ORIGINAL ARTICLE

The Importance of Place of Residence on Hospitalized Outcomes for Severely Injured Trauma Patients: A Trauma Registry Analysis

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Abstract

Purpose: Socioecological factors are understudied in relation to trauma patients' outcomes. This study investigated the association of neighborhood socioeconomic disadvantage (SED) and remoteness of residence on acute length of hospital stay days (ALSD) and inpatient mortality.

Methods: A retrospective cohort study was conducted on adults hospitalized for major trauma in a Level 1 trauma center in southeast Queensland from 2014 to 2017. Neighborhood SED and remoteness indices were linked to individual patient variables. Step-wise multivariable negative binomial regression and proportional hazards regression analyses were undertaken, adjusting for injury and patient factors. Outcomes were ALSD and inpatient mortality.

Findings: We analyzed 1,025 patients. Statistically significant increased hazard of inpatient mortality was found for older age (HR 3.53, 95% CI: 1.77-7.11), injury severity (HR 5.27, 95% CI: 2.78-10.02), remoteness of injury location (HR 1.75, 95% CI: 1.06-2.09), and mechanisms related to intentional self-harm or assault (HR 2.72, 95% CI: 1.48-5.03). Excess mortality risk was apparent for rural patients sustaining less severe injuries (HR 4.20, 95% CI: 1.35-13.10). Increased risk for longer ALSD was evident for older age (RR 1.35, 95% CI: 1.07-1.71), head injury (RR 1.39, 95% CI: 1.19-1.62), extremity injuries (RR 1.82, 95% CI: 1.55-2.14), and higher injury severity scores (ISS) (RR 1.51, 95% CI: 1.29-1.76).

Conclusions: Severely injured rural trauma patients are more likely to be socioeconomically disadvantaged and sustain injuries predisposing them to worse hospital outcomes. Further research is needed to understand more about care pathways and factors influencing the severity, mechanism and clinical consequences of rural-based traumatic injuries.

Key words injuries, mortality, rural, socioeconomic status, trauma.

There have been substantial reductions in the number of fatalities that result from injuries in countries like Australia, where modern integrated trauma systems exist.¹⁻⁴ However, as more people survive and receive definitive trauma care, increased rates of hospitalization⁵ and morbidity^{6,7} have ensued. Almost half a million people are hospitalized each year in Australia because of

injuries,⁸ and injury hospitalizations have been estimated to cost upward of around \$5 billion annually.⁹

The health care system has only a small influence on health outcomes when compared to the social, structural, environmental, and economic factors that characterize a person's place of residence or their neighbourhood.¹⁰ Socioecological factors are thought to act as distal exposures,

influencing individuals' health behaviors, which in turn interact with biological and physiological processes that are more proximal to disease causation.¹¹ They provide a contextual framework for understanding and addressing health inequalities, and can be used to potentially promote positive functional outcomes after trauma.¹² Neighborhoods suffering socioeconomic disadvantage (SED), best conceptualized as a multifaceted indicator of average income and education, housing values, labor force participation, and employment, are associated with a higher risk of serious injury and death,¹³⁻¹⁸ even after controlling for individual factors such as personal income and education.^{15,17} The potential for a "place," therefore, to be a risk factor to all its inhabitants, as opposed to just some of them, has prompted concerns that unless contextual factors are addressed, individual risk and inequalities will fester.¹⁹⁻²¹

Whilst Australia has had a universal health care scheme since 1984, a complex range of factors relating to geography and social and economic disadvantage has been shown to adversely influence health care access and outcomes.^{22,23} There has been little research on how "place" in all its forms affects outcomes after traumatic injuries. This is an emerging area of public health concern, given that more patients are now surviving serious traumatic injuries and are subsequently discharged back to their place of residence. Patients who have survived serious trauma to be admitted to a Level 1 trauma center (one that provides the highest level of trauma care) therefore represent a highly select cohort of survivors.

Various components of SED, usually expressed as median income, have been used to predict inpatient trauma deaths in countries without universal health coverage^{24,25}; however, not all these studies have accounted adequately for injury severity, which is also associated with SED. The period of hospitalization, which reflects patient morbidity, and to some extent injury severity, tends to be longer for trauma patients suffering the most social and material deprivation.^{26,27}

Because access to definitive trauma care is critical for survival, rural location, another component of "place," has been widely studied in relation to trauma outcomes. Rural and remote areas in Australia are characterized by long distances between trauma centers, lower population density, poorer health infrastructure, and fewer resources for dealing with severe trauma.²⁸ When compared to urban Australians, rural residents, particularly those living in the most remote parts of the country, are at greater risk of injury and death²⁹ despite advances in integrated trauma systems.³⁰

Research into the impact of remoteness of residence on hospital trauma outcomes in Australia has produced conflicting results. Explanations for this include variations in

the ways in which "place" has been studied (either as remoteness of residence or as remoteness of injury location), selective survivorship, or unmeasured variations in care and triage decisions in regional trauma services, which are often the first point of care for patients requiring stabilization before transferral to definitive trauma care.²⁸

For the most part, and in the absence of other, more precise measures, remoteness is measured in Australia using an unambiguous index of geographical distance to service centers. Conceptually, "access" is at the forefront of this measure, yet it does not specifically measure access to definitive trauma care. Using this measure, studies examining associations with inpatient mortality show improvements over time, for those injured in rural locations.³¹ This suggests that factors such as the regionalization of trauma centers and improved transport to tertiary care are important.³² In Western Australia, where there are vast areas remotely located from urban centers, there is compelling evidence of increased deaths according to the remoteness of the site where the injury occurred.²⁹ Other studies have shown an increased risk of death in hospital for patients residing in rural areas compared to urban patients, after accounting for traditional prognostic factors.^{33,34} Aside from inpatient mortality, there is limited evidence of rural-urban gradients for other hospital outcomes. However, in one study of brain injured patients, length of hospital of stay, an outcome related to morbidity, reported no variations according rural/urban residence for brain-injured patients.³⁵

In Australia, socioeconomic disadvantage and a rural place of residence are closely related, and this has recently been shown for severely injured hospitalized patients.³⁶ The prevailing theory is that in terms of rural/urban health disparities, entrenched SED is the most important factor, which is compounded by remoteness.³⁷

The various dimensions of "place" are rarely studied together in relation to trauma patients and trauma outcomes, so it is unclear whether poorer outcomes are the result of preventable factors embedded within disadvantaged rural neighborhoods, or whether the issue is with geographical access to essential trauma care.

Identification of patients at risk of poor trauma outcomes because of their social, economic and physical environment could influence decisions about early management and prognosis after discharge. The aim of this study was to understand the prognostic importance of neighborhood factors, namely SED and remoteness of residence, on patient outcomes following severe injury, whilst also accounting for other dimensions of "place," such as remoteness of injury location and the location of the first care provider. The catchment area for this trauma center incorporates just 1 major city and includes

regional areas that cross 2 state borders. The hospital does not typically receive patients from very remote areas; this study therefore offers a unique perspective on the effect of regional trauma patterns on patient outcomes, which may differ from studies of trauma outcomes in remote areas of Australia.

Methods

Study Design and Study Setting

Detailed information about the study population and setting is published elsewhere.³⁶ Briefly, the study was a retrospective cohort study of adult injury cases hospitalized for at least 24 hours in a Level 1 trauma center in southeast Queensland (SE QLD), Australia. Eligible patients were sourced from the hospital's trauma registry and satisfied the standard criteria for a major trauma event, aged over 18 years, and admitted to the hospital for at least 24 hours, from January 2014 to December 2017. The study received full ethics approval from the human research ethics committees of the tertiary hospital and the affiliated university (HREC/QGC/256), and from the Queensland government, which granted approval to access patient data via the Public Health Act (RD007485).

The hospital provides trauma care for severely injured patients across 2 state borders, including the wider population in the designated catchment area of SE QLD and patients injured in mostly regional areas of northern New South Wales (NSW). The catchment area for injury admissions includes people living mostly in major cities in SE QLD (68%), with the remainder coming mostly from inner regional areas of the catchment area in both QLD and NSW, which is dominated by patients transferred from northern NSW (71%). Both states have advanced trauma services, with well-developed rural and regional referral networks.

Place-Related Variables

Area-level measures of relative disadvantage and remoteness were developed using the Australian Statistical Geography Standard (ASGS) framework and geocoded information about the patients' residential address at the time of injury and Census Tract data.³⁸

Neighborhood Socioeconomic Disadvantage

The Index of Relative Socioeconomic Disadvantage (IRSD) was used as an area-level proxy measure to describe individual socioeconomic status.³⁸⁻⁴⁰ This Index does not incorporate any measures of remoteness, and it is multifaceted, defined by 17 different pieces of information depicting the relative wealth of a community and

its capacity to use its material and social resources and participate in society (Table S1, available online only). Each patient was assigned an IRSD score. A low score indicated relatively greater rates of disadvantage in that area compared to other areas, characterized by many low-income families, and people with little training and working in unskilled occupations. A high score indicated a relative lack of disadvantage according to these characteristics.

Geographical Remoteness of Residence

Remoteness of residence for the study sample was represented by an index describing the physical distance of a location from the nearest urban center—a proxy measure of the level of access to goods and services.³⁸ Study participants were divided into 5 classes of remoteness based on their relative access to services, otherwise known as Remoteness Areas (RAs). A value of 1 defines major cities of Australia, 2 defines inner regional Australia, 3 is outer regional Australia, 4 is remote Australia, and 5 defines very remote Australia. Because of small numbers of cases in categories 3, 4 and 5 ($N = 26$), all were combined with category 2. For this study, the one major city in the catchment area is likely to be the city where the Trauma Center is located.

Geographical Location of Injury Site

Postcode of injury location was used to create 2 variables: the state in which the injury occurred (NSW or QLD) and the ASGS remoteness categories (RA) as described above.

First Provider

Details of the first hospital provider of care after the injuries were recorded. This is because some patients were initially treated at a regional hospital before being transferred to definitive tertiary trauma care.

Individual Patient Factors

Patient covariates for the study included age, sex, injury severity, Glasgow Coma Score (GCS), injury mechanism, number of comorbidities, discharge disposition for trauma survivors (home or rehabilitation), and anatomical region of injury defined by the Abbreviated Injury Scale (AIS).⁴¹ Polytrauma was defined as AIS >2 in 2 or more AIS regions. Injury severity was defined using the Injury Severity Score (ISS), an ordinal scale ranging from 1 to 75, reflecting the sum of the highest AIS scores for the 3 most severely injured body regions. The mechanism of injury and number of comorbidities were derived from

standard ICD-10 codes. Injury mechanism was divided into 4 groups detailing injuries caused by transport, falls, “other external causes,” and intentional causes.

Outcome Variables

The 2 outcomes for this study were death in hospital and a measure of morbidity described as the number of days spent receiving acute care for patients who survived to hospital discharge. This latter measure was the preferred measure of morbidity compared to hospital length of stay, as it excludes time spent in hospital receiving other forms of care such as rehabilitation, palliative care or mental health care, which could produce spuriously inflated estimates of time spent receiving trauma care. The acute length of stay days (ALSD) was coded according to standard criteria (<https://meteor.aihw.gov.au/content/index.phtml/itemId/181162>).

Statistical Analysis

The IRSD scores were categorized into quartiles to create an ordinal variable. A dichotomized measure of ISS was produced by plotting a receiver operator curve (ROC) of ISS scores against in-hospital mortality. The cut-off was defined as the point that maximized the true positive rate of the statistical model whilst minimizing the false positive rate. The Area under the Curve (AUC) for ISS was 78.6% (95% CI: 0.72.9-0.84.2, $P < .001$).

Chi-square (χ^2) statistics were used in bivariate analysis to compare categorical variables. Where continuous variables were not normally distributed, nonparametric were used. For the mortality outcome, Kaplan-Meier estimates were plotted for each independent (factor) variable, to describe the cumulative proportion of deaths in acute care and the median time to death for the study sample. The log rank statistic was used to identify statistically significant differences between the groups. Patients were censored if they did not die during the acute phase of hospital care.

Regression modeling was done to examine the independent contribution of neighborhood patient factors responsible for both outcomes.⁴² As the various definitions of “place” defining rurality and disadvantage were highly correlated, decisions to include any of these variables in the final multivariate models (for both outcomes) were made based on the statistical results from the goodness of fit in the model. The final models were built by entering the covariates one at a time to enable a step-by-step assessment of the goodness of fit of the model, the statistical significance of the covariate in the model, and the presence of correlating variables.

For the morbidity outcome, a negative binomial regression analysis was performed to predict the number of acute stay days based on the main explanatory factors with confounding factors. Variables were included into the models if they were deemed to be clinically important confounders, or if P values were statistically significant in the bivariate analysis at $P < .10$. Goodness of fit was assessed using the Pearson chi-squared goodness-of-fit and the likelihood ratio chi-squared statistic. The exponentiated values, $\exp(b_i)$, or risk ratios of the coefficient estimates are reported as the main effect estimates, risk ratios.

For mortality, variables identified as important from the Kaplan-Meier analyses were incorporated in a multilevel regression model. The individual trauma patient data were defined as Level 1, nested within the spatial units of analyses (Level 2), defined as SA4, or Statistical Local Areas 4.³⁸ Random effect terms were used to account for correlation of individuals nested within the same spatial group. This analysis did not show statistically significant, independent neighborhood effects on mortality.

As the precision of multilevel modeling is highly dependent on the number of outcomes and ecological units for analysis,⁴³ we subsequently performed Cox proportional hazards regression multivariate analyses. Contributing predictors to the model were determined by successive chi-square changes from previous steps between the -2 log-likelihood of the model, and the statistical significance (P value) being as $< .05$. The hazard ratios (HR), defined by the exponentiated values of the coefficient estimates $\exp(b_i)$ were produced for each covariate and interpreted as the predicted change in the hazard for a unit increase in the predictor. Results for all models are reported with their respective 95% confidence intervals.

SPSS statistical software (version 22.0, 2013, IBM Corp, Armonk, NY) was used for this analysis.

Results

A detailed description of the study sample is published elsewhere³⁶ and shown in the Appendix (Table S2, available online only). Briefly, 1,025 patients were available for analysis with a mean age of 45 years and 790 (77%) were male. A total of 67 people died in hospital, and the crude cumulative mortality rate for the study period was 6.1%. The median length of acute stay days was 8 (IQR 14). Table S3 (available online only) describes the bivariate associations of patient and injury factors in relation to the main area-level variables of interest. Most patients who resided in rural locations were injured in rural locations. Rurality overall was statistically significantly

associated with SED, ISS, NSW state of residence, first provider (regional), injury mechanism, GCS, polytrauma, external injuries, and head injuries. Rural residents were also significantly more likely to be discharged to a rehabilitation facility rather than home, compared to their urban counterparts. Lower IRSD was significantly associated with some, but not all factors also related to rurality, including remoteness of injury site and residence, NSW state of residence and GCS.

Inpatient Mortality

The bivariate associations of individual and area-level factors with crude hospital mortality are shown in Table 1. There is a significant and positive gradient of increasing hazard of death according to IRSD. Similar patterns were seen for age group. Inpatient deaths were also significantly associated with injury mechanisms other than transport causes, along with injuries to the head where patients were around 6 times more likely to die compared to those without head injuries. People with severe GCS and higher ISS were 9 and 7 times at higher risk of death, respectively, compared to those with mild to moderate GCS and lower ISS. There was an inverse association between mortality and injuries to the extremities, yet, because of the small number of deaths for this injury site, this estimation is relatively unstable. People living in regional areas were more than twice as likely to die in hospital compared to people in major cities with similar, significant trends apparent for those who were injured in regional or remote areas, and in NSW compared to QLD. There was no significant association between first provider of care and mortality.

Multivariate Analyses

Statistically significant covariates entered in the baseline model included patient age, injury severity and AIS head injury. Glasgow Coma Scores were significantly correlated with ISS. ($P < .001$). Because of the high probability that low GCS scores in the Registry reflected intubated patients and given that ISS is a stronger and more widely accepted predictor of mortality, the decision was made to retain ISS in the model. Other AIS regions that were statistically significant in the bivariate analysis were not examined because of extremely small cell counts ($N < 5$) in the “death” category.

The positive trend for IRSD and mortality remained but was not statistically significant. As remoteness of injury location was a better statistical fit compared to remoteness of residence, it was included in the final model (see Table 2). This showed that people who were injured in a relatively remote location were nearly twice

as likely to die (HR 1.75, 95% CI: 1.86-2.89) compared to those injured in major cities ($P = .028$). Other important covariates in the final model included increased age ($P = .003$), where for patients over 75 years, the hazard for death was 3.53 times higher compared to younger patients aged 16-44 years. For patients with ISS scores over 23 the hazard of dying was 5 times higher compared to those with less severe injuries ($P < .001$). Compared to people who had transport-related injuries, people with injuries that were self-inflicted, caused by assault or external legal interventions were nearly 3 times more likely to die. Patients sustaining head injuries were 2.53 times more likely to die compared to those without head injuries (HR 2.53, 95% CI: 2.78-10.02, $P = .028$).

The impact of remoteness was further explored by stratifying the data for level of injury severity (Table S4, available online only). For patients with relatively less severe injuries (ISS 13-23), age and remoteness of injury location retained statistical significance in the final model. Notably, head injuries ($P = .38$) and injury mechanism ($P = .14$) were not statistically significant factors associated with higher hazard of death. Increased age remained an important predictor ($P = .001$); however, people injured in a rural location were over 4 times (HR 4.20, 95% CI: 1.35-13.10) more likely to die in hospital independently of injury mechanism, injury type and age. The 95% confidence intervals are wider than in the nonstratified analysis, suggesting reduced precision of the effect estimates.

For patients with more severe injuries (ISS > 23), inpatient mortality was not predicted by older age ($P = .46$) or remoteness of injury site ($P = .20$). However, head injuries and injury mechanisms (those that were self-inflicted, caused by assault or external legal interventions) remained significant predictors, with similar patterns to that observed in the un-stratified analysis.

Acute Length of Stay Days (ALSD)

The ALSA analysis was conducted on all trauma patients who survived hospitalization to discharge. Bivariate analyses of median values for individual and area-level factors with ALSA are shown in Table 3. The median ALSA was higher by 3 days for older people (aged 65 years+) compared to those aged 16-44, and for people living in regional and remote areas, where the median ALSA was 12 days compared to 8 days for urban dwellers ($P < .001$). For those injured in NSW, the median ALSA was 3 days more than those injured in QLD ($P < .001$). Risk for longer ALSA was more than doubled for people with higher ISS compared to those with lower ISS ($P < .001$). Similar patterns were evident for patients with polytrauma. The median ALSA for those

Table 1 Bivariate Analysis: Association of Injury Patterns, Remoteness and Socioeconomic Factors With Inpatient Deaths^a

		Survivors N (%)	Deaths N (%)	Hazard Ratio	95% CI
Age group ^b	16-44	478 (94.5)	28 (5.5)	1.00	
	45-64	307 (94.8)	17 (5.2)	0.92	0.50-1.68
	65+	173 (88.7)	22 (11.3)	1.87	1.07-3.19*
Sex	Female	224 (95.7)	10 (4.3)	1.00	
	Male	734 (92.9)	56 (7.1)	1.70	0.86-3.32
Comorbidity ^{b, c} group	None	322 (93.1)	24 (6.9)	1.00	
	1 or more	636 (93.7)	43 (6.3)	0.86	0.52-1.43
Injury mechanism ^{d, e}	Transport	572 (95.8)	25 (4.2)	1.00	1.03-3.29*
	Falls	246 (92.1)	21 (7.9)	1.84	1.93-10.35***
	Other external cause	36 (83.7)	(16.3) ^b	4.46	1.52-6.31**
	Intentional/self harm/assault/ legal interventions	85 (88.5)	11 (11.5)	3.10	
ISS ^d	12-23	706 (98.1)	14 (1.9)	1.00	
	≥24***	252 (82.9)	52 (17.1)	7.22	3.99-13.08***
GCS ^d	Mild/mod	721 (97.4)	19 (2.6)	1.00	5.13-16.28***
	Severe	116 (74.4)	40 (25.6)	9.30	
Polytrauma					
AIS >2 in 2 or more AIS regions	No	665 (84.1)	42 (5.9)	1.00	0.60-1.65
	Yes	293 (92.1)	25 (7.9)	0.99	
AIS injury regions					
Abdomen ^c	No	804 (92.9)	61 (7.1)	1.00	0.29-1.10
	Yes	154 (96.2)	(3.8) ^b	0.48	
Chest	No	416 (92.7)	33 (7.3)	1.00	0.50-1.32
	Yes	542 (94.1)	34 (5.9)	0.81	
External	No	945 (93.5)	66 (6.5)	1.00	0.18-0.57
	Yes	13 (92.9)	(7.1) ^b	1.44	
Extremity ^d	No	708 (92.2)	60 (7.8)	1.00	0.09-0.52***
	Yes	250 (97.3)	(2.7) ^b	0.22	
Face	No	917 (93.5)	64 (6.5)	1.00	0.18-2.94
	Yes	41 (93.2)	(6.8) ^b	0.72	
Head ^d	No	638 (97.6)	16 (2.4)	1.00	2.94-9.01***
	Yes	320 (86.3)	51 (13.7)	5.17	
IRSD: socioeconomic disadvantage ^{b, d}	Q1 Least disadvantaged	238 (96.4)	(3.60) ^b	1.00	0.718-3.82
	Q2	234 (94.4)	14 (5.60)	1.65	1.02-5.01*
	Q3	226 (92.2)	19 (7.8)	2.27	0.97-4.73
	Q4 Most disadvantaged	223 (92.1)	19 (7.9)	2.14	
Remoteness of residence ^d	Major cities: GC	727 (94.9)	39 (5.1)	1.00	1.12-3.09**
	Regional/remote	199 (89.2)	24 (10.8)	1.86	
Remoteness of injury location ^d	Major cities: GC	663 (94.7)	37 (5.3)	1.00	
	Regional/remote	216 (88.2)	29 (11.8)	2.10	1.29-3.42**
State of injury ^d	QLD	701 (94.6)	40 (5.4)	1.00	
	NSW	212 (89.1)	26 (10.9)	1.82	1.11-2.98*
First provider	Tertiary Level 1 center	771 (93.3)	55 (6.7)	1.00	
	Regional/other	186 (94.4)	11 (5.6)	0.79	0.42-1.52

*** $P \leq .001$, ** $P \leq .01$, * $P \leq .05$.^aExcludes 1 patient who died after the acute phase of care.^bData not shown ($N < 10$) to preserve patient confidentiality.^cLog rank (Mantel-Cox) statistic < 0.10 , ≥ 0.05 .^dLog rank (Mantel-Cox) statistic < 0.05 .^eExcludes 10 cases of undetermined mechanism.

with 1 or more comorbidities was 9 days compared to 7 days for patients with no comorbidity ($P = .004$). Patients with injuries to the chest, abdomen, extremities, and head had a significantly higher median length of

acute stay days ($P < .001$). For those patients who were ultimately discharged to other facilities, the median ALSD was nearly 3 times that of patients who were discharged home ($P < .001$). Patients with a severe GCS had a

Table 2 Multivariate Analysis: Predictors of In-Hospital Deaths^a

Variables		HR	95% CI	P Value
Age group	16-44	1.00		
	45-64	1.19	0.61-2.06	.003
	65-74	1.06	0.43-2.62	
	75+	3.53	1.77-7.11	
Injury severity	Low	1.00		<.001
	High	5.27	2.78-10.02	
Head injury	No	1.00		.003
	Yes	2.53	1.38-4.62	
Injury mechanism	Transport	1.00		.001
	Falls	1.23	0.66-2.29	
	External—other causes intentional/ self harm/assault/legal interventions	2.72	1.48-5.03	
Remoteness of injury location	Major cities	1.00		.028
	Regional/remote	1.75	1.06-2.89	

^aExcludes 10 cases of undetermined mechanism and 1 death that did not occur during acute care phase.

median ALSD 3 times that of those with mild to moderate GCS scores. ($P < .001$).

Table 4 shows the results of multivariate analysis. Statistically significant covariates in the baseline confounder model included patient age, injury severity, head injuries, extremity injuries, and discharge disposition. Discharge disposition (to rehabilitation facility) was highly correlated with remoteness of residence and was removed from the final model. Here, all baseline covariates retained statistical significance in the model, apart from remoteness of residence (RR 1.11), yet the data trend toward increased risk (95% CI: 0.95-1.29). There was a notably sustained increased risk according to age, most pronounced in the second oldest age category where risk of median ALSD was 1.38 times higher than that compared to younger patients. For patients with ISS scores over 23, the risk of a higher median ALSD was 1.51 times that of patients with lower ISS ($P < .001$). The estimates of the other injury-related covariates were of a similar magnitude and all statistically significant ($P < .001$); the relative risk for extremity injuries was 1.81 and for head injuries 1.39.

As for the mortality outcome, remoteness was further explored by stratifying the data for level of injury severity (Table S5, available online only). For patients with relatively lower injury severity (ISS 13-23), the significant associations remained with apparent increases in the rate ratio for patients with extremity injuries and head injuries. Notably, the trend toward increased mean ALSD for patients living rurally became more pronounced (RR 1.16, 95% CI: 0.96-1.42), with a P value of .13. For patients with more severe injuries, the only factor significantly influencing extended mean ALSD was head injuries, where the effect estimate was nearly 3 times

higher than in the unstratified analysis (RR 3.33, 95% CI: 1.55-7.15).

Discussion

This study linked area-level dimensions of “place” to individual trauma patients to examine neighborhood contextual factors on hospital mortality length of stay in acute care. Socioeconomic disadvantage had little overall impact on the length of acute stay days, which appears to be predicted by increasing age, injury severity, and head and extremity injuries. While there are trends toward increased ALSD according to remoteness of residence, the results are not statistically significant. These findings are somewhat consistent with that reported in other studies. Australian studies of brain-injured patients³⁵ and a large cohort study of all NSW trauma patients have reported little differences in rural/urban variations in length of hospital stay.⁹ However, the length of *acute* stay days was not measured in these other studies and not all studies were of patients from Level 1 trauma centers.

Injuries to the head and extremities were also significantly associated with longer length of acute care stay, independently of other factors. The findings in relation to head injuries are not unexpected assuming that traumatic brain injury (TBI) is most likely involved. Evolving damage to the brain and secondary injuries are serious consequences of TBI, increasing the likelihood of inpatient death and prolonging acute hospital care. Injuries to the extremities involve the upper and lower limbs and the pelvis. If these injuries involved vascular trauma, limb loss, amputations, or polytrauma, then the risk of death would be higher and longer stays in acute care would be

Table 3 Bivariate Analysis: Association of Injury, Regional, and Socioeconomic Factors With Acute Length of Stay Days (ALSD) for Trauma Survivors^a

	Level of Variable (N)	Length of Acute Stay Median (IQR)	Test Statistic ^b	P
Age group	16-44 (506)	7.00 (4, 16)	10.17	.038
	45-64 (324)	9.00 (4, 19.75)		
	65-74 (102)	10.00 (5, 22)		
	75+ (93)	10.00 (5, 18)		
Sex	Male (790)	8.00 (4, 18)	89,132 ^b	.353
	Female (235)	9.00 (4, 18)		
Comorbidity group	0 (346)	7.00 (4, 15.25)	104,425	.004
	≥ 1 (679)	9.00 (4, 18)		
IRSD socioeconomic disadvantage (IRSD) N (%)	1. Most disadvantaged (243)	9.00 (5, 19)	7.44	.115
	2. (245)	9.00 (4, 17)		
	3. (248)	8.00 (4, 17)		
	4. Least disadvantaged. (247)	9.00 (4, 23)		
Remoteness of residence	Major cities (766)	8.00 (4, 16)	70249.00 ^b	< .001
	Regional/remote (224)	12 (.25, 22.75)		
Remoteness of injury location	Major cities (700)	8.00 (4, 17)	79282.5 ^b	.064
	Regional/remote (246)	9.00 (4.75, 20.25)		
State of injury	State of tertiary trauma care (741)	8.00 (4, 17)	74499.00 ^b	< .001
	Adjoining state (239)	11.00 (6, 20)		
Injury mechanism ^c	Transport (572)	9.00 (4, 20)	5.22	.16
	Falls (246)	9.00 (5, 18)		
	Other external cause (131)	7.00 (4, 12)		
	Intentional, self-harm/legal intervention (85)	6.00 (4, 15)		
ISS	12-23 (720)	7.00 (4, 13)	72,303 ^b	< .001
	≥ 24 (305)	15.00 (6.5, 30)		
GCS	Mild-moderate (721)	8.00 (4, 16.5)	21963.5 ^b	< .001
	Severe (116)	25.00 (11.30)		
	Missing (121)	6.00 (3.12)		
Polytrauma	No (804)	7.00 (4, 13)	60,413	< .001
AIS > 2 in 2 or more AIS regions	Yes (154)	15 (7, 30)		
AIS injury regions	No (804)	8 (4, 17)	50,744 ^b	< .001
	Yes (154)	11 (6, 23.5)		
Abdomen	No (416)	10.0 (5, 19)	4,864 ^b	.196
	Yes (542)	8 (4, 19)		
External	No (945)	13.4 (4, 19)	17,540	.47
	Yes (13)	6.0 (4, 10)		
Extremity	No (708)	7.0 (4, 15)	83,487	< .001
	Yes (250)	16 (8, 30)		
Face	No (917)	9.0 (4, 19)	6.0 (3, 25)	
	Yes (41)	6.0 (3, 25)		
Head	No (638)	8.0 (4, 15)	11.0 (5, 27)	
	Yes (320)	11.0 (5, 27)		
First provider	GCUH (827)	8.00 (4, 18)	75,438 ^b	.106
	Regional/other hospital (197)	9.00 (5, 18)		
Discharge disposition	Home (698)	7.00 (4-12)	18273.5	< .001
	Rehabilitation (141)	26.00 (14.5-30)		

Statistical significance is $P < 0.05$.^aExcludes in-hospital deaths.^bTest statistic is Mann-Whitney U test. All other statistical tests are Kruskal-Wallis tests.^cExcludes 10 cases of undetermined mechanism.

Table 4 Predictors of Length of Acute Stay Days for Severe Trauma Survivors

Variables		RR	95% CI	P Value
Age group	16-44	1.00		
	45-64	1.28	1.10-1.49	<.001
	65-74	1.38	1.10-1.73	
	75+	1.35	1.07-1.71	
AIS extremity injury	No	1.00		
	Yes	1.81	1.55-2.14	<.001
AIS head injury	No	1.00		
	Yes	1.39	1.19-1.62	<.001
Injury severity	Low	1.00		
	High	1.51	1.29-1.76	<.001
Remoteness of residence	Major cities	1.00		
	Regional/remote	1.11	0.95-1.29	.21

expected. However, musculoskeletal injuries to the extremities, in general, are costly and typically associated with ongoing pain, disability, and poor function.⁶ Evaluation of acute care management on rehabilitation outcomes could help to justify the expense associated with longer stays in acute care for extremity injuries.

Significantly longer lengths of stay in acute care could be largely explained by relatively limited access to rehabilitation services in rural areas. Rehabilitation facilities are relatively scarcer in rural areas compared to major cities, and more difficult to access. Rehabilitation attendance, whether it is received as an inpatient at the trauma hospital or in a facility external to the trauma hospital, should not influence the ALSD outcome of this analysis unless there are “access related” factors preventing appropriate transferral of patients from acute care to rehabilitation. We were not able to analyze differences in acute length of stay according to inpatient rehabilitation offered by the trauma center or rehabilitation offered elsewhere. However, in our cohort, discharge to a rehabilitation facility (compared to home) was statistically significantly associated with rurality of residence (Table S3, available online only). As for most other community health services in Australia, there is probably spatial variation in the location and type of rehabilitation services.²²

As rural patients in this study mostly lived and were injured in NSW, cross-border factors could additionally explain these results. In Australia, state and territory governments manage public hospitals. Longer stays in tertiary trauma care facilities could be the result of delays in repatriation to NSW, either in the form of cross-border hospital transfers or discharges home.

If so, these findings have implications for inter-state health service planning, evaluation of outcomes, and allocation of public resources. Inappropriate use of acute

beds is reported to be greater than 20% across many settings,⁴⁴ and prolonged duration in hospital can adversely affect inpatient morbidity and mortality.⁴⁵ Compared to other health services, trauma care is extremely resource-intensive and incurs significant direct and indirect health care costs.⁴⁶ Higher costs are reportedly associated with rural and remote road trauma,⁴⁷ and extended durations of stay increase these costs.

Many patient-related factors influence early deaths from acute trauma, potentially overriding the impact of contextual factors. Our results that showed no statistical association between SED and hospital mortality are consistent with at least one other study,⁴⁸ yet the trend toward increased SED and risk of death remained. SED and rurality are closely correlated in our study sample and our step-wise model building approach enabled a fine-grained examination of each, with risk of early trauma death.

Unsurprisingly, higher ISS scores independently predicted higher risk for morbidity and mortality outcomes. The ISS, while the most commonly used prognostic factor for hospital-based trauma mortality,⁴⁹ has known limitations^{50,51} and the extent to which it is a proxy measure for other significant prognostic factors related to “place” is unknown. In this study, the ISS was significantly worse for rural areas, but not for disadvantaged areas. ISS is assigned after the acute injury event, often after patient discharge. It may not adequately capture other elements of trauma severity associated with rural injuries and rural injury mechanisms that predispose people to early death.

The significant association found between rural place of injury and mortality in the present study is not consistent with other Australian work showing that, for patients who survived to receive definitive trauma care, risk of in-hospital death did not vary by remoteness, after accounting for time factors and other covariates.^{29,52,53} In our stratified ISS analysis, excess risk for mortality was apparent for patients with comparatively *less* severe injuries. This association has been reported elsewhere³³ and could be explained by the nature of the rural or remote area where the injury occurred. For example, the management of traumatic injuries in rural areas probably involves unmeasured variations in factors such as the time to discovery and rescue, the nature of emergency on-site care, coordination of retrieval and transferrals, availability of specialists, and triage practices at regional hospitals.^{30,54} For patients whose injuries are deemed less severe, care protocols may not be as explicitly or consistently applied. This is further complicated by the cross-border context of the catchment area in our study, where 2 states independently manage retrieval services.

Our results suggest that rural patients who survive to definitive trauma care are quite different from their surviving urban counterparts. Of interest, then, is whether these differences systematically predispose rural patients to greater risk of death. People with injuries involving more serious mechanisms (self-inflicted or the result of assault or a legal intervention) were at higher risk of dying compared to other injury mechanisms, and stratified analysis showed that this applied to the more severely injured patients. These injuries are regarded as significantly serious, most likely consisting of mechanisms involving machinery, fire, electrocution, and firearms. While these injuries are more common in rural areas,^{31,34,55} we did not find a significant association with rurality for this patient subgroup. It is possible that we lacked sufficient study power, or that another unmeasured aspect of “place” not captured by our remoteness variable confers additional risk.

Increased age was an independent predictor of both outcomes and this has been reported elsewhere.⁵⁶ Excess mortality risk was more confined to the very elderly patients, aged over 75 years. This pattern supports the findings of a systematic review of predictors of geriatric trauma mortality,⁵⁷ suggesting that different prognostic factors other than established ones are important in terms of outcomes for this age group.

Limitations

There are limitations to this study that should be considered when interpreting the results. We were not able to account for some trauma-induced physiological factors predictive of death, or in-hospital complications, which are associated with adverse outcomes.^{58,59} This is worthy of consideration if these prognostic factors vary systematically according to neighborhood disadvantage or remoteness.

Furthermore, while a measure of physical distance from the injury site to definitive care would have enriched this analysis, it does not account for mode of transport. Australian data show that severely injured patients in rural areas are more likely to be flown to the hospital providing definitive care compared to their urban counterparts.³¹ Similarly, we could not account for the time of arrival to definitive care, which is confounded by mode of transport.

The nature of coexisting conditions could further inform interpretation of the results; however, the number of comorbidities was not significantly associated with either outcome in this analysis. As trauma care evaluation is increasingly focused on community outcomes, our study would have benefited from analysis of longer-term, out-of-hospital outcomes; however, in the

absence of data linkage systems, this analysis was not possible.

Because of small sample sizes, we were unable to study people living in remote or very remote areas. For this reason, we cannot rule out that type 2 errors exist with the reported data. And finally, we could not include deaths occurring prior to arrival at a hospital. This is of concern if the early deaths vary systematically according to rurality and disadvantage. However, if there is a positive association between these factors and the deaths not included in our sample, then our findings likely underestimate the true associations.

Implications

The social and structural components of neighborhoods can shape peoples' lives and influence opportunities for health gain. However, the ways in which aspects of “place” affect prognosis after trauma are not well understood. It is possible that existing geographic measures of distance to services and the SED may not adequately capture the social, environmental and cultural complexity that varies among communities and induces higher individual trauma risk, injury severity and worse injury mechanisms.

Deciphering the unique qualities of rural life that predispose people to behavioral risk and trauma adversity might therefore be the next step in socioecological trauma research. Some pose the view that aspects of rural life pose unique and subtle risks that are not directly related to SED or remoteness, but to social norms influencing health risk and health-seeking behaviors, occupational risk associated with rural industries, and environmental hazards.^{37,54} For example, the effects of climate change are experienced more profoundly in rural areas with weak infrastructure⁶⁰ and may adversely affect mental health^{61,62} and subsequent, intentional injury patterns in rural areas.

Social capital is an area worthy of further empirical study and could potentially contribute to the evidence base of socioecological factors and trauma outcomes.⁶³ Social capital defines an individual's ability to access social infrastructure, which is characterized by trust, shared norms and reciprocity, thereby enabling people to access much-needed resources.⁶⁴ Social capital is mostly defined as a community-level resource and can influence a community's economic prosperity⁶⁵ and resilience.⁶⁶ Research has found that people living in communities with strong social capital experience better health.⁶⁷ However, Australian data suggest there are rural and urban disparities in social capital, adversely influencing physical health in rural areas.⁶⁸ Ongoing efforts to unravel these phenomena and develop linkages to individual trauma data,

as has been done here, can hopefully yield more conclusive information.

Conclusion

This study hypothesized that socioecological explanatory factors of neighborhoods could predict early, adverse trauma outcomes. Social economic and geographical factors related to place of residence and place of injury are associated with certain patterns of injury and adverse inpatient outcomes following traumatic injury. Factors specific to rural culture and life could also be important. Identifying these factors early, in the acute phase of trauma care, could be important for reducing the risk of lengthy acute hospital stay, mortality and ongoing morbidity.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.