

Associations of race, mechanism of injury, and neighborhood poverty with in-hospital mortality from trauma

A population-based study in the Detroit metropolitan area

Jacey A. Loberg, MD, R. David Hayward, PhD*, Mary Fessler, BA, Elango Edhayan, MD, FACS

Abstract

Health disparities based on race and socioeconomic status are a serious problem in the US health care system, but disparities in outcomes related to traumatic injury have received relatively little attention in the research literature.

This study uses data from the State Inpatient Database for Michigan including all trauma-related hospital admissions in the period from 2006 to 2014 in the Detroit metropolitan area (N=407,553) to examine the relationship between race (White N=232,109; African American N=86,356, Hispanic N=2709, Other N=10,623), socioeconomic background, and in-hospital trauma mortality.

Compared with other groups, there was a higher risk of mortality after trauma among African Americans (odds ratio [OR]=1.20, $P < .001$), people living in high-poverty neighborhoods (OR=1.01, $P < .001$), and those enrolled in public health insurance programs (OR=1.53, $P < .001$). African American patients were more likely to have had traumatic injuries caused by certain mechanisms with higher risk of death ($P < .001$). After controlling for mechanism alone in multiple logistic regression, African American race remained a significant predictor of mortality risk (OR=1.12, $P < .001$). After additionally controlling for the socioeconomic factors of insurance status and neighborhood poverty levels, there were no longer any significant differences between racial groups in terms of mortality (OR=0.99, $P = .746$).

These results suggest that in this population the racial inequalities in mortality outcomes were fully mediated by differences between groups in the pattern of injuries suffered and differences in risk based on socioeconomic factors.

Abbreviations: BIC = Bayesian Information Criteria, FPL = Federal Poverty Level, GLMM = generalized linear mixed modeling, GSW = Gunshot wound, HCUP = Healthcare Cost and Utilization Project, MSA = metropolitan statistical area, MVT = motor vehicle traffic, OR = odds ratio, SES = socioeconomic status, SID = State Inpatient Database.

Keywords: health inequalities, multilevel analysis, poverty, race, traumatic injury

1. Introduction

Health disparities are a serious and persistent problem in the United States, with socioeconomic status (SES) and race/ethnicity being related to risks of negative outcomes across a wide variety of measures.^[1] Many of the key causes of these disparities appear to be linked with access to treatment and preventative care,^[2] with poor and minority patients more likely to lack insurance coverage for treatment,^[3] and less likely to have access to tools for health promotion.^[4] In certain respects, therefore, treatment for traumatic injury (i.e., sudden physical injuries requiring immediate medical treatment) might be expected to be a circumstance that minimizes the risk of these inequalities, because treatment access is

universal (hospitals must provide emergency treatment irrespective of insurance status), and because the acute circumstances of injury make preventative care less relevant. However, although relatively little disparities research has focused on traumatic injury, several studies have found that socioeconomic and race/ethnicity factors are related to outcome quality for trauma patients.^[5] This study uses data on all trauma admissions in the Detroit metropolitan area over a 9-year period to examine the relationship of race, mechanism of injury, insurance status, and neighborhood poverty with in-hospital mortality after traumatic injury.

1.1. Trauma impacts and disparities

Traumatic injury results in more than 41 million emergency department visits annually, and is the third-leading cause of death in the United States.^[6] While this serious public health problem affects individuals of all types, some groups are at greater risk than others. For example, men suffer from more traumatic injuries of most types than women,^[7] and older adults are at especially high risk of trauma related to falling.^[8] Reflecting broader patterns of health disparities related to socioeconomic factors, race and poverty also appear to play a role in trauma risk. African Americans throughout the country in particular are more likely than their White counterparts to experience traumatic injury.^[9] Individuals with lower income and those who live in high-poverty communities are also more likely to experience traumatic injury.^[10,11] Similar findings with respect to community SES and trauma incidence in other national contexts,

Editor: Ediriveera Desapriya.

The authors have no funding and conflicts of interest to disclose.

Department of Surgery, St. John Hospital and Medical Center, Detroit, MI.

* Correspondence: R. David Hayward, Senior Medical Researcher, Department of Surgery, St. John Hospital and Medical Center, 22151 Moross Rd, PB 1, Suite 212, Detroit, MI 48236 (e-mail: Richard.Hayward@ascension.org)

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Medicine (2018) 97:39(e12606)

Received: 14 March 2018 / Accepted: 31 August 2018

<http://dx.doi.org/10.1097/MD.00000000000012606>

including in Sweden^[12] and the United Kingdom,^[13] suggest that this pattern exists across national contexts.

These disparities do not end after the injury has occurred. There is evidence that inequalities persist in treatment as well, with race and poverty also linked with negative outcomes among trauma patients. A meta-analysis of research published before 2011 concluded that African Americans had a 19% higher rate of mortality due to trauma compared with White patients.^[15] Another large study found that trauma patients in the lowest quartile of income were 32% more likely to die than wealthier patients.^[14] Thus, vulnerable populations including poor and minority patients face a cycle of multiple disadvantages, being both more likely to suffer from traumatic injury and more likely to suffer from worse outcomes after trauma care. These inequalities are further compounded because minority group members are disproportionately likely to also have lower SES.

1.2. Possible mechanisms of disparity

In order to begin to reduce the extent of socioeconomic and racial disparities in trauma outcomes, it is important to understand the underlying mechanisms that may contribute to them. People in higher-risk groups may also have different patterns of risk for specific types of trauma that may contribute to unequal outcomes. For example, although young White and African American men experience similar rates of injury due to interpersonal violence, African Americans are much more likely than their White counterparts to be victims of gun violence,^[15] which may contribute to unequal levels of injury severity between the 2 groups. Intergroup differences in trauma mechanism and severity have not been fully addressed in previous research, although some studies have cast doubt on this interpretation at least with respect to some specific subsets of injury types.^[15]

One of the most important factors in the promulgation of disparities in health outcomes more generally is believed to be inequalities in health insurance.^[16] Because emergency services must by law be provided to patients regardless of ability to pay, it should not have a determinative impact in this case. However, lack of insurance may nevertheless discourage trauma patients from seeking immediate care. People without insurance, or those with lower quality insurance, may also have less access to ongoing preventative care, which may contribute to having worse overall health and more comorbid conditions at the time of trauma, which may in turn have a damaging effect on care outcomes.

Similar factors may apply to other factors related to socioeconomic background, such as personal and neighborhood poverty. A substantial body of research from the stress process perspective^[17] shows that chronic exposure to stressful living conditions has deleterious effects on the body that lead to long-term health problems.^[18,19] The same physiological processes also deplete the body's ability to recover from damage due to injury.^[20] Trauma victims living with this type of chronic stress may be at greater risk for experiencing complications that lead to greater risk of mortality and other negative outcomes. Both poverty and the experience of racial discrimination are major sources of chronic stress,^[21–23] which may contribute directly to these deleterious outcomes.

1.3. Hypotheses

Hypothesis 1: Consistent with previous research, it is anticipated that race and SES will be significantly related to differences in risk of in-hospital mortality among trauma patients.

Hypothesis 2: Racial disparities in mortality are at least partially explained by co-occurring differences in trauma mechanism, insurance status, and socioeconomic background.

2. Methods

Individual-level admissions data for this project were obtained from the Healthcare Cost and Utilization Project (HCUP), sponsored by the Agency for Health Research and Quality. One element of the HCUP is the compilation of an annual database including medical details of all hospital discharges in each state, known as the State Inpatient Database (SID). Data for the present analyses come from the Michigan SID for the period of years from 2006 to 2014. Patients residing in the Detroit metropolitan statistical area (MSA) were identified using the US Census Bureau definition as consisting of Wayne, Lapeer, Livingston, Macomb, Oakland, and St. Clair counties. Trauma cases were identified using ICD-9 diagnostic codes present at admission (cases including ICD-9 codes between 800 and 959 were identified for analysis). Approval was received from the Institutional Review Board of St. John Hospital and Medical Center.

2.1. Measures

2.1.1. Trauma mechanism. Trauma mechanisms were recorded in the SID using ICD-9 diagnostic codes for external causes (e-codes). Mechanisms with a high enough rate of incidence among patients to analyze individually include falls, gunshot wounds (GSWs), and motor vehicle traffic (MVT).

2.1.2. Neighborhood poverty. Neighborhood-level data on approximate poverty rates in 2014 were obtained from US Census Bureau data. The Census Bureau compiles ZIP-code level estimates of poverty based on responses to the annual American Community Survey. Data at the ZIP code level are aggregated across a rolling 3-year period (e.g., data for 2014 are an aggregate of data collected in 2012, 2013, and 2014) to ensure sufficient response within each geographic region to draw valid estimates. Poverty estimates are derived from reported household size and income, based on the Federal Poverty Level (FPL) for the corresponding year. The dollar amount of the FPL income threshold for poverty depends on family size. For example, in 2014 the poverty threshold was \$11,670 for a single person, \$15,730 total gross household income for a 2-person household, \$19,790 for a 3-person household, and so forth. The Census Bureau data use these statistics to determine the approximate poverty rate for each ZIP code. Each patient's neighborhood poverty rate was determined based on their ZIP code of residence at the time of hospitalization. Because the ZIP code-level index of poverty is not available for years prior to 2012, the 2014 values are used regardless of the year in which hospitalization occurred.

2.1.3. Insurance status. Data on the primary expected payer for each patient's treatment was used to measure insurance status (private insurance, Medicare, Medicaid, self-pay, or other). Medicare and Medicaid are public health insurance programs. Medicare is fully funded and administered by the US Federal Government, and covers most legal US residents aged 65 and older, regardless of income.^[24] Medicaid receives a combination of federal and state funds, and covers some groups of low-income individuals, based on their household income relative to the FPL. During almost the full period covered by this study, Medicaid was available in the state of Michigan to the following groups: pregnant women and infants younger than 12 months living at or below

185% FPL, children living at or below 150% FPL (ages 1–15) or 100% FPL (ages 16–18), parents of covered children at or below 50% FPL, disabled adults living at or below 100% FPL, and adults aged 65 or older with very low financial assets and income below 100% FPL.^[25] As a result of the federal Affordable Care Act, the state of Michigan expanded Medicaid eligibility to all adults living at or below 138% FPL beginning in April 2014.^[26]

2.1.4. Individual demographics. Individual patient factors recorded included age, gender, and race. Age was recorded in years. In the SID data, race was coded as African American, Hispanic, non-Hispanic White, Asian/Pacific Islander, Native American, or other. Reflective of the Detroit metropolitan area population, Asian/Pacific Islander, and Native American patients each comprised <0.5% of the sample, and therefore were combined for analysis with the “other” category.

2.2. Analysis

Generalized linear mixed modeling (GLMM) was used to analyze the relationship between trauma patients’ demographic and socioeconomic characteristics and mortality in hospital. The GLMM procedure allows for the inclusion of a combination of both individual and group-level effects. Because clusters of patients living in the same areas share the same neighborhood poverty levels, the GLMM analysis groups individual-level patient observations within ZIP codes, and treats poverty level as a group-level effect. The full model was constructed in multiple steps because of the associations among race, mechanism of injury, and socioeconomic background. Model 1 includes demographic variables only (age, gender, and race). Model 2 adds the impact of trauma mechanism to the analysis. Finally, Model 3 adds insurance status and neighborhood poverty level to the analysis.

3. Results

There were a total of 407,553 trauma admissions in the Detroit MSA during the period from 2006 to 2014. In-hospital mortality occurred in 10,062 of these cases (2.5%). This in-hospital

mortality rate is relatively low in comparison to recent estimates based on national US data^[27] and in comparison with similar figures from Europe^[28] and Japan.^[29] A total of 75,955 (18.6%) of these admissions were excluded from the final analyses because of missing data. Race was the most common missing data element (missing in 18.6% of admissions), with a much smaller number of cases excluded due to missing mortality status (0.3%), age (0.3%), gender (0.3%), and ZIP code (0.2%) data. Descriptive statistics for the independent variables included in the analysis are shown in the first column of Table 1. There were a number of important differences between the White and African American populations of trauma patients. The African American group was much younger on average, disproportionately male, and had a much higher average neighborhood poverty rate. African Americans were also much more likely to have had trauma related to causes other than falls (especially GSW, which accounted for 6.0% of African American patients but only 0.3% of White patients), and they were much more likely to be enrolled in Medicaid or to be uninsured, and less likely to have Medicare.

GLMM results for mortality are shown in Table 2. Model 1 examines the association of patient demographics alone. Older age was related to greater risk of in-hospital mortality among trauma patients (odds ratio [OR]=1.02, *P*<.001), and women had a lower risk of mortality than men (OR=0.59, *P*<.001). In terms of race, African American trauma patients had a 20% higher risk of mortality in comparison to White trauma patients (*P*<.001), while the risk associated with Hispanic and “other” race patients did not differ significantly from that of White patients.

Model 2 adds mechanism of trauma to the GLMM analysis. In comparison to trauma due to falls, which had the lowest rate of mortality, the mortality rate for firearm-related trauma was more than 5 times higher (OR=5.14, *P*<.001). Categories of injury mechanism including MVT (OR=1.78, *P*<.001), other (OR=1.37, *P*<.001), and unspecified (OR=1.52, *P*<.001) were associated with mortality risk significantly higher than for falls, but lower than for GSW. The magnitude of the coefficient for

Table 1
Descriptive statistics summary by race/ethnicity.

	Total (N=407,553)	White (N=232,109)	African American (N=86,356)	Hispanic (N=2709)	Other (N=10,623)	<i>P</i>
	M (SD) or %	M (SD) or %	M (SD) or %	M (SD) or %	M (SD) or %	
Age	61.2 (23.6)	65.1 (22.2)	49.2 (22.9)	40.7 (24.0)	53.5 (25.8)	<.001
Gender						<.001
Female	49.6%	53.6%	39.8%	32.2%	44.6%	
Male*	50.4%	46.4%	60.2%	67.8%	55.4%	
Mechanism						<.001
Falls*	31.5%	35.7%	21.5%	19.6%	23.2%	
GSW	1.9%	0.3%	6.0%	3.8%	1.8%	
MVT	5.9%	4.9%	8.5%	10.4%	7.5%	
Other	25.2%	22.3%	32.8%	33.2%	26.7%	
Unspecified	35.5%	36.9%	31.2%	33.0%	40.8%	
Insurance status						<.001
Private	27.0%	27.2%	26.1%	24.1%	31.5%	
Medicare	52.9%	59.8%	36.8%	24.3%	41.0%	
Medicaid	12.0%	7.3%	23.2%	28.0%	18.8%	
Self-pay	5.0%	3.1%	9.7%	12.7%	5.1%	
Other	3.2%	2.7%	4.2%	11.0%	3.7%	
Neighborhood poverty rate*	18.8 (13.8)	13.8 (10.0)	34.8 (12.3)	30.5 (15.3)	22.0 (15.9)	<.001

GSW = Gunshot wound, M = mean, MVT = motor vehicle traffic, SD = standard deviation.
* Proportion of patient’s neighborhood (based on ZIP code) living in poverty.

Table 2**Generalized linear mixed model results for mortality.**

	Model 1		Model 2		Model 3	
	OR	P	OR	P	OR	P
Age	1.02 [1.02, 1.02]	<.001	1.03 [1.03, 1.03]	<.001	1.03 [1.02, 1.03]	<.001
Female	0.59 [0.56, 0.61]	<.001	0.61 [0.59, 0.64]	<.001	0.60 [0.58, 0.63]	<.001
Race/ethnicity						
African American*	1.20 [1.12, 1.29]	<.001	1.12 [1.04, 1.20]	.002	0.99 [0.92, 1.06]	.746
Hispanic*	1.03 [0.78, 1.37]	.820	1.00 [0.75, 1.33]	.985	0.96 [0.72, 1.28]	.782
Other*	1.07 [0.94, 1.23]	.283	1.04 [0.91, 1.19]	.536	0.98 [0.86, 1.12]	.754
Mechanism						
GSW†			5.14 [4.49, 5.88]	<.001	5.38 [4.69, 6.17]	<.001
MVT†			1.78 [1.59, 1.99]	<.001	1.95 [1.74, 2.18]	<.001
Other†			1.37 [1.29, 1.47]	<.001	1.37 [1.29, 1.47]	<.001
Unspecified†			1.52 [1.44, 1.60]	<.001	1.51 [1.43, 1.59]	<.001
Insurance						
Medicare‡					1.18 [1.11, 1.27]	<.001
Medicaid‡					1.53 [1.40, 1.67]	<.001
Self-pay‡					0.52 [0.44, 0.61]	<.001
Other‡					0.66 [0.54, 0.80]	<.001
Neighborhood poverty rate					1.01 [1.01, 1.01]	<.001
BIC	75,124.3		74,575.6		74,261.5	

BIC = Bayesian Information Criteria, GSW = Gunshot wound, MVT = motor vehicle traffic, OR = odds ratio.

* Comparison group is non-Hispanic White.

† Comparison mechanism is falls.

‡ Comparison group is private insurance.

African American race/ethnicity was smaller in this model (OR = 1.12, $P = .002$), indicating that some but not all of the disparity in mortality risk between African American and White trauma patients was statistically attributable to differences in the patterns of trauma mechanisms between these 2 groups. The Bayesian Information Criteria (BIC) statistic was significantly smaller in Model 2 in comparison with Model 1, indicating that adding trauma mechanism to the model improved its fit with the data.

Model 3 additionally adds socioeconomic factors: individual insurance status and neighborhood poverty level. Compared with patients with private insurance, those relying on public insurance were significantly more likely to die (53% more likely for Medicaid patients, $P < .001$, and 18% more likely for Medicare patients, $P < .001$). Interestingly, patients not using insurance had lower mortality risk than those with either private or public insurance (OR = 0.52, $P < .001$). Finally, neighborhood poverty was also related to mortality risk, with residents of poorer neighborhoods more likely to die in the hospital (OR = 1.01, $P < .001$). In the final model, the coefficient for African American race was reduced to nonsignificance (OR = 0.98, $P = .754$), indicating that the difference in mortality risk between African American and White patients was fully statistically mediated by collective differences in mechanisms of trauma. The BIC for Model 3 indicated that it improved the degree of fit over Models 1 and 2.

4. Discussion

The results of this study support both the hypothesis that race is associated with trauma mortality and the hypothesis that this association may be at least partially attributed to differences in the pattern of trauma type, as well as differences in SES between African American and White patients. African American trauma patients were 20% more likely to die in the hospital in comparison with White trauma patients. These disparities were not fully statistically explained by differences in trauma types.

Although African American patients were more likely to have experienced higher-mortality trauma mechanisms, race remained significantly associated with mortality risk even after controlling for these differences. Additionally, there were substantial differences in risk based on 2 key indicators of SES—insurance status and neighborhood poverty rate. The risk of mortality among trauma patients increased by 1% for every 1% increase in neighborhood poverty rate, and the risk is also higher for patients with Medicare (25% increased risk) or Medicaid (57% increased risk) compared with privately insured patients. These results suggest that both socioeconomic disparities and differences in the epidemiology of traumatic injury may affect racial disparities in treatment outcomes among trauma patients. These results are concordant with a recent study of race and neighborhood SES in association with all-cause mortality in Baltimore.^[30]

Insurance status can be regarded as a partial, but by no means ideal, proxy for individual SES. Eligibility for Medicaid requires that the recipient be living near or below the FPL (\$23,850 annual household income for a family of 4 in 2014), but during the period covered in this study most nondisabled adults were excluded from this program. Many people with low SES would have been uninsured during this period (reflected by “self-pay” status), while a smaller number would likely have been covered by private insurance. Overall, it is likely that Medicaid recipients and the uninsured had the lowest SES, while privately insured patients would have had somewhat higher SES. The older adult population covered by Medicare includes a wide spectrum of SES. The finding that Medicaid recipients have the highest risk of mortality, therefore, supports the existence of severe disparities for those living in poverty. More moderately elevated rates of mortality among Medicare recipients, even after controlling for age, may reflect the heterogeneity of this group compared with the privately insured. The finding that uninsured patients had better mortality outcomes in comparison to the privately insured is unanticipated from this standpoint, since lack of insurance

would be expected to be related to low SES. One possibility is that the uninsured group contains a large number of relatively healthy patients who choose not to pay for insurance and also lack significant comorbidities that raise the risk of death after traumatic injury. More research is needed to clarify this finding.

In contrast to findings with respect to a number of other forms of racial health disparities, these results appear to suggest that socioeconomic inequality and differences in injury typology may fully account for differences in mortality outcomes for trauma between White and African American patients. This is an encouraging finding to the extent that it implies a lack of direct prejudice in the administration and quality of acute trauma treatment; patients with similar injuries and similar background levels of risk would appear to face similar risk of mortality regardless of race. At the same time, the extent of disparities observed before controlling for these background factors reinforces the impact that social inequalities continue to have on treatment outcomes. At a practical level, trauma patient caregivers should seek to take patient socioeconomic and racial background into consideration when estimating the risks of negative treatment outcomes.

The absence of individual-level income data presents a limitation for drawing complete conclusions regarding the role of SES. Although neighborhood SES and individual insurance status provide useful proxies, these data lack complete information about patients' SES. It seems likely that the availability of these individual-level SES measures would account for greater interpatient variability in outcomes, and would therefore only strengthen the conclusion that SES disparities (along with differences in injury types) may largely account for demographic disparities in trauma outcomes. However, research employing more precise measures of individual SES is called for to support these conclusions.

Additional limitations include the fact that data for this study came from a single metropolitan area. The Detroit area has a number of characteristics that, while posing significant social challenges, also make it useful for studying health disparities, including high degrees of social stratification and residential segregation,^[31] and a high rate of violent crime.^[32] Generalization of these results to regions and populations with very different social backgrounds should be undertaken with caution. Additionally, a moderately high number of cases were missing data for mechanism of trauma, leading to the possibility of underestimating the importance of trauma type as a predictor of mortality outcome. Finally, because ZIP-code level estimates of the poverty rate were not available for the entire period covered by the study, neighborhood-level SES was treated as if it were the same across time. It is likely that poverty rates remained relatively stable, particularly relative to one another, during the 9 years covered by this study. Nevertheless, this approach may obscure differences related to neighborhoods' upward or downward trajectory in terms of SES, and future research should seek to address this possibility.

Addressing health disparities remains one of the most urgent problems facing the US health care system. Inequalities in trauma outcomes are an especially important focus of research, because disparities in this area have not received attention proportionate to the status of traumatic injury as the third-leading cause of death in the US population. Since young African American men are at greatly disproportionate risk of suffering from traumatic injury,^[9] any racial disparities in outcomes are further magnified within an already vulnerable population. We hope that this study will serve to advance understanding of this type of these

disparities, and will stimulate further research aimed at accounting for and ultimately reducing them.

Author contributions

Conceptualization: Jacey A. Loberg, R. David Hayward, Mary Fessler, Elango Edhayan.

Data curation: R. David Hayward.

Formal analysis: R. David Hayward.

Investigation: Jacey A. Loberg.

Methodology: Jacey A. Loberg, R. David Hayward.

Software: R. David Hayward.

Supervision: Elango Edhayan.

Writing – original draft: Jacey A. Loberg, R. David Hayward, Mary Fessler.

Writing – review & editing: Jacey A. Loberg, R. David Hayward, Elango Edhayan.

R. David Hayward orcid: 0000-0002-9845-6131

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