0.5)</td>
<td>592 (0.1)</td>
</tr>
<tr>
<td>Intent</td>
<td></td>
<td></td>
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<tr>
<td>Unintentional</td>
<td>442,770 (88.2)</td>
<td>569,324 (97.7)</td>
</tr>
<tr>
<td>Self-inflicted</td>
<td>6288 (1.3)</td>
<td>544 (0.1)</td>
</tr>
<tr>
<td>Assault</td>
<td>49,879 (9.9)</td>
<td>1010 (0.18)</td>
</tr>
<tr>
<td>Undetermined</td>
<td>2488 (0.5)</td>
<td>70 (0.01)</td>
</tr>
<tr>
<td>Other</td>
<td>742 (0.2)</td>
<td>30 (0.01)</td>
</tr>
<tr>
<td>Type of injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blunt</td>
<td>450,820 (89.8)</td>
<td>568,485 (99.6)</td>
</tr>
<tr>
<td>Penetrating</td>
<td>51,171 (10.2)</td>
<td>2543 (0.5)</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;9</td>
<td>275,019 (54.8)</td>
<td>218,819 (38.3)</td>
</tr>
<tr>
<td>9-15</td>
<td>158,443 (31.6)</td>
<td>307,850 (53.9)</td>
</tr>
<tr>
<td>16-24</td>
<td>51,171 (10.2)</td>
<td>39,224 (6.9)</td>
</tr>
<tr>
<td>25-75</td>
<td>17,137 (3.4)</td>
<td>5077 (0.9)</td>
</tr>
<tr>
<td>Severe head or neck injury (Abbreviated Injury Scale score ≥3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>69,566 (13.9)</td>
<td>57,705 (10.1)</td>
</tr>
<tr>
<td>No</td>
<td>432,601 (86.2)</td>
<td>513,323 (89.9)</td>
</tr>
<tr>
<td>Charlson Comorbidity Index score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>400,434 (79.7)</td>
<td>247,287 (43.3)</td>
</tr>
<tr>
<td>1</td>
<td>71,068 (14.2)</td>
<td>172,299 (30.2)</td>
</tr>
<tr>
<td>2</td>
<td>17,925 (3.6)</td>
<td>83,881 (14.7)</td>
</tr>
<tr>
<td>≥3</td>
<td>12,740 (2.5)</td>
<td>67,561 (11.8)</td>
</tr>
<tr>
<td>Mortality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>8837 (1.8)</td>
<td>19,697 (3.4)</td>
</tr>
<tr>
<td>No</td>
<td>493,263 (98.2)</td>
<td>551,331 (96.6)</td>
</tr>
</tbody>
</table>

Abbreviation: NA, not applicable.
the potential confounding effects of medical comorbidities. Nonetheless, the findings are consistent with those previously reported in other fields, including the Veterans Affairs health care system in which racial disparities after surgical procedures that are well described in the general population are not present in a population with ubiquitous insurance coverage.\textsuperscript{28} Thus, improved access to health care may lead to better overall health status and a reduction in race-based disparities for patients of all ages.

It is also possible that the disparities in trauma outcomes with respect to race are different in younger compared with older patients partially because there is reduction in treatment biases. Reported perceptions of racial biases within the health care system are much greater among patients who are younger than 65 years.\textsuperscript{29} In addition, the mortality effect of discrimination is more pronounced in white patients compared with black patients in an older population,\textsuperscript{30} suggesting that treatment biases against black patients compared with white patients may have less of an overall effect on mortality in the older population. It is also possible that there exists a healthy survivor bias in the older black group. There are well-documented disparities in access to care for younger black patients.\textsuperscript{31} Therefore, it is possible that black patients who survive to 65 years or older potentially have reached that age using minimal health care or without the benefit of care and thus are less frail than their white counterparts of similar age. This theory is somewhat counterintuitive in that it appears to refute the concept of the weathering hypothesis proposed by Geronimus.\textsuperscript{32} The weathering hypothesis states that, because black patients tend to be exposed to a greater allostatic load with repeated stressors and required adaptation, they have a tendency toward earlier health deterioration. However, it is possible that the weathering hypothesis is not applicable to trauma, which usually occurs as a single isolated event rather than a series of stressors, or that by the time patients reach 65 years of age, those with the greatest allostatic loads have already succumbed to the stresses of life, leaving behind only the heartiest of the original population. One potential way to assess the latter hypothesis would be to compare outcomes after trauma in older patients matched by age with respect to life expectancy because the life expectancy of US blacks is nearly 5 years less than that of US whites.\textsuperscript{33} There are also various measures of frailty that have been developed in nontrauma populations that could potentially be useful for evaluating our observed outcomes in this context.\textsuperscript{34,35}

The differences in outcomes observed between black patients and white patients in the older trauma population were only demonstrable after patient comorbidities and other covariates were taken into account. On univariable analysis, there were no reportable differences in mortality within the older patients. Previously published research on the subject of racial disparities after trauma is limited by the lack of comorbidity information.\textsuperscript{1,5-8,27} As demonstrated by the low prevalence of comorbidities in the younger population in our study (only 20% of patients <65 years hadCCI scores >0), the inclusion of this variable may not be important in these studies; young black patients had higher mortality after trauma compared with white patients in both our unadjusted and adjusted analyses (Figure). However, comorbidity information appears to be much more relevant in the analysis of outcomes for the older age group; more than 50% of patients 65 years or older had at least 1 comorbidity in our study, and more than 25% have more than 1. Whether older patients experience mortality after trauma specifically as a result of their traumatic injuries, their comorbidities, or a combination of the two remains to be determined, but clearly comorbidity information is an important consideration in the interpretation of outcomes within an older population.

The limitations of our study deserve discussion. The basis of our data is the NIS, which is an administrative database. Although the NIS is a well-respected national database, its use in trauma is infrequent because of a lack of traumatic injury scoring. Clark et al\textsuperscript{19} developed the ICDPIC, which enabled us to overcome this shortcoming and which has been previously validated to perform just as well as the Injury Severity Score at predicting mortality.\textsuperscript{16} However, as with any administrative database, there is the potential for incorrect coding, and a number of assumptions must be made regarding the accuracy and reliability of the data. In addition, all retrospec-

### Table 2. Results of Coarsened Exact Matching

<table>
<thead>
<tr>
<th>Variable</th>
<th>&lt;65 Years Old (n = 502 167)</th>
<th>≥65 Years Old (n = 571 028)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Blacks</td>
<td>Whites</td>
</tr>
<tr>
<td>All</td>
<td>89 095</td>
<td>413 072</td>
</tr>
<tr>
<td>Matched</td>
<td>87 485</td>
<td>407 944</td>
</tr>
<tr>
<td>Unmatched</td>
<td>1610</td>
<td>5128</td>
</tr>
</tbody>
</table>

Figure. Odds Ratio for Mortality: Blacks vs Whites by Age Category

There was a higher unadjusted odds of death for blacks vs whites for patients younger than 65 years but not for patients 65 years or older. After coarsened exact matching (CEM), racial disparities in survival persisted in the younger black group but were reversed in the older group. These findings were consistent across 3 different analysis techniques. Error bars indicate 95% CIs; dotted line, reference group.
tive analyses are limited by data availability, although we mini-
mized the amount of missing data in our study by excluding
patients from states that do not reliably report race data. It is
also possible that we did not consider an important variable
in our analysis that may better explain the racial differences
in mortality after trauma that we report. We chose the covar-
iates for our regression modeling based on model parsimony
and their ubiquitous use in previous outcomes-based trauma
studies. Although the range in age was large for the older popu-
lation, any heterogeneity in this group should have been ad-
justed for using the CEM technique; the L1 statistical distance
we report after CEM was excellent, indicating effective matching
of the black and white patient groups. However, one could
argue that among older trauma patients, other factors, such
as hospital length of stay and preretirement income bracket,
may also be important. In addition, we assessed the effect
of race on in-hospital mortality after trauma, which in the older
population may not actually translate to trauma-related death.
Finally, we restricted our analysis to white and black patients
only. We chose to exclude Hispanic patients and other minor-
ity populations because there are lower numbers in the older
age group and a tendency for more heterogeneity in patients
within these populations that can lead to disparate findings
dependent on the outcomes studied.9 Future studies that ad-
dress the effects of age on racial disparities in outcomes after
trauma in Hispanic, Asian, and other minority groups will be
of interest.

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Conclusions

The results of the present study suggest that differential ra-
cial disparities exist between white and black patients depend-
ing on their age group. We also demonstrate the feasibility of
using the NIS database for trauma-based analyses by extract-
ing injury severity measures using the ICD-9-CM and STATA
CCI programs. Further exploration of the racial disparities within
different populations, including analysis of the effect of in-
urance status on outcomes in the population 65 years or older,
may help us better understand the mechanisms that lead to
disparities in trauma outcomes. In addition, future studies that
incorporate the use of frailty indexes, surrogate measures of
morbidity (ie, hospital length of stay), and trauma-specific mor-
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Pedestrians struck by motor vehicles further
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5.

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Study concept and design: All authors.

Acquisition, analysis, or interpretation of data:
Hicks, Hashmi, Velopulos, Efron, Haider.

Drafting of the manuscript: Hicks, Hashmi,
Velopulos, Haider.

Critical revision of the manuscript for important
intellectual content: All authors.

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Obtained funding: Haider.

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Study supervision: Velopulos, Schneider, Cornwell,
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Dr Hau reported receiving royalties from Lippincott
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interpretation of the data; preparation, review, or
approval of the manuscript; and decision to submit
the manuscript for publication.

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outcome of adults suffering major traumatic injury:
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