

# BMJ Open Between-hospital and between-neighbourhood variance in trauma outcomes: cross-sectional observational evidence from the Detroit metropolitan area

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## ABSTRACT

**Objective** Disparities in treatment outcomes for traumatic injury are an important concern for care providers and policy makers. Factors that may influence these disparities include differences in risk exposure based on neighbourhood of residence and differences in quality of care between hospitals in different areas. This study examines geographical disparities within a single region: the Detroit metropolitan area.

**Design** Data on all trauma admissions between 2006 and 2014 were obtained from the Michigan State Inpatient Database. Admissions were grouped by patient neighbourhood of residence and admitting hospital. Generalised linear mixed modelling procedures were used to determine the extent of shared variance based on these two levels of categorisation on three outcomes. Patients with trauma due to common mechanisms (falls, firearms and motor vehicle traffic) were examined as additional subgroups.

**Setting** 66 hospitals admitting patients for traumatic injury in the Detroit metropolitan area during the period from 2006 to 2014.

**Participants** 404 675 adult patients admitted for treatment of traumatic injury.

**Outcome measures** In-hospital mortality, length of stay and hospital charges.

**Results** Intraclass correlation coefficients indicated that there was substantial shared variance in outcomes based on hospital, but not based on neighbourhood of residence. Among all injury types, hospital-level differences accounted for 12.5% of variance in mortality risk, 28.5% of variance in length of stay and 32.2% of variance in hospital charges. Adjusting the results for patient age, injury severity, mechanism and comorbidities did not result in significant reduction in the estimated variance at the hospital level.

**Conclusions** Based on these data, geographical disparities in trauma treatment outcomes were more strongly attributable to differences in access to quality hospital care than to risk factors in the neighbourhood environment. Transfer of high-risk cases to hospitals with greater institutional experience in the relevant area may help address mortality disparities in particular.

## Strengths and limitations of this study

- Data cover all hospital admissions in a major metropolitan area over a 9-year period.
- Multilevel analysis allows decomposition of differences in patient outcomes shared within neighbourhood of residence and hospital of treatment.
- Range of outcomes included mortality, length of stay and hospital charges.
- The study cannot assess mortality occurring before hospital admission.
- Differences in intake patterns may increase between-hospital variance.

## INTRODUCTION

The persistence of disparities in patient outcomes is a serious challenge for the US healthcare system.<sup>1</sup> People with low income and members of racial and ethnic minority groups experience worse health outcomes across a broad spectrum, from lower birth weight<sup>2</sup> to greater risk of functional disability in older adulthood.<sup>3</sup> The causes of these disparities are complex and multifaceted, including differing levels of environmental exposure to health hazards,<sup>4</sup> cultural differences in health behaviours<sup>5</sup> and unequal access to quality care.<sup>6</sup> Within the field of health disparities research, traumatic injury has received relatively little attention in comparison with areas such as chronic disease and infection.<sup>7</sup> Nevertheless, there is a significant body of evidence finding that factors including race<sup>7 8</sup> and socioeconomic status (SES)<sup>9 10</sup> may affect patients' risk of negative outcomes following trauma treatment.

The local geography of cities may play an important role in forming these disparities. Cities in the USA remain heavily segregated by both race and SES, with sharp differences in the demographic make-up of

neighbourhoods that may be in close proximity to one another.<sup>11</sup> These neighbourhoods may differ in terms of the risks they pose for traumatic injury. For example, socioeconomically disadvantaged neighbourhoods may have higher rates of trauma from causes like assault, which may entail greater risks of poorer outcomes. More broadly, residents of marginalised neighbourhoods may face greater background health challenges, leaving them more likely to suffer from multiple comorbidities that are likely to complicate recovery from traumatic injury.<sup>12 13</sup>

A related facet of metropolitan geography potentially impacting trauma outcomes relates to hospital quality and access. Quality of care issues are an increasing concern in the realm of public policy.<sup>14</sup> Large cities contain numerous hospitals providing emergency trauma care, and most trauma patients are likely to receive treatment at facilities in close proximity to the places in which they live. Hospitals and other healthcare facilities serving primarily poor and marginalised local populations may face challenges with funding levels and patient demands that inhibit care quality.<sup>6 15</sup> Insurance issues and patient familiarity may also serve to funnel high-risk patients towards under-resourced hospitals, as patients may be more likely to opt to seek care at institutions with which they are more familiar and which they may perceive as less costly.<sup>16</sup>

The extent to which these two aspects of local geography within metropolitan areas—residential neighbourhood and care facility—may be related to trauma outcomes has not been thoroughly assessed. In this study, we use data from all trauma patients admitted for traumatic injury to hospitals in the Detroit metropolitan area between 2006 and 2014 and apply statistical techniques to determine the extent to which three outcomes (mortality, length of hospital stay and hospital charges) differ as a function of (1) the neighbourhoods in which patients reside and (2) the hospital providing care. The Detroit metropolitan area has some of the highest levels of residential racial and ethnic segregation in the USA, as well as some of the most extreme economic inequalities.<sup>17</sup> As a region that has experienced a historical pattern of economic decline and rejuvenation, as well as successive waves of movement between urban and suburban neighbourhoods, it serves to exemplify a number of the socioeconomic challenges facing policy makers and healthcare providers in numerous US cities. It has a well-developed emergency and trauma infrastructure, including three hospitals with American College of Surgeons (ACS) level I trauma designation and 13 with level II designation during the period covered by this study.

## METHODS

Individual-level admissions data for this project were obtained from the Healthcare Cost and Utilization Project (HCUP), sponsored by the Agency for Healthcare 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). Because the data were derived from clinical patient records and were fully anonymous and de-identified, participant consent was not required.

Data for the present analyses come from the Michigan SID for the period of 2006–2014.<sup>18</sup> Patients residing in the Detroit Metropolitan Statistical Area 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 the International Classification of Diseases, Ninth Revision (ICD-9) diagnostic codes present on admission (ICD-9 codes 800–959 were included; no exclusions were made for codes indicating late effects of trauma or superficial injuries).

### Hospitals

Each record in the SID includes a unique, anonymised, identification code corresponding to the hospital to which the patient was admitted. This allows patients to be clustered according to hospital. After excluding institutions with fewer than 100 trauma admissions during the 9-year study period, there were a total of 66 hospitals represented in the data, with a median of 2845 observations in each cluster.

### Neighbourhoods

Patient residence was identified by Zip code in the SID, and in this study each Zip code is treated as a separate neighbourhood. There were a total of 214 neighbourhoods represented in the data, with a median of 1633 observations in each.

### Patient outcomes

Patient outcomes include in-hospital mortality, length of stay (LOS) and total hospital charges. Mortality was derived from the case disposition code (0=did not die, 1=died). LOS is given by the number of days between admission and discharge. Total hospital charges is a dollar amount corresponding to the total amount billed to any payer for each admission.

### Patient comorbidities

The SID database includes data on a range of comorbid conditions (ie, medical conditions existing prior to the present hospitalisation episode). Examples include asthma, substance abuse and obesity. The total number of comorbidities noted in each patient's record was computed to serve as an index of underlying patient health for the purposes of these analyses.

### Trauma mechanism

Trauma mechanisms are derived from the ICD-9 diagnosis codes included for each admission case in the SID. The three most common specific mechanisms in this sample were examined in these analyses: falls, firearms and motor vehicle traffic.

**Table 1** Descriptive statistics at the individual, hospital and neighbourhood levels

	Individual (n=404 675) Mean (SD) or %	Hospital (n=66) Median (IQR)	Neighbourhood (n=214) Median (IQR)
Individuals (n)		2845 (349–9683)	1630 (765–2879)
Age	60.4 (23.7)	62.0 (53.2–66.6)	60.8 (57.3–65.2)
Female	49.8%	50.6% (40.1%–56.7%)	50.5% (46.3%–54.2%)
Race			
White	70.0%	74.6% (40.6%–91.0%)	70.8% (45.5%–82.4%)
Black	26.0%	7.6% (2.2%–19.3%)	2.3% (0.9%–10.0%)
Other	4.0%	8.2% (3.6%–23.2%)	17.2% (12.0%–30.7%)
Mechanism			
Falls	44.3%	43.7% (26.9%–54.1%)	46.7% (40.4%–52.2%)
Firearms	2.4%	0.4% (0.04%–1.1%)	0.6% (0.2%–1.4%)
Motor vehicle	8.6%	5.4% (2.8%–12.1%)	8.4% (7.0%–10.4%)
Severity	4.9 (5.4)	4.5 (3.5–5.5)	5.0 (4.7–5.2)
Comorbidities	2.7 (2.0)	2.8 (2.0–3.1)	2.7 (2.5–2.8)
Mortality	2.5%	2.2% (1.6%–3.0%)	2.4% (2.0%–2.7%)
Length of stay	6.4 (8.3)	5.9 (5.2–6.7)	6.3 (5.9–6.7)
Charges (thousands of dollars)	36.3 (55.2)	32.5 (25.5–41.2)	36.9 (33.7–39.5)
Poverty rate	17.4 (14.4)	14.5 (11.8–19.9)	10.7 (6.5–18.7)

### Injury severity

The ICD-9 diagnosis codes included in the SID were used to calculate estimated Injury Severity Scores (ISS) for all patients. This procedure was carried out using ICDPIC-R,<sup>19</sup> an open-source program executed in the R statistical environment which computes Abbreviated Injury Score (AIS) by body region based on the ICD-9 codes, and then calculates an estimated ISS based on regional AIS, and is based on a set of procedures that have been extensively validated for this purpose.<sup>20 21</sup>

### Patient and neighbourhood demographics

Individual demographics included age (in years), gender and race (white, black or other). Neighbourhood SES was measured using Zip code-level poverty rate estimates published by the US Census Bureau.<sup>22</sup> These estimates represent a 3-year rolling average (eg, the estimates for 2014 represent data from 2012 to 2014). Because poverty rate data were not made available until 2012, whereas this study covers the period from 2006 to 2014, neighbourhood SES is represented in this study as a single rate regardless of year (rather than varying across time), using data from 2014. It was not possible to include information about hospital characteristics (eg, trauma-level designation) because the Michigan SID excludes identifiers that would enable cross-referencing hospital identifications with American Hospital Association data.

### Analytical approach

In this study, we used a generalised linear mixed modelling (GLMM) framework to estimate the proportion of variance in individual outcomes that is attributable to

each of three levels: hospitals, neighbourhoods and individuals (ie, residual variance after hospital and neighbourhood variance has been accounted for). The GLMM method<sup>23</sup> is a statistical modelling technique which includes a mixture of fixed and random effects. Random effects represent shared group-level linear relationships. Individual outcome values are allowed to vary at random around a group mean, allowing for an estimate of the part of the outcome that varies between groups and that varying between individuals. In these analyses, random intercept effects are specified for both hospital and neighbourhood, meaning that individual outcomes are allowed to vary at random around both a hospital mean and a neighbourhood mean. The group-level design matrix is specified as cross-classified, meaning that both sets of higher level clusters are included in the same model, with each individual belonging to both a hospital and neighbourhood cluster. Because the distributions of the outcome variables are not the same, different linking functions are used in GLMM models with different outcomes. Mortality is a binary variable and uses a binary linking function. LOS and total charges both have highly skewed continuous distributions, making the use of a log-normal linking function appropriate.

The proportion of variance at the group level is given by the intraclass correlation coefficient (ICC) corresponding to the level of clustering (in this case, hospital and neighbourhood). For outcomes with a non-binary function (ie, LOS and charges), the ICC is computed by dividing the group-level variance parameter by the sum of the group and residual variance parameters. For binary

**Table 2** Individual descriptive statistics by poverty quartile

	First quartile (<6.5%) n=103 004	Second quartile (6.5%–10.8%) n=79 738	Third quartile (10.8%–18.7%) n=90 554	Fourth quartile (>18.7%) n=134 257	P values*
Age, mean (95% CI)	63.9 (63.7 to 64.0)	65.1 (64.9 to 65.2)	62.3 (62.1 to 62.4)	53.8 (53.6 to 53.9)	<0.001
Female (%)	53.0	54.0	52.0	43.4	<0.001
Race (%)					<0.001
White	86.9	93.5	83.1	38.5	
Black	9.5	3.3	13.7	56.3	
Other	3.6	3.2	3.2	5.2	
Mechanism (%)					<0.001
Falls	49.8	51.7	47.3	35.4	
Firearms	1.0	0.4	1.0	5.1	
Motor vehicle	8.0	7.6	8.1	9.6	
Severity (ISS), mean (95% CI)	5.0 (4.9 to 5.0)	4.9 (4.9 to 4.9)	4.7 (4.7 to 4.7)	4.9 (4.9 to 5.0)	<0.001
Comorbidities, mean (95% CI)	2.7 (2.7 to 2.7)	2.8 (2.8 to 2.8)	2.9 (2.8 to 2.9)	2.7 (2.7 to 2.7)	<0.001
Mortality (%)	2.4	2.5	2.4	2.6	0.002
LOS, median (IQR)	4.0 (2.0–7.0)	4.0 (2.0–7.0)	4.0 (2.0–7.0)	4.0 (2.0–8.0)	<0.001
Charges (thousands of dollars), median (IQR)	22.2 (13.0–37.8)	22.7 (13.2–38.9)	22.3 (13.0–38.0)	23.3 (13.3–41.7)	<0.001

\*P values for one-way analysis of variance (age, ISS), Kruskal-Wallis (LOS, cost) or  $\chi^2$  (female, race, mechanism, mortality). ISS, Injury Severity Score; LOS, length of stay.

GLMM (ie, mortality), the ICC is given by dividing the group-level variance parameter by the sum of the group-level parameter and 3.29, an estimate of the theoretical variance in the binomial distribution.<sup>24</sup> In the results, these figures are expressed as a percentage of the total variance at each level. Cases with missing outcome data

were excluded on a pairwise basis. LOS and charge analyses exclude cases with in-hospital mortality.

For each analysis, two GLMM models are computed. The first model includes random effects only and provides an estimate of the total variance at each level, ignoring differences in outcomes arising due to systematic

**Table 3** Individual descriptive statistics by injury severity group

	Less severe injuries ISS≤15 (n=380 218)	More severe injuries ISS>15 (n=25 997)	P values*
Age, mean (95% CI)	60.6 (60.6 to 60.7)	57.0 (56.7 to 57.3)	<0.001
Female (%)	50.8	35.8	
Race (%)			<0.001
White	70.4	64.0	
Black	25.7	31.1	
Other	3.9	4.9	
Mechanism (%)			<0.001
Falls	44.4	41.7	
Firearms	2.0	8.1	
Motor vehicle	7.4	24.2	
Comorbidities, mean (95% CI)	2.8 (2.7 to 2.8)	2.5 (2.5 to 2.5)	<0.001
Mortality (%)	2.1	8.2	<0.001
LOS	4.0 (2.0, 7.0)	6.0 (3.0, 11.0)	<0.001
Charges (thousands of dollars), median (IQR)	22.0 (12.8–37.5)	37.2 (19.6–80.2)	<0.001
Neighbourhood poverty rate, median (IQR)	12.4 (6.5–26.5)	13.2 (6.5–32.3)	<0.001

\*P values for one-way analysis of variance (age), Kruskal-Wallis (LOS, cost) or  $\chi^2$  (female, race, mechanism, mortality). ISS, Injury Severity Score; LOS, length of stay.



**Table 4** Variance decomposition statistics, all cases

	Hospital ICC (95% CI)	Neighbourhood ICC (95% CI)	Residual ICC (95% CI)	Patients (n)
Mortality, unadjusted	12.5% (7.4 to 17.0)	0.4% (0.2 to 0.6)	87.1% (82.4 to 92.3)	404 675
Mortality, adjusted for casemix	9.3% (5.5 to 12.8)	0.2% (0.05 to 0.4)	90.5% (86.9 to 94.4)	397 170
Length of stay, unadjusted	28.5% (20.6 to 35.0)	0.3% (0.2 to 0.4)	71.2% (64.7 to 79.1)	386 886
Length of stay, adjusted for casemix	23.9% (16.9 to 29.8)	0.2% (0.1 to 0.2)	76.0% (70.0 to 82.9)	379 881
Total charges, unadjusted	32.2% (21.7 to 40.5)	0.2% (0.1 to 0.3)	67.5% (59.3 to 78.1)	269 816
Total charges, adjusted for casemix	22.7% (16.5 to 28.2)	0.3% (0.2 to 0.4)	77.0% (71.5 to 83.3)	266 861

Hospital, n=66; Zip code, n=214.

Unadjusted models include random effects only. Adjusted models include fixed effects for patient age, Injury Severity Score, mechanism of injury and number of patient comorbidities.

ICC, intraclass correlation coefficient.

between-group differences in patient demographics and injury characteristics. The second model additionally includes fixed effects to control for some of these differences in casemix, including patient age, number of comorbidities, ISS and mechanism of injury. By comparing the CIs of the ICC estimates, it is possible to evaluate whether or not a significant proportion of the shared variance at each random effects level can be attributed to the factors controlled for as fixed effects. Analyses were conducted using SAS V.9.4, except for the estimation of ISS, which was carried out using ICDPIC-R in R V.3.5.

### Patient and public involvement

This study addresses patient priorities by seeking to better understand how trauma care systems may be able to reduce patient mortality rates, the length of hospitalisation and charges incurred. Data are derived from administrative records, so patients were not directly involved in the design, recruitment or conduct of the study. Results will be accessible to the public, including to individuals who may have patients during the study period.

## RESULTS

**Table 1** presents the descriptive statistics for the full patient sample at the individual, hospital and neighbourhood levels. There were a total of 404 675 admissions for traumatic injury during the time period included in this study, representing a total of 66 hospitals and 214 Zip codes. The mean number of patients per hospital was 2845 (IQR: 349–9683), and the mean number per neighbourhood was 1630 (IQR: 765–2879). The three largest subgroups based on mechanism were falls (n=117 931), motor vehicle traffic (n=22 755) and firearms (n=6512).

**Tables 2 and 3** allow for comparisons of case characteristics by neighbourhood SES (defined by poverty rate quartiles) and injury severity (defined by cases with ISS up to 15 and those with ISS greater than 15). Patients from the poorest neighbourhoods were substantially younger than the patient population as a whole and were more likely to be male and black. Mortality rates, LOS and charges were all significantly higher in poorer

neighbourhoods, but the magnitude of these differences in outcomes was small (eg, 2.4% mortality in the lowest quartile poverty neighbourhoods, compared with 2.6% in the highest poverty quartile). Both outcomes and demographics differed substantially by injury severity. Severely injured patients were much more likely to be male and were somewhat younger and somewhat more likely to be black. Firearm and motor vehicle traffic mechanisms were also much more common among the more severe injuries. As would be expected, mortality was substantially higher among those with more severe injuries, as were median LOS and charges.

**Table 4** presents the ICC results for the full and stratified samples, along with the number of patients included in each model. All patients were included in the analyses of mortality. Sample sizes for the analyses of LOS were somewhat smaller, likely reflecting patients who were transported to a hospital but died before admission (1.8% of the full sample was lost at this stage). Total charge data were available for only a subset of patients, due to under-reporting of this variable by hospitals (31.4% of the total sample was lost at this stage). Supplemental analyses (not shown) indicated that patients with missing charge data were substantially more likely to be black, male and live in high-poverty neighbourhoods. A substantial proportion of these missing data may be due to hospitals waiving or not reporting charges for uninsured patients with means to pay, and thus directly confounded with the aims of the study. Charge results should therefore be interpreted with some caution.

There was significant variance at the hospital level for all outcomes. The extent of the hospital-level variance was significantly higher for LOS and total charges than for mortality. In each case, the magnitude of the ICC estimate was lower in the casemix adjusted model than in the unadjusted model, but none of these differences were statistically significant (ie, between-hospital differences in the factors controlled in the adjusted model did not account for a significant proportion of the between-hospital disparities in outcomes). Although neighbourhood ICC was statistically significant in all of the models presented in **table 4**,

**Table 5** Variance decomposition statistics by injury severity

	Hospital ICC (95% CI)	Neighbourhood ICC (95% CI)	Residual ICC (95% CI)	Patients (n)
Less severe injuries (ISS≤15)*				
Mortality, unadjusted	12.3% (7.2 to 16.8)	0.4% (0.1 to 0.6)	87.3% (82.7 to 92.6)	378 788
Mortality, adjusted for casemix	9.5% (5.6 to 13.1)	0.1% (−0.1 to 0.3)	90.4% (86.7 to 94.4)	371 287
Length of stay, unadjusted	16.6% (11.3 to 21.3)	0.2% (0.1 to 0.2)	83.2% (78.4 to 88.5)	363 469
Length of stay, adjusted for casemix	13.4% (9.0 to 17.4)	0.1% (0.06 to 0.1)	86.5% (82.5 to 90.9)	356 467
Total charges, unadjusted	33.4% (22.6 to 41.6)	0.1% (0.08 to 0.2)	66.5% (58.2 to 77.3)	253 507
Total charges, adjusted for casemix	30.3% (20.3 to 38.2)	0.3% (0.2 to 0.4)	69.4% (61.5 to 79.5)	250 555
More severe injuries (ISS>15)†				
Mortality, unadjusted	4.8% (1.2 to 8.0)	0.4% (−0.2 to 1.1)	94.8% (90.9 to 99.0)	25 887
Mortality, adjusted for casemix	4.3% (0.9 to 7.4)	0.6% (−0.1 to 1.3)	95.1% (91.3 to 99.3)	25 883
Length of stay, unadjusted	19.7% (12.0 to 26.4)	1.5% (0.9 to 2.2)	78.9% (72.0 to 86.8)	23 417
Length of stay, adjusted for casemix	17.0% (9.9 to 23.3)	0.1% (0.06 to 1.6)	81.9% (75.5 to 89.3)	23 414
Total charges, unadjusted	17.2% (9.5 to 24.1)	0.1% (0.04 to 1.6)	81.8% (74.8 to 89.8)	16 309
Total charges, adjusted for casemix	13.5% (7.2 to 19.2)	0.5% (0.1 to 0.8)	86.0% (80.2 to 92.5)	16 306

\*Hospital, n=66; Zip code, n=214.

†Hospital, n=64; Zip code, n=212.

Unadjusted models include random effects only. Adjusted models include fixed effects for patient age, ISS, mechanism of injury and number of patient comorbidities.

ICC, intraclass correlation coefficient; ISS, Injury Severity Score.

the magnitude of the variance explained at this level was not clinically meaningful (less than 0.5% in all models).

Tables 5 and 6 present the stratified analyses by injury severity (table 5) and mechanism of trauma (table 6). There was significant variance at the hospital level across outcomes and trauma mechanism, although the extent of this variance ranged from 2.9% for mortality due to falls to 33.4% for total charges among less severe injuries. Again, there were no cases in which the unadjusted and casemix adjusted models differed significantly in the estimation of hospital ICC. Neighbourhood variance was minimal across outcomes and mechanisms as well, with the highest estimate being 1.6% for motor vehicle traffic mortality (after casemix adjustment).

Sensitivity analyses were conducted to evaluate whether the decision to exclude cases with in-hospital mortality from the LOS and total charges affected the results. No significant differences were detected in any ICC statistics between analyses conducted with and without these cases.

## DISCUSSION

The persistence of disparities in health outcomes is an important concern for public policy makers and for hospital administrators. These results reflect a growing literature finding substantial between-hospital differences in outcomes for injured patients, related to hospital factors including patient volume,<sup>25</sup> trauma level designation<sup>26</sup> and treatment efficiency.<sup>27</sup> This analysis addresses two important issues. First, the extent of disparity in outcomes from trauma treatment has received relatively

little attention, with most research focusing primarily on treatment of acute and chronic disease. Second, a long-standing question has been the relative importance of placement of care facilities versus neighbourhood risk factors and individual differences in creating patterns of geographical health inequality—that is, do marginalised neighbourhoods suffer because they have access to hospitals that have worse outcomes; because they exhibit environmental risk factors like exposure to greater violence, more toxic substances, and generally unsanitary and stressful conditions; or because their populations have other underlying risk factors, like higher rates of chronic disease and lower levels of insurance coverage, unrelated to specific neighbourhood conditions?

With respect to the first question, these results suggest that there are substantial disparities in trauma outcomes related to factors outside of the facts of the trauma case and individual differences in trauma patients. Ideally, these individual factors (represented here as part of the residual variance) should account for all of the variance in outcomes—patient outcomes should be equal across hospitals and across neighbourhoods. Regarding the second question, these data indicate that identifiable inequalities account for between 2% and 33% of outcomes, depending on the outcome and trauma type examined. They also suggest that most of these disparities in trauma outcomes appear to be due to hospital-level disparities, with the independent influence of neighbourhood being comparatively trivial. This lends support to the view that geographical disparities in trauma outcomes

**Table 6** Variance decomposition statistics by selected injury mechanisms

	Hospital ICC (95% CI)	Neighbourhood ICC (95% CI)	Residual ICC (95% CI)	Patients (n)
<b>Falls*</b>				
Mortality, unadjusted	2.9% (1.0 to 4.7)	0.2% (-0.2 to 0.7)	96.9% (94.6 to 99.3)	117 454
Mortality, adjusted for casemix	2.4% (2.4 to 2.4)	0.0% (0.0 to 0.0)	97.6% (97.6 to 97.6)	117 454
Length of stay, unadjusted	19.3% (11.2 to 26.2)	0.2% (0.1 to 0.3)	80.5% (73.6 to 88.7)	112 954
Length of stay, adjusted for casemix	13.5% (7.3 to 18.9)	0.1% (0.06 to 0.2)	86.4% (80.9 to 92.6)	112 915
Total charges, unadjusted	22.5% (10.9 to 31.7)	0.09% (0.02 to 0.2)	77.4 (67.2 to 89.1)	76 409
Total charges, adjusted for casemix	24.0% (11.1 to 33.8)	0.04% (-0.006 to 0.1)	75.9 (66.1 to 88.8)	76 385
<b>Firearms†</b>				
Mortality, unadjusted	20.2% (15.9 to 32.9)	0.8% (-2.9 to 4.2)	79.1% (64.5 to 101.9)	6 498
Mortality, adjusted for casemix	16.4% (-0.6 to 28.5)	1.5% (-2.2 to 4.9)	82.1% (68.1 to 103.3)	6 498
Length of stay, unadjusted	20.3% (6.7 to 30.4)	0.0% (0.0 to 0.0)	79.7% (69.6 to 93.3)	2 970
Length of stay, adjusted for casemix	12.6% (4.9 to 19.7)	0.2% (-0.2 to 0.8)	87.1% (79.8 to 95.2)	5 857
Total charges, unadjusted	12.2% (5.0 to 18.8)	0.2% (-0.2 to 0.6)	87.6% (80.8 to 95.1)	5 858
Total charges, adjusted for casemix	21.3% (5.8 to 33.6)	0.07% (-0.4 to 0.8)	78.6% (66.2 to 94.7)	2 970
<b>Motor vehicle‡</b>				
Mortality, unadjusted	4.7% (-0.8 to 9.7)	1.1% (-1.1 to 3.4)	94.2% (87.3 to 101.9)	22 604
Mortality, adjusted for casemix	2.7% (-0.4 to 5.7)	1.6% (-1.0 to 4.2)	95.6% (90.4 to 101.5)	22 604
Length of stay, unadjusted	13.0% (6.0 to 19.2)	0.3% (0.1 to 0.6)	86.7% (80.3 to 93.8)	21 082
Length of stay, adjusted for casemix	14.5% (7.0 to 21.2)	0.2% (-0.002 to 0.4)	85.3% (78.6 to 93.0)	21 057
Total charges, unadjusted	19.6% (10.0 to 27.7)	0.6% (0.2 to 1.2)	79.8% (71.5 to 89.7)	12 430
Total charges, adjusted for casemix	18.3% (8.9 to 26.4)	0.5% (0.2 to 1.0)	81.1% (73.0 to 90.8)	12 418

\*Hospital, n=65; Zip code, n=213.

†Hospital, n=52; Zip code, n=178.

‡Hospital, n=65; Zip code, n=211.

Unadjusted models include random effects only. Adjusted models include fixed effects for patient age, Injury Severity Score, mechanism of injury and number of patient comorbidities.

ICC, intraclass correlation coefficient.

(at least within the specific context of the Detroit metropolitan area) seem to be mainly due to differences in care provided by facilities available in these areas.

Comparative analyses based on neighbourhood poverty levels and injury severity illustrate some potentially confounding factors. For example, patients living in high-poverty neighbourhoods are at higher risk for negative outcomes in some regards—particularly in terms of incidence of firearm injuries—but they are also substantially younger on average, and thus may suffer from fewer risks related to comorbid conditions, which tend to increase with age. Hospital-level disparities in outcomes remained after stratifying the analyses by injury severity and by mechanism of injury, as well as after controlling for some individual-level and case-level risk factors (including age, injury severity and comorbidity). This suggests that the differences between hospitals are not solely based on different background case characteristics. Although there are clearly disparities in terms of risk for different types of injury based on geographical location, these differences in casemix do not appear to fully explain differences in hospital outcomes. Nevertheless, it remains likely that

different patient populations with different risk profiles play an important role in some fraction of the interhospital variability seen here. Although it is beyond the scope of a single study to identify all of these factors, it remains an important area for focus in future research.

These findings suggest that, at least in the case of trauma outcomes, policy should focus on reducing disparities in treatment quality between hospitals in order to reduce community-level disparities in outcomes. More broadly, it suggests that factors influencing geographical disparities in trauma outcomes may arise at the point of treatment, rather than being the result of different levels of risk derived from the neighbourhood environment, at least when considered within a single metropolitan area. Disparities in treatment quality may have a number of causes, including differences in investment, differences in resource allocation and differences in institutional experience with treating trauma. In addition to addressing funding and investment disparities, ways of addressing these differences might include transferring high-risk cases to hospitals with more extensive institutional experience in the relevant field.



Limitations of this study include the inherent inability to fully differentiate hospital-level variance that may be caused by differences in the patient population served at different institutions. Although the adjusted models partially account for some of the most plausible of these factors, including injury severity and mechanism, as well as patient age and comorbidities, it is not possible to control for all factors that may contribute to disparities in casemix between hospitals. Additionally, our data did not include information on prehospital mortality, which has been identified in previous research as a critical phase for trauma management.<sup>28</sup> Since there is the potential for significant inequalities in prehospital care, for example due to geographical differences in response times, this is an important element of the trauma care system to address in future research on disparities. Although sensitivity analyses indicated that loss of cases with mortality did not significantly affect the results of the LOS and charge analyses, the problem of dealing with right-censored data remains a limitation. Other shortcomings include a lack of hospital-level data, including trauma level designation, due to limitations on the Michigan SID data aimed at preserving institutional anonymity. Charge data must be interpreted with some caution, because charges billed do not necessarily reflect hospital costs and can vary between regions based on a variety of factors unrelated to care.<sup>29</sup> Finally, the use of Zip code as a proxy for neighbourhood (although necessary in this case because of a lack of alternate geographical identifiers in the data) presents limitations, because Zip codes reflect administrative divisions that do not necessarily reflect the realities of the social geography in which they are situated; they may divide or combine genuine neighbourhoods, limiting their usefulness as indicators of residential conditions. Alternative ways of identifying neighbourhood clusters other than Zip code (eg, census tracts or homogeneous Zip code groups) might yield more accurate information regarding neighbourhood variation. Future research should seek to create and validate better methods of defining neighbourhoods.

As policy makers look for ways to reduce both disparities in trauma outcomes and the cost of providing care for traumatic injury, it is important to have a clear picture of the extent to which they differ as a function of local geography. This study represents a step towards addressing that question, indicating that differences between hospitals may play an important role in determining the extent of these differences.

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