Association between socioeconomic and geographical factors in severely injured trauma patients using trauma registry data.

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Introduction

The development of modern trauma care and the establishment of coordinated trauma systems has led to improvements in major injury outcomes, worldwide. (Celso et al., 2006) Despite these gains, traumatic physical injuries in Australia remain a major cause of death and disability and represent one of the five disease groups causing the most burden of ill health in society. (AIHW(b), 2016)

Inequalities exist in trauma populations where, in Australia, there is an over-representation of people from socioeconomically disadvantaged backgrounds. Low

levels of income, education, blue collar work and unemployment are strong indicators of an individual disadvantage and associated with increased injury mortality, (Ali et al., 2013, Chen et al., 2010, Cubbin et al., 2000b) however these indicators appear to have varying impacts on injury patterns. American data show that being unemployed is independently related to increased risk of death from suicide, where race and ethnicity, income or education is not. Being in a blue-collar occupation is a significant risk factor for non-fatal injury and injury severity, over and above factors such as educational attainment or income. (Cubbin et al., 2000b)

Disadvantage is also associated with higher rates of risky behaviours, speeding, and alcohol and drug intake. (Kweon and Kockelman, 2003) Greater levels of comorbidity are reportedly associated with disadvantage (Ali et al., 2013, Brattström et al., 2015), as is severity of the crash (Hasselberg et al., 2005) the degree of injury severity (Ali et al., 2013, Hasselberg et al., 2005) and the crash mechanism, where traffic related accidents prevail over others. (Pointer, 2015) As such this information is collected by Trauma Registries to monitor trauma care, assist with injury prevention and control and identify areas for clinical and epidemiological research.

However, an individual's SES is influenced by a myriad of social and environmental factors, all interacting with their individual level factors to shape behaviours. (Duncan et al., 1996, Marmot, 2005, Richard et al., 2011, Richard et al., 1996) These social determinants of health have been described by Marmot and are fundamentally important to the theory and practice of public health, (Marmot, 1999, Marmot, 2005, Richard et al., 2011, Richard et al., 1996) recognising that an individual's social and physical environment provides opportunities or the capacity for positively influencing health behaviours. At the centre of this framework are the individual, their personal and biological characteristics, behaviours, attitudes and preferences. The social context includes individuals or groups who have close relationships with the individual, such as family, friends, peers, schools, sporting, religious or community groups, health service personnel or work colleagues. The physical environment defines the natural environment and places where people live and work and include roads, transport, parks, and housing, community or health facilities. Access to services is an important part of this layer. Finally, policies from any level of Government are important in terms

of creating environmental change and providing work force and urban planning, funding and taxes.

From the injury perspective, these linkages between an individual and their community are key to addressing disparities in injury risk and outcomes. The neighbourhood factors important to injury but not routinely collected by Trauma Registries include its material wealth, which influences the quality of housing and the built environment. (Cubbin and Smith, 2002) Family and social networks, occupational exposures, and availability of services or resources that provide education or promote safety are also important. (Cubbin et al., 2000a, Cubbin and Smith, 2002) Neighbourhood factors have been shown to be more powerful predictors of injury mortality and morbidity beyond individual factors. (Cubbin et al., 2000a) Notably, many of these factors are strongly linked to various dimensions of 'place' representing a plausible link with studies of injury causes, given that injury has 'external (or environmental) causes' entwined in its definition.

Rurality, or remoteness of residence is a contextual factor strongly associated with the socioeconomic dimensions of 'place' but is not included in traditional measures of SES. Compared to urban dwellers, rural residents have relatively poorer access to health services, higher levels of risk behaviours including occupational and physical risk, and higher rates of disease and injury. (Phillips, 2009) Patterns of injury are different for rural residents compared to urban residents. Compared to urban dwellers, rural residents are more likely to be involved in serious incidents involving firearms, farming, mining, natural environmental factors and road injuries and are at least twice as likely to be admitted to hospital for injury compared to urban residents (Mitchell and Chong, 2010). Rates of traffic related injuries are more common in rural areas, compared to urban areas. (Dinh et al., 2013, Kristiansen et al., 2013)

Measures of residential rurality or remoteness from services have not been routinely factored into studies of social and economic variations in injury patterns. This is surprising, given that the time taken to receive definitive care following severe trauma is a critical factor influencing survival. People who are injured in rural and rural areas pose specific challenges in this respect, yet the location of injury does not always reflect

the location of where the person lives. This distinction has also not been adequately addressed in studies of SES or remoteness, in the injury context.

Because of the strong relationship between injury and disadvantage, many studies adjust for social disadvantage in analyses, however there is little understanding of how SES might operate as a primary explanatory factor for injury. Increasingly, people are now surviving serious injury and are discharged home to their communities. Therefore, understanding the nature of disadvantage from the communities that people come from, and return to, could ultimately assist in understanding patterns of primary risk, and the appropriate types of rehabilitation programs for injury survivors.

The existing evidence base of the role of socio-ecological factors on health is vast, (Stewart et al., 2004, Sun and Stewart, 2007, Sun and Stewart, 2008) yet is littered with subjective assessments from individuals and prone to information biases. There is a comparative lack of objective, empirical evidence as to whether, or which factors are effective in changing health behaviours or outcomes in injured patients. (Glanz et al., 2008)

The aim of this study was to report the association between objective neighbourhood measures of socioeconomic disadvantage and geographical remoteness with patterns of injury, for severely injured trauma patients admitted to a Level 1 Tertiary Trauma Centre between 2014 and 2017.

Methods

Study setting

The study population was severely injured patients admitted to a Level 1 Tertiary referral centre in Queensland (Qld). This hospital provides care for severely injured patients across two State borders, including the wider population injured in the designated catchment area of the region (68%) where the Trauma Centre is located, and patients injured in mostly regional areas of northern New South Wales (NSW). The remainder come largely from inner regional areas of the catchment area in both States, dominated by patients referred from hospitals in northern NSW (71%).

(Gardiner et al., 2018) Both States have advanced trauma services, with well-developed rural and regional referral networks.

Study design and data sources

The study design is a retrospective analysis of adult injury cases hospitalised for >24 hours, in a Level 1 Trauma Centre in Australia, where the date of injury occurred any time after January 01 2014 to December 31, 2017. Eligible patients were aged over 18 years, admitted to the hospital for severe (ISS > 12) traumatic physical injury resulting from external causes.

Patient data were sourced from the Hospital's Trauma Registry which represents all patients presenting to hospital satisfying the standard criteria for a major trauma event, defined by the injury mechanism, the pattern of injury and various clinical features. The Registry focuses on collecting information that enables analysis of the quality of patient care, improvements in patient care, and reduction in mortality and morbidity from traumatic injury. The Trauma Registry has well-defined data integrity processes that ensure data reliability and validity. (Gardiner et al., 2018)

Area level variables

Information about the patients' residential address at the time of injury obtained from the 2011 Census of Population and Housing was used to generate area-level measures described below.

Socioeconomic status

Many individual characteristics associated with disadvantage and trauma outcomes, such as gender, injury severity, comorbidity, substance abuse, and occupation. Trauma Registry staff typically collect this information for the purposes of injury surveillance and control. However, information on SES contextual factors is not routinely collected. Linkage of Census Tract data to Trauma Registries can enable the study of the multi-dimensional construct of socioeconomic disadvantage at the 'neighbourhood' level. In Australia, socio-demographic information is summarised into an Index or Relative Social Disadvantage (IRSD) (Australian Bureau of, 2011, Australian Bureau of, 2012) as shown in Table 1. The IRSD is often analysed as an area-level explanatory factor or exposure for individual level outcomes and has explained health differentials and influenced health policies (Glover et al., 2004) This index summarises 17 different pieces of information about the economic and social conditions of people and households in an area, such as low income, low education, high unemployment and unskilled occupations. A low score indicates relatively greater rates of disadvantage in that area compared to other areas, and is characterised by many low-income families, people with little training and working in unskilled occupations A high score indicates a relative lack of disadvantage according to these characteristics.

Table 1: Properties of the IRSD index

Variable	Description
Annual household income	Less than $20,799
Employment	% Families with children under 15 years of age who live with jobless parents
	% Employed people classified as 'labourers'
	% people in the labour workforce unemployed
	% Employed people classed as machinery operators or drivers
	% People classified as Low Skill Community and Personal Service workers
Internet connection	% Occupied private dwellings with no internet connection
Education	% people aged 15 years or over whose highest level of education is Year 11 or lower
	% people aged 15 years and over who have no educational attainment
Household factors	% Occupied private dwellings paying rent less than $166/week.
	% Occupied private dwellings with no car
	% Occupied private dwellings requiring one or more extra bedrooms
Family structure	% one-parent families with dependent offspring
	% People aged 15 or over who are separated or divorced
	% People who do not speak English very well.
Health	% people aged <70 who have a longer-term health condition or disability and need assistance

Source: Socio-Economic Indexes for Areas (SEIFA) 2011. Canberra. ABS Catalogue no. 2033.0.55.001.

Geographical remoteness

Geographic remoteness is a measure of the physical distance of a location from the nearest urban centre, which serves as a proxy measure of the level of access to goods and services. For this analysis, the enhanced Accessibility/Remoteness Index of Australia classification (ARIA$^+$) was used to describe areas in terms of relative remoteness. (Australian Bureau of Statistics. Analytical Services, 2011) These scores are used by many Government organisations in Australia, including the Australian Bureau of Statistics to publish statistics that are comparable and spatially integrated. The ARIA scores are categorised into five classes of remoteness: 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. The hospital catchment area for this study sample lies mostly in Categories 1 and 2, hence there are small numbers of cases in categories 3,4 and 5 (N=26), these were combined within category 2. For this

analysis, two remoteness variables were developed and assigned to each patient describing their area of residence, and where the injury was sustained.

Individual patient factors

Data from the Trauma Registry considered to be important covariates for the study's hypothesis were analysed. Age and sex are risk factors for injury, as is injury severity. Injuries were classified according to the Abbreviated Injury Scale (AIS) (Gennarelli and Wodzin, 2008) that codes injuries according to their anatomic location (head or neck, face, chest, abdominal or pelvic contents, extremities or pelvic girdle and external) and assigns a severity score from 1-6, based on the probability of death or disability. Injuries >2 are classified as 'severe'.

For this analysis, injury severity was examined using the Injury Severity Score (ISS), an ordinal scale ranging from 1 to 75, reflecting the sum of the highest AIS scores for the three most severely injured body regions. While ISS was the primary measure for this analysis, the New Injury Severity Score (NISS) was also assessed. This is the sum of the squares of the three highest Abbreviated Injury Scale scores for each patient, regardless of body region. Both have similar predictive capacity for mortality, however some studies suggest that the NISS is thought to be a better measure of severity for blunt trauma patients, (Tohira et al., 2012) which constitute most (95%) of injury cases in Australia.

The mechanism of injury, injury location and the number of comorbidities were also included in the analysis. Details of the first hospital provider after the injury were also incorporated into the analysis, as some patients were initially treated at another hospital before being transferred to definitive care.

Statistical analysis

The patients were categorized by their IRSD score into four groups (quartiles of relative socioeconomic disadvantage) such that each quartile contained about 25% of the total patient population Exploratory analysis firstly determined the patients' age, sex, and injury characteristics and area-level socio-demographic (IRSD) and geographical variables. Categorical variables were summarised using counts and percentages; continuous variables were described according to means and standard deviations (SD). For the bivariate analyses, independent t-tests were used where the variables were

normally distributed. Chi-square (X^2) statistics were used to compare categorical variables. Where the variables were not normally distributed, non-parametric methods were used (Kruskall Wallis H Test, Mann Whitney U Test) and median values reported.

Binary logistic regression was performed to determine the relative odds (adjusted for age and sex) of sustaining injury based on remoteness of residence, injury, referring hospital and State of injury, where, for each factor, IRSD was the main explanatory variable. Similarly, multiple regression was performed to evaluate the relationship between IRSD and the following dependent variables: the number of comorbidities and ISS, NISS. For each analysis, IRSD was forced into the model to help determine the relationship between IRSD, remoteness and patient and injury factors.

SPSS statistical software (IBM Corp. Released 2013. IBM SPSS Statistics for Macintosh, Version 22.0. Armonk, NY: IBM Corp) was used for this analysis. The study received full Ethics approval from the GCH Human Research Ethics Committee, the GCUH Trauma Registry, Griffith University, and approval under the Public Health Act, from the Queensland Government.

Results

Socio-demographic and injury data

A total of 1025 patients were identified from the hospital's Trauma Registry data base for the four-year period 2014 to 2017. Of these 790 (77%) were male and 235 (23%) were female. The median ISS was 17 (IQR 14-26), with 30% of patients in the high ISS category. The median NISS was 24 (IQR 17-34), with 30% of patients in the high ISS category Compared to those living in 'Major Cities', 22% of patients lived in areas defined as 'regional' or 'remote' and 24% sustained their injuries in these locations (Figure 1). There were 34% of patients with no comorbidities, where 28% had more than two co-morbidities. The median number of comorbidities was 1 (IQR=0-3).

In relation to people sustaining severe injuries (AIS >2), 16% of these were abdominal injuries, 1%, external injuries, 25%, injuries to the extremities, 56%, injuries to the chest and 36% sustained severe head injuries. Of those sustaining abdominal injuries (N=371), 43% were severe (AIS>2), for external injuries (N=863), 2% were severe, for extremity injuries (N=629), 41% of injuries were severe, for face injuries (N=229), 19%

were severe, for chest injuries (N=709), 81% were severe, and for head injuries (N=536), 69% were severe.

Figure 1. Residential Origin of the study sample (location by central point of the Postal Code – one point may indicate many patients)

Table 2: Socio-demographic and injury data according to sex

		Male (n=790)	Female (N=235)
Age Mean (SD)		49.6 (21.41)	44.4 (18.7)
Year of admission	2014: 214 2015: 256 2016: 293 2017: 294	168 (21.3) 194 (24.2) 230 (29.1) 230 (29.1)	46 (19) 62 (26.4) 63 (26.8) 64 (27.2)
Remoteness of residence category*	Major Cities (766) Regional/Remote (224)	590 (76.7) 179 (23.3)	176 (79.6) 45 (20.4)
State of Injury**	A (NSW) (239) B (QLD) (741)	186 (24.8) 565 (75.2)	53 (23.1) 176 (76.9)
Relative Socioeconomic Disadvantage	Q1. Most disadvantaged (243) Q2. (245) Q3. (248) Q4. Least disadvantaged (247)	193 (25.4) 192(25.3) 188 (24.7) 187 (24.6)	50 (20.6) 53 (21.6) 60 (24.2) 60 (24.3)
Severity- Injury Site (AIS>2)			
Abdominal injuries N, (%)	Nil Minor-Moderate Severe	509 (64.4) 160 (20.3) 121 (15.3)	145 (61.7) 51 (21.7) 39 (16.6)
External injuries N, (%)	Nil Minor-Moderate Severe	124 (15.6) 654 (82.8) 12 (1.5)	38 (16.2) 195 (83) 2 (0.9)
Extremity injuries N, (%)	Nil Minor-Moderate Severe	315 (79.5) 277 (35.1) 198 (25.1)	81 (34.5) 95 (40.4) 59 (25.2)
Face injuries N, (%)	Nil Minor-Moderate Severe	612 (77.5) 142 (18) 44 (4.3)	184 (78.3) 43 (18.3) 8 (3.4)
Head Injuries N, (%)	Nil Minor-Moderate Severe	378 (47.8) 132 (16.7) 280 (35.4)	111 (47.2) 33 (14.0) 91 (38.7)
Chest injuries N, (%)	Nil Minor-Moderate Severe	246 (31.1) 102 (12.9) 442 (55.9)	70 (29.8) 32 (13.6) 133 (56.6)
ISS Median (IQR)		17 (14-26)	18 (14-26)
NISS Median (IQR)		24 (17-34)	22 (17-33)
Number comorbidities	0 1 >=2	272 (34.4) 164 (20.8) 354 (77.0)	74 (31.5) 55 (23.4) 106 (45.1)

***Missing data =42 (patients' residences not listed in Australia), ** Missing data=45 ,**

Bivariate association of IRSD with patterns of severe injury for hospitalised patients

Table 3 shows the association of key injury and geographic variables, with relative socioeconomic disadvantage (IRSD). A total of 983 cases were available for analysis, and additional data were missing for remoteness of residence (0.5%), remoteness of injury location (8%), and State of Injury (4%).

There were no statistically significant differences between IRSD category and age group, year of admission and sex. Similarly, quartiles of IRSD did not significantly vary according to both measures of injury severity, however a positive trend for injury severity and disadvantage is apparent. There is also an apparent trend in injury mechanism where injuries that are not transport related, or caused by falls are twice as likely to occur for people in the most disadvantaged group compared to those in the least disadvantaged group.

Of those who lived in regional or remote areas, 33% were in the 'most disadvantaged' category compared to 9% in the 'least disadvantaged category'. For those people living in major cities the difference is 21% and 29% respectively ($p<0.001$). Similar patterns were evident for the geographical location of the injury ($p<0.001$), and for State of Injury ($p<0.001$).

There were more comorbidities in people in the 'most disadvantaged' category (Median=2, IQR 0-3)) compared to those in other groups with median values of 1 ($p=0.01$).

There is a significant association trending towards increased disadvantage according to those patients whose first provider was a hospital other than the main Trauma Centre. For those whose first point of treatment was at a regional hospital (N=197), 27% were in the most disadvantaged category compared to 15% in the least disadvantaged category ($p=0.003$). This was related to the State of injury, where, of the 239 cases that were injured across the border from the Trauma Centre, (NSW) 133 cases (56%) were managed at one or more referring hospitals prior to arrival at the tertiary trauma

centre. This contrasts to those who were injured in Qld where most of the 740 patients (91.4%) were directly managed at the tertiary trauma centre in Qld ($p<0.001$).

Table 3: Association of relative socioeconomic disadvantage with injury patterns

		Quartiles of socioeconomic disadvantage					
Variables		**IRSD 1 Most disadvantaged N (%)**	**IRSD 2 N (%)**	**IRSD 3 N (%)**	**IRSD 4 Least disadvantaged N (%)**	**χ^2**	**P**
Age Group	16-44 (480) 45-64 (311) 65-74 (100) 75+ (92)	119 (49.0) 78 (32.1) 26 (10.7) 20 (8.2)	128 (52.2) 74 (30.2) 23 (9.4) 20 (8.2)	131 (52.8) 73 (29.4) 19 (7.7) 25 (10.1)	102 (41.3) 86 (34.8) 32 (13.00) 27 (10.9)	10.74	0.29
Sex N (%)	Male (760) Female (223)	193 (79.4) 50 (20.6)	192 (78.4) 53 (21.6)	188 (75.8) 60 (24.2)	187 (75.7) 60 (24.3)	1.46	0.692
Year of admission	2014 (208) 2015 (243) 2016 (283) 2017 (249)	52 (21.4) 61 (25.1) 69 (28.4) 69 (25.1)	48 (19.6) 65 (26.5) 62 (25.3) 70 (28.6)	58 (23.4) 61 (24.6) 74 (29.8) 55 (22.2)	50 (20.2) 56 (22.7) 78 (31.6) 63 (25.5)	5.54	0.78
Remoteness (residence)	Major Cities (763) Regional/Remote (216)	162 (66.9) 80 (33.1)	184 (75.1) 61 (24.9)	193 (78.8) 52 (21.2)	224 (90.7) 29.4 (9.3)	41.61	<0.001
State of injury event	Tertiary Trauma Care (720) Northern NSW (220)	157 (62.6) 88 (37.4)	170 (73.0) 63 (27.0)	201 (85.5) 34 (14.5)	202 (85.2) 35 (14.8)	47.89	<0.001
Remoteness (Injury location)	Major Cities (675) Regional/Remote (232)	148 (64.3) 82 (35.7)	167 (74.2) 58 (25.8)	177 (77.6) 51 (22.4)	183 (81.7) 41 (18.3)	19.73	<0.001
ISS (Median, IQR) N=983		25.00 (17, 41.2)	22 (17,29)	22 (17, 34)	22 (17,29)	3.096*	0.38

NISS (Median, IQR) N=983		27 (17,41.5)	22 (17,29)	22 (17, 34)	22 (17,29)	5.02*	0.17
Injury Region							
Head	Yes No	120 (49) 123 (50.6)	141 (57.6) 104 (42.4)	122 (49.2) 126 (50.8)	123 (49.8) 124 (50.2)	4.84	0.18
Face	Yes No	60 (24.7) 183 (75.3)	52 (21.2) 193 (78.8)	48 (19.4) 200 (80.6)	53 (21.5) 194 (78.5)	2.13	0.55
Chest	Yes No	167 (68.7) 76 (31.3)	171 (69.8) 74 (30.2)	172 (69.4) 76 (30.6)	175 (70.9) 72 (29.1)	0.279	0.97
Abdomen	Yes No	78 (32.1) 165 (67.9)	85 (34.7) 160 (65.3)	89 (35.9) 159 (64.1)	103 (41.7) 144 (58.3)	5.26	0.15
External	Yes No	213 (87.7) 30 (12.3)	203 (82.9) 42 (17.1)	208 (83.9) 40 (16.1)	200 (81.0) 47 (19.0)	4.28	0.23
Extremity	Yes No	151 (62.1) 92 (37.9)	141 (57.6) 104 (42.4)	151 (60.9) 97 (39.1)	160 (64.8) 87 (35.2)	2.80	0.42
Injury mechanism	Transport-Pedestrian (46) Transport-Cyclist (77) Transport-Motorbike (198) Transport-Vehicle occupant (255) Falls (260) Other# (139)	13 (5.4) 17 (7.0) 43 (17.9) 59 (24.4) 58 (24.0) 52 (21.5)	12 (5.0) 20 (8.3) 49 (20.2) 61 (25.2) 70 (28.9) 30 (12.4)	13 (5.3) 17 (6.9) 53 (21.6) 64 (26.1) 68 (27.8) 30 (12.2)	8 (3.3) 23 (9.4) 51 (20.9) 71 (29.1) 64 (26.2) 27 (11.1)	18.10	0.26
Injury location##	Residence (224) Street/Highway (460) Commercial (58) Other/Unspecified (167)	63 (27.6) 115 (50.4) 13 (5.7) 37 (16.2)	51 (22.1) 117 (50.9) 17 (7.4) 48 (19.9)	48 (21.9) 113 (51.6) 14 (6.4) 44 (20.1)	62 (26.8) 115 (49.8) 14 (6.1) 40 (17.3)	4.54	0.872
Number of Comorbidities (Median, IQR)		2 (0-3) 243	1 (0-3) 245	1 (0-3) 248	1 (0-2) 247	11.26*	0.01
First Provider	GCUH (795) Regional /Other hospital (187)	178 (73.3) 65 (26.7)	198 (80.8) 47 (19.2)	210 (84.7) 38 (15.3)	209 (85.0) 37 (15.0)	14.14	0.003

* Kruskall Wallis H Test Statistic
# Includes self-harm, assault, legal intervention, undetermined mechanism
Excludes school/sports injuries (due to small numbers in cells)

Multivariate association of IRSD with key explanatory injury for hospitalised patients

Table 4 shows the association of IRSD with key geographical parameters, after adjusting for age and sex. The 'least disadvantaged' category is the reference category. For each geographical characteristic, there is a statistically significant and positive trend towards increasing disadvantage according to remoteness of residence ($p<0.001$). People living in regional and remote areas were nearly five times more likely to be in the 'most disadvantaged' category compared to those in the 'least disadvantaged' category. Similarly, the odds of being injured in a regional and remote area were nearly threefold higher in the 'most disadvantaged' category compared to those in the 'least disadvantaged' category. Positive, increasing gradients of disadvantage were also evident for injuries occurring in NSW compared to QLD, and where the first provider was a hospital other than the GCUH Trauma Service.

Table 4: Association of relative socioeconomic disadvantage with geographic parameters #

		Quartiles of socioeconomic disadvantage OR (95% CI)			
Variables		**IRSD 1 Most disadvantaged**	**IRSD 2**	**IRSD 3**	**IRSD 4 Least disadvantaged**
Area of residence	Major cities Regional/Remote	4.90 (2.95 -8.15)***	3.32 (1.97-5.85)***	2.72 (1.60-4.62)***	1.00
Area of injury incident	Major cities Regional/Remote	2.51 (1.63-3.89)***	1.59 (1.01-2.50)*	1.33 (0.84-2.11)	1.00
State of injury incident	Queensland NSW	3.57 (2.28-5.58)***	2.28 (1.40-3.54)**	1.02 (0.61-1.71)	1.00
First provider	Trauma Centre Other	2.16 (1.37-3.40)***	1.42 (0.88-2.23)	1.08 (0.66-1.79)	1.00

 # Adjusted for age group and sex
**** p<=0.001, ** p<=0.01, *p<=0.05*

In terms of patient factors, there was a statistically significant inverse correlation between the number of comorbidities and disadvantage ($p<0.001$), however neither

measure of injury severity was significantly associated with relative socioeconomic disadvantage (Table 5). Further analysis showed that both ISS (B=2.18, 95% CI 0.80-3.67, p<0.01) and NISS (B=3.25, 95% CI 1.35-4.94, p<0.001) were positively and significantly associated with remoteness of residence independently of age, sex and remoteness of injury site (data not shown). However the number of comorbidities was not statistically significantly associated with remoteness of residence (OR 0.99 95% CI 0.92-1.05, p=0.68) (data not shown).

Table 5: Association of IRSD with patient factors: number of comorbidities and injury severity #

Variables	B (95% CI)
Number of comorbidities	-0.26 (-0.39 - -0.13)***
ISS	-0.77 (-0.60-0.44)
NISS	-0.41 (-1.08-0.27)

 # Adjusted for age group and sex

****** p<=0.001, ** p<=0.01, *p<=0.05***

Further, as Table 6 shows, the relationship between relative socio-economic disadvantage and remoteness of residence persists and in fact strengthens, after adjusting for age, sex, injury severity and remoteness of injury location. In this model ISS was not statistically significant (OR 1.01 95% CI 0.99-1.03, p=0.37) and there was an inverse relationship between disadvantage and remoteness of injury location (OR 0.03, 95% CI 0.02-0.05). The findings for age and sex were not statistically significant in this model.

Table 6: Association of IRSD with residential remoteness, accounting for remoteness of injury location and injury severity#

	Quartiles of socioeconomic disadvantage OR (95% CI)			
Variables	**IRSD 1 Most disadvantaged**	**IRSD 2**	**IRSD 3**	**IRSD 4 Least disadvantaged**

Area of residence	Regional/Remote	6.21 (3.07 -12.57)***	6.09 (2.94-12.62)***	5.14 (2.45-10.78)***	1.00

 # Adjusted for age group and sex, ISS, remoteness of injury location

****** p<=0.001, ** p<=0.01, *p<=0.05***

Discussion

The places in which people live and work are inextricably linked to their health behaviours and health outcomes, however the causal mechanisms through which these factors influence injury risk are unclear. For this study, we applied Marmot's model of the social determinants of health to better understand the relationship of social disadvantage and residential remoteness in hospitalised patients with severe traumatic injuries.

We found that neighbourhood socioeconomic disadvantage is positively linked to residential remoteness, defined by limited accessibility to services, which is most likely occurring in NSW regional areas, compared to QLD. Furthermore, there is a positive and statistically significant gradient of increased risk of disadvantage if living in a regional or remote area. These trends persisted after controlling for age, sex, injury severity and remoteness of injury location, where the odds of living in a regional or remote area are nearly six-fold higher for people in the most disadvantaged group, compared to those in the least disadvantaged group.

Additional analysis showed similar significant trends, but of a lesser magnitude, for those who received initial trauma cares from a hospital other than the main trauma centre. Unsurprisingly, the numbers of comorbidities in patients were significantly and positively associated with increased disadvantage, but not remoteness. There was no statistical evidence of variations in disadvantage according to the severity of the injuries, injury mechanism and location and the body region of injury, however injury severity was significantly associated with remoteness of residence.

Studies of socioeconomic disadvantage and injury patterns in people who have survived serious trauma long enough to be transported to definitive trauma care are sparse. Furthermore, there is limited evidence of the association of remoteness of residence with disadvantage, independently of where the injury occurred.

Our primary findings are somewhat consistent with those from a large comprehensive Australian study of newly licensed drivers hospitalised for crash injuries. The study reported higher risks for people low SES areas, which persisted after adjusting for rurality, and a range of driver behavioural factors. (Chen et al., 2010) The study sample

was considerably younger than our sample. Income was excluded from the SES index and proxy measures of injury severity were analysed as confounding factors. Elsewhere, a population case-control study of 7,382 trauma patients and residential controls found that cases with low levels of income and education were, for each, independently associated with increased odds of being in the lowest categories of SES. (Brattström et al., 2015) The study also showed associations with comorbidity and disadvantage, similar to our results.

We did not find any associations with injury mechanism and socioeconomic disadvantage and this has been reported elsewhere. (Brattström et al., 2015) However, a large study of neighbourhood SES category in adult patients (N=17,658) admitted to a level one trauma centre found significant trends for increased admission rates for injuries and disadvantage according to all categories of blunt mechanisms of injury, penetrating mechanism, and injury severity.(Zarzaur et al., 2010) Other research of hospitalised children has confirmed the relationship between relative socioeconomic disadvantage and transport related injuries. (Poulos et al., 2007).

Contrary to our results, an analysis of hospitalised trauma patients in NSW showed that injury severity did not vary according to rural/urban status, yet the mechanism of injury and the site of severe injury did. Also, road trauma and head injuries were respectively more common in rural areas compared to urban areas. (Dinh et al., 2013)

About 80% of all trauma deaths occur either at the scene, or within a few hours of injury (Trunkey, 1983) and presumably, in Australia, most of these deaths occur in rural or remote areas. These patients would not be represented on most Trauma Registries. Our sample of hospitalised trauma survivors might explain the non-significant association with injury severity and SES/remoteness, a pattern that has also been reported elsewhere in Australia. (Dinh et al., 2013) Regional hospitals are often the first point of contact for severely injured people in rural areas and evidence is mixed as to whether trauma care regionalisation decreases the risk of adverse outcomes compared with patients who are directly transferred to major trauma centers. (Liberman et al., 2005, Sampalis et al., 1997, Vali et al., 2017) It is possible that many small, regional hospitals are ill-equipped to manage major trauma. If, as our results suggest, these patients more

likely to be more disadvantaged, further empirical research about patterns of care in rationalised trauma systems is required to support this view.

Studies of remoteness and injury patterns in Australia further highlight the importance of interpreting the results in the context of the 'study setting'. In Western Australian (WA) a significant and positive gradient for trauma deaths according to remoteness has been reported, independent of injury severity, age and time to definitive care, with the findings more pronounced in remote to very remote areas. (Fatovich and Jacobs, 2009, Fatovich et al., 2011) WA differs from most of the other States as it has vast areas of remoteness and only one tertiary trauma centre in Perth. Transferral of severe trauma cases often involves travel distances of thousands of kilometres. (Fatovich and Jacobs, 2009) Hence, the geographical characteristics of WA are quite different to our study setting, which straddles the NSW and Qld border and where most of the population lived in major cities or 'inner regional' areas. Distance to definitive care is vastly less here, compared to those injured in WA. However, the WA study supports the concept that remoteness is more than just a 'distance' measure to services, but most likely reflects the social, environmental and economic fabric of neighbourhoods that differentially expose people to injury risk.

Limitations

Multiple, interacting ecological factors underlie the expression of individual behaviours and provide a framework for understanding the socioeconomically disadvantaged communities in which people live. (Susser 1996) The ecological fallacy is also an important consideration where area-level SES exposure was used as a proxy for individual SES status, limiting our ability to account for factors that confound the relationship between an individual's SES and injury patterns. However, the IRSD is a widely used and robust index of SES in Australia. As a multi-faceted measure, it appropriately captures the community context, particularly its wealth, which in turn influences the quality of municipal services, road conditions, crime rates and access to material resources that could mitigate injury risk.

Trauma patients who survive serious injuries to receive definitive trauma care at a Level 1 Trauma Centre represent a unique, highly select group of severe trauma survivors and care should be taken in terms of extrapolating these findings to all cases

of traumatic injuries in other settings. Arguably, the many different dimensions of SES are specific to time and place. (Braveman et al., 2005) In terms of acute serious trauma, there are numerous, unmeasured confounding factors in place, particularly in relation to known variations in patterns of pre-tertiary care, care given by the 'first provider' along with different types of transportation modalities to the Trauma Centre. Trauma systems are State-based and the extent of cross-border variations in trauma referrals and management are not known. The characteristics of our hospital sample might not be comparable with the findings of other studies.

Compared to other studies our sample size was relatively small and it is possible that our study lacked sufficient study power to detect real differences if any existed. Additionally, we could not examine SES in relation to people living in remote or very remote areas, or the impact of race on these associations. Aboriginal people are more likely to live in regional areas and have higher rates of disadvantage.

Conclusions

Severely injured trauma patients who are from social and economically disadvantaged communities are more likely to reside in areas that have comparatively less access to service centres. They tend to have more comorbidities and have received initial trauma care from a regional hospital, mostly located in NSW rather than the Trauma Centre located in QLD. These factors are all potentially important in terms of understanding variations in trauma outcomes in this study region. Studies of social and economic disadvantage in relation to injury risk and outcomes should include measures of co-morbidity, the first provider of care and remoteness of residence, in addition to injury location.

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