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The relationship between geographic location and outcomes following injury: A scoping review

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ABSTRACT

Introduction: Globally, injury incidence and injury-fatality rates are higher in regional and remote areas. Recovery following serious injury is complex and requires a multi-disciplinary approach to management and community re-integration to optimise outcomes. A significant knowledge gap exists in understanding the regional variations in hospital and post-discharge outcomes following serious injury. The aim of this study was to review the evidence exploring the association between the geographic location, including both location of the event and place of residence, and outcomes following injury.
Materials and Methods: A scoping review was used to investigate this topic and provide insight into geographic variation in outcomes following traumatic injury. Seven electronic databases and reference lists of relevant articles were searched from inception to October 2018. Studies were included if they measured injury-related mortality, outcomes associated with hospital admission, post-injury physical or psychological function and analysed these outcomes in relation to geographic location.
Results: Of the 2,213 studies identified, 47 studies were included revealing three key groups of outcomes: mortality (n = 35), other in-hospital outcomes (n = 8); and recovery-focused outcomes (n = 12). A variety of measures were used to classify rurality across studies with inconsistent definitions of rurality/remoteness. Of the studies reporting injury-related mortality, findings suggest that there is a greater risk of fatality in rural areas overall and in the pre-hospital phase. For those patients that survived to hospital, the majority of studies included identified no difference in mortality between rural and urban patient groups. In the small number of studies that reported other in-hospital and recovery outcomes no consistent trends were identified.
Conclusion: Rural patients had a higher overall and pre-hospital mortality following injury. However, once admitted to hospital, there was no significant difference in mortality. Inconsistencies were noted across measures of rurality measures highlighting the need for more specific and consistent international classification methods. Given the paucity of data on the impact of geography on non-mortality outcomes, there is a clear need to develop a larger evidence base on regional variation in recovery following injury to inform the optimisation of post-discharge care services.

Contents

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Introduction

Regionalised trauma systems (RTS) are widely recognised as best-practice in trauma care, with the establishment of these systems shown to improve survival rates [1–4] and longer term functional outcomes [5,6] following serious injury. These systems involve the implementation of processes to ensure timely transport of seriously injured patients to specialised trauma centres with appropriately trained staff and expertise to manage these complex patients [3,7]. As a result of these advances and the reduced risk of dying from injury, understanding patterns of recovery following serious injury, and decreasing the injury burden from non-fatal outcomes has become a key area for research and health policy development [4,6].

Globally, injury incidence has been noted to be higher in regional and remote areas relative to urban areas [8–10]. There is also evidence to suggest that fatality rates are higher in regional and remote areas [11–18]. However, no published reviews were located that compared outcomes between geographic locations. This is particularly important due to the complexities of providing appropriate and timely acute and rehabilitation care of trauma patients in outer urban, regional and remote areas to ensure adequate and equitable provision of care in these areas.

For survivors of serious injury, resource and health care service utilisation is complex, long term and expensive [19]. Research has shown that patterns of recovery are prolonged in nature with 80% of survivors experiencing functional limitations at one-year post injury [5] and continue to report ongoing problems with mobility, pain, usual care and anxiety/depression at three years post injury [20]. Both the World Health Organization (WHO) and the American College of Surgeons-COmmittee on Trauma (ACS-COT) have recognised that best practice of an injured individual in a RTS requires coordinated efforts along the entire patient pathway from pre-hospital care through to rehabilitation, and community re-integration to optimise outcomes [21,22].

A potential limitation of regionalised trauma systems is the centralisation of major trauma resources and expertise in metropolitan areas [23–25], particularly in relation to rehabilitation [26]. In Australia, approximately 35% of patients hospitalised as a result of injury reside in regional and remote areas [27]. It is important to acknowledge that interventions designed to reduce injury-related mortality have not changed the rate of hospitalisations following injury [27] and there remains a significant knowledge gap in understanding the regional variations in hospital and post-discharge outcomes following serious injury. Therefore, the aim of this study was to review the evidence exploring the association between the geographic location, including both location of the event and place of residence, and outcomes following injury.

Materials and methods

A scoping review was undertaken to provide new perspectives and inform research in the area of outcomes following injury. The design of this review was guided by the scoping review framework developed by Arksey and O'Malley [28] and refined by more recent publications [29,30]. Steps included formulating a research question; identifying relevant studies for review; selecting relevant literature to be synthesized; charting data to identify key themes and concepts and collating and summarising the findings.

Identification of relevant studies

A systematic search strategy which included a combination of controlled vocabulary (MeSH) and free text terms was formulated to identify relevant peer-reviewed studies published up until October 2018 (Supplementary Material). The search strategy was reviewed by and conducted in association with a senior librarian who verified the methodology. The search was conducted in the following electronic databases on 24 October 2018: MEDLINE, Embase, Scopus, Web of Science and CINAHL. PubMed was also searched for articles published between January 1 2018 – October 24, 2018 to capture those not yet indexed with MeSH headings and therefore not identified with Ovid Medline. Google Scholar was searched to identify any additional peer-reviewed literature not found in other databases with the first 100 results reviewed. Forward citation searching of included studies was also carried out using Google Scholar as well as backward citation searches via reference lists of the included articles. Results were screened on title and abstract, with those remaining undergoing full-text review.

Selection of literature to be synthesized

All mechanisms of unintentional traumatic injury were included in this review. Studies were included if they measured injury-related mortality, outcomes associated with hospital admission, and physical or psychological function following injury. To be included in this review studies were required to analyse these outcomes in relation to geographic location, reporting both a rural and urban cohort. Injury-related mortality studies were included if they specified statistics relating to overall mortality, pre-hospital mortality or in-hospital mortality. In-hospital mortality was defined as mortality occurring between presentation to an emergency department through to hospital discharge and also included 30-day mortality outcomes. Longer-term outcomes relating to patients' recovery included, but were not limited to, measures of psychological and physical function, return to work, and health-related quality of life.

Studies were excluded if the primary outcome of interest was in relation to healthcare utilisation, trauma systems, resource organisation, transfer time, injury or injury-mortality risk explanatory factors, injury incidence or injury hospitalisation rates or Emergency Department presentations. Editorial or commentary pieces were excluded but otherwise there were no restrictions on design or type of study included. Research that were solely based on self-reported injury surveys as the outcome measure were excluded, as were those including only children (aged 15 years of age or under) or not published in English.

Data describing the study demographic, statistics and outcome measures reported, rurality classification methods and whether rurality was classified by place of residence or place of injury in the included studies were extracted. Data were summarised in Microsoft Excel to identify key outcomes explored in the literature. This enabled the sorting of studies geographically, and according to primary outcome investigated. Due to the heterogeneity of the literature in this field, a qualitative synthesis of outcomes according to key themes and concepts identified was conducted.

Results

Our search strategy yielded 2213 non-duplicate articles, of which 2114 were excluded after screening of titles and abstracts. A total of 99 papers underwent full-text review, of which 52 were excluded (see Fig. 1). The 47 included studies were classified into three key groups of outcomes: mortality (n = 35), other in-hospital outcomes (n = 8); and recovery-focused outcomes (n = 12). In-hospital mortality was reported within mortality outcomes. Other in-hospital outcomes were reported separately and included hospital length of stay, intensive care unit (ICU) length of stay, ICU admission and 28-day re-admission rates.

Study characteristics

Countries of origin included United States of America (USA) (n = 19), Australia (n = 9), Canada (n = 5), Scotland (n = 2), Taiwan (n = 3), China (n = 2), Norway (n = 1), South Africa (n = 1), Ireland (n = 1), Finland (n = 1), Sweden (n = 1), Sudan (n = 1) and Guyana (n = 1). Of the studies reporting pre-hospital and in-hospital outcomes (n = 35), geographic status was classified similarly by place of injury event (n = 17) and place of usual residence (n = 18). For studies reporting long-term outcomes, geographic status was classified more commonly by place of usual residence (n = 9), compared to place of injury (n = 2). Most studies included cases of all ages (n = 28) or only adults (n = 15). Two studies focused on adolescents [35,36] and two on older adults ($\geq$ 65 years of age) [37,38].

All studies included in this review had large sample sizes that were representative their target populations, limiting the risk of selection bias. The number of participants ranged from 275 to 883,473 participants in mortality studies, 412 to 256,536 participants in hospital related outcome studies, and 78 to 34,933 participants in studies on recovery outcomes. These studies also utilised outcome measures that were reliable, valid and relevant to the constructs being measured. As all studies were retrospective cohort studies, important methodological factors must be considered due to the impact of potential biases. Retrospective studies may result in poorer quality of results due an inability to control for potential risk factors that may have influenced the outcome if this information was not collected with the data collection. Further information on confounding factors addressed in specific papers are reported within each outcome group. Whilst adjustment for potential confounding factors in statistical analyses was variable, outcomes measured were relevant to the constructs being assessed.

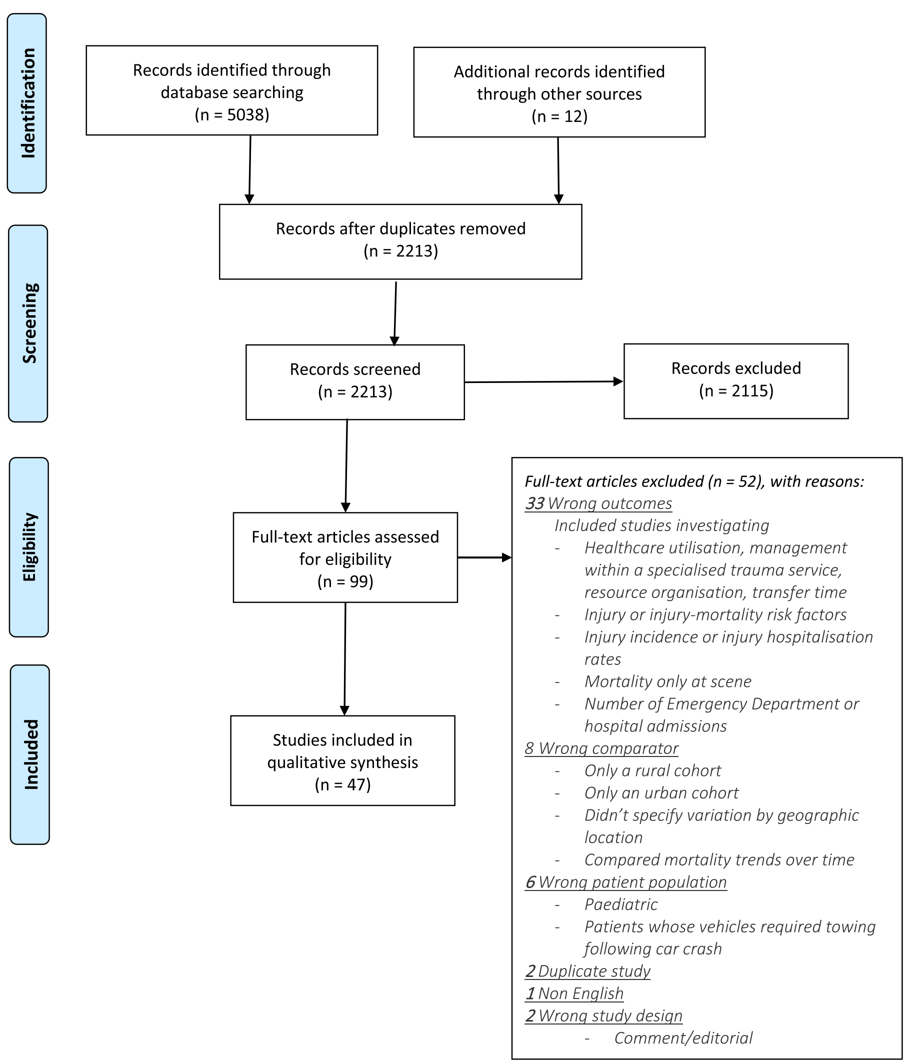

Fig. 1. Systematic Citation Review Process.

A variety of measures were used to classify rurality (Table 1). Population density was the most common measure (n = 11). There was inconsistency however between studies using this measure in definitions considered to be rural. For example, one study from the USA [31] considered the most rural group to be counties with a population < 25,000. In contrast, a Norwegian study [32] described the most rural group as counties with less than 9 people per square kilometre while a Scottish study [33] classified the most rural district as those with less than 0.5 people per acre. The most consistent use of a rurality classification system was reflected in the Australian studies in which 75% referenced the Australian Statistical Geographical Standard Remoteness Area (ASGS RA) Classification [34] using the Accessibility Remoteness Index of Australia extended (ARIA+) value index to classify the degree of rurality. This index provides a geographical approach to classifying remoteness based on distance to service centres (populated localities). Other commonly used measures in the USA were the Rural-Urban Continuum Codes and Urban Influence Codes. These classify metropolitan counties by the population size and non-metropolitan counties by either the degree of urbanization and proximity to metropolitan areas.

Most studies included cases of all ages (n = 28) or only adults (n = 15). Two studies focused on adolescents [35,36] and two on older adults ($\geq$ 65 years of age) [37,38].

Mortality outcomes

Of the studies which presented overall mortality statistics (n = 29), 93% (n = 27) reported statistically significant higher mortality outcomes for those injured in rural areas or for rural residents (Table 2; for expanded tables with additional details such as full results, confounding factors adjusted for, data sources and classification methods see Supplementary Material). Statistical measures reported in the studies reviewed included Standardised Mortality Rate (SMR), injury-mortality rates, rate ratios, odds ratios (OR) and the proportion of fatalities that were patients from rural compared to urban areas. Of the studies that reported overall mortality rates (n = 20), there was variability in the denominators and adjustments for confounding factors, as well as populations studied, making direct comparison of studies difficult. Overall mortality was reported with the SMR (per 100,000), using population-based estimates as the denominator, in 12 studies.

One South African study reported the age-SMR to be significantly higher in the urban province for unintentional (non-transport) injury-related mortality, which included mechanisms of injury such as burns, drowning, falls and poisoning [39]. However, when the data were analysed for transport-related injury mortality, the age-SMR was significantly higher in the rural group [39].

Among studies which investigated pre-hospital mortality (n = 8), all reported significantly higher rates or likelihood of fatality in the rural groups, whether rurality was classified by place of injury or place of residence. The risk of pre-hospital fatality was reported as twice as likely in the rural group [40,41] with one study finding the likelihood of death-at-scene as five times greater for patients involved in a rural motor vehicle crash [42].

Only one of the 10 studies reporting in-hospital mortality found higher 30-day mortality rates for rural patients hospitalised for fall-related injuries [38]. Of the remaining studies, there was either lower in-hospital mortality for rural patients or no difference between urban and rural groups.

Table 1
Commonly Referenced Rural-Urban Classification Measures.

Classification Scale	Country	Description
Population Density [1]	Global	Measure of urbanization defined in scale, based on a distribution of population in an area of interest. Typically calculated as resident population of a land area as listed in a census and divided by the size of land area.
Australian Statistical Geographical Standard – Remoteness Area (ASGS RA) [2]	Australia	Geographical classification based on relative access to services and defined by ARIA + index values which measure remoteness of a point based on the physical road distance to the nearest urban centre (defined as a population cluster of 1000 or more people). 5-level scale; 'Major Cities', 'Inner Regional', 'Outer Regional', 'Remote' and 'Very Remote'. ARIA + is an extended version of previously used ARIA methodology.
Urban Influence Codes [1,3]	USA	12-level system. County-level, 2 metropolitan and 10 nonmetropolitan codes. Distinguishes metropolitan by population size of metro area, and nonmetropolitan by size of the largest city or town and proximity to metro and micropolitan areas.
Rural-Urban Continuum Codes [1]	USA	9-level scale; County-level. Takes into account adjacency to a larger economy but does not consider the large or small size of the adjacent area in their definition for non-core areas. Counts the entire urban population (as defined in the Census) within the county, rather than the city or town of largest size.
U.S Census Bureau Tracts [4]	USA	Census block level; To qualify as an urban area, the territory identified according to criteria must encompass at least 2500 people, at least 1500 of which reside outside institutional group quarters. "Rural" encompasses all population, housing, and territory not included within an urban area. Does not have stable boundaries over different Census years.
Office of Management and Budget (OMB) [5]	USA	Metropolitan Area (MA) and Non-Metropolitan Area (Non-MA) counties. MA = 1) at least one central county with a minimum population of 50,000 or a Census Bureau defined urbanized area and a total population of at least 100, 000; and 2) one or more outlying counties that have close economic and social relationships with the central county.
National Centre for Health Statistics (NCHS) Rural-Urban Classification [5]	USA	County-level; 6-level system: 4 metropolitan (large central metro, large fringe metro, medium metro, and small metro) and 2 nonmetropolitan (micropolitan and noncore). Based on population range and OMB delineation of metropolitan and micropolitan statistical areas.
Metropolitan Influence Zones, Canada [6]	Canada	The MIZ classification reflects the relative influence of an urban centre on a rural area. This classification system is applied at the census subdivision level and disaggregates non-Census Metropolitan Areas/Census Agglomerations (CMA/CAs)* into four zones of metropolitan influence (Strong MIZ, Moderate MIZ, Weak MIZ, No MIZ), primarily defined on the basis of commuting flows of the employed labour force to and from CMAs/CA.

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Table 2
Mortality Outcomes - Rural Vs Urban.

Better outcomes for rural patients
No difference in outcomes
Worse outcomes for rural patients

Country	Author(s)	Mortality Outcome	Measures reported/Denominator	Population Studied	Age (years)	n	Rurality Classification	Rurality Classified By
USA	Baker et al. 1987 [7]	Overall	MVC mortality rates per 100,000 population (denominator = US population estimates)	All injury-related fatalities from MVC in USA	All ages	127,110	Population density	Residence
	Beck et al. 2017 [8]	Overall	Age-adjusted MVC mortality rates per 100,000 population (denominator = US population estimates)	Passenger-vehicle-occupant deaths from MVCs	≥ 18	19,528	RUCC	Injury
	Brown et al. 2000 [9]	Overall	MVC mortality rates per 100,000 population(denominator = US population estimates)	All injury-related fatalities from MVC in USA	All ages	875,405	U.S. Census Bureau	Injury
		Pre-Hospital	Death at scene rate per 100,000 population using (denominator = US population estimates)	All deaths-at-scene following MVC		329,767		
	Clark et al. 2001[10]	Overall	Traffic fatality rates of elderly population per 100,000 people by quartiles of US county population density (denominator = population of US counties)	Elderly fatalities within 30 days of injury from a MVC	≥ 65	32,064	Other country specific	Injury
	Donaldson et al. 2006 [11]	Overall	Adjusted OR	All reported MVCs occurring on public roads in Utah that either resulted in passenger injury or had at least $1000 in property damage	All ages	514,648	RUCC	Injury
	Gabella et al. 1997 [12]	Overall	Age-adjusted mortality rate from TBI per 100,000 population and (denominator = US population estimates) and rate ratios	All TBI mortality cases in Colorado, involving Colorado residents	All ages	1312	U.S Census Bureau	Residence
		Pre-hospital	Age-adjusted mortality rate from TBI per 100,000 population (denominator = US population estimates) and rate ratios	All TBI mortality cases in Colorado where place of death was not 'inpatient'		855		
	McCowan et al. 2007 [13]	In-hospital	Adjusted OR	Patients transported to hospital by HEMS following blunt trauma	≥ 15	411	Population density	Injury
	Muelleman et al. 2007 [14]	Overall	OR	All fatal or injury-related MVC mortality (Nebraska)	All ages	225	UIC	Injury
		Pre-Hospital	OR	All MVC mortality-at-scene (Nebraska)		64		
	Newgard et al. 2017 [15]	Overall	% fatal injuries	Injured patients transported by 44 EMS agencies to 28 hospitals in Oregon and Washington	All ages	17, 633	Other country specific	Injury
		Pre-Hospital	% out-of-hospital deaths	Out-of-hospital deaths following injury recorded by EMS agencies (Oregon & Washington)		612		
	Peek-Asa et al. 2004 [16]	Overall	Age-adjusted mortality rates by urbanization level (per 100,000) using denominator of US county population	All unintentional traumatic injury captured by National Center for Health Statistics in the USA	All ages	Not stated	Other country specific	Residence
	Peura et al. 2015 [17]	Overall	Adjusted OR	All police-reported fatal MVC in 11 states of USA	All ages	26,582	RUCC	Injury
	Sihler et al. 2009 [18]	In-hospital	OR	Hospital admissions following traumatic injury	All ages	34,933	UIC	Injury

	Travis et al. 2012 [19]	Overall	Adjusted OR	Police-reported MVC resulting in injury	All ages	883,473	RUCC	Residence
	Zwerling et al. 2005 [20]	Overall	Injury fatality rate (per 1000 crashes with injury) in USA; Denominator = total crashes with injuries	All fatal and injury-related fatalities from MVC	≥ 16	53,049	Population density	Injury
AUSTRALIA	Chen et al. 2010 [21]	Overall	Fatality rate per 10,000 drivers (denominator = all licensed drivers) and relative risk	Police-recorded passenger vehicle crashes (NSW)	17-25	644	ASGS RA	Residence
	Fatovich et al. 2009 [22]	Overall	Age-SMR (per 100,000 PY): Denominator = Person-time at risk from all deaths	All trauma related deaths (WA)	All ages	101,425	ASGS RA	Injury
	Fatovich et al. 2011 [23]	Overall	OR mortality	All major trauma patients, ISS > 15 (WA)	All ages	3,333	ASGS RA	Injury
		In-hospital	OR mortality if survive to metro hospital admission	Major trauma patients (ISS > 15) who survive transport to Perth by RFDS				
	Mitchell & Chong 2010 [24]	Overall	Age- and gender-SMR (per 100,000); Denominator = age- and sex-specific population estimates	Injury-related mortality for NSW residents	All ages	11,577	ASGS RA	Residence
	Sukumar et al. 2016 [25]	In-hospital	30-day mortality rate adjusted for age, sex & comorbidities (denominator = all falls-related hospital admissions) and relative risk	All falls-related hospital admissions (NSW)	≥ 65	256,536	ASGS RA	Residence
CANADA	Bell et al. 2012 [26]	Overall	Age-standardized rate ratios	All transport-related pre-hospital, in-transport and in-hospital deaths in BC with ISS > 12	≥ 18	1,851	Population density	Residence
	Gomez et al. 2010 [27]	Pre-Hospital	Relative risk (OR)	Trauma-related deaths occurring prior to ED	All ages	1,877	Other country specific	Injury
		In-hospital	% deaths in-hospital	All trauma-related in-hospital deaths if survived to ED		1,609		
	Lagace et al. 2007 [28]	Overall	Age-adjusted standardised mortality ratios; Denominator = population estimates	All injury related MVC deaths	All ages	Not stated	ASGS RA (Aus); MIZ (Canada)	Residence
	Simons et al. 2010 [29]	Overall	Age- and sex-adjusted SMR for trauma-related deaths; Denominator = population estimates	All trauma related deaths (BC)	All ages	Not stated	Rural = NW BC; Urban = Vancouver Coastal Health Authority	Residence
		Pre-Hospital	% pre-hospital deaths	All trauma-related pre-hospital deaths (BC)				
		In-hospital	% in-hospital deaths	All injury related in-hospital deaths (BC)				
CHINA	Hu et al. 2010 [30]	Overall	Age- and gender- injury mortality rates (per 100,000); Denominator = deaths recorded in Chinese Death Registry	Injury-related deaths in China	All ages	~10% population	Population density	Residence
	Liu et al. 2012 [31]	Overall	Age- adjusted injury mortality rates (per 100,000); Denominator = population estimates and rate ratios	Injury-related deaths (Hubei Province)	All ages	9714	Other country specific	Residence
SCOTLAND	McGuffie et al. 2005 [32]	In-hospital	% injury-related deaths	All patients arrived to hospital with moderate or major injuries (ISS ≥ 8)	All ages	4,636	Population density	Injury
	Williams et al. 1991 [33]	Overall	Gender-SMRs (Denominator = Census population estimates)	Mortality from MVC in Scotland	All ages	6,643	Population density	Residence
IRELAND	Boland et al. 2005 [34]	Overall	SMR (per 100,000); Denominator = Census population estimates	All unintentional injury deaths in Ireland	All ages	18,185	Other country specific	Residence
SWEDEN	Gedeborg et al. 2010 [35]	Pre-Hospital	Morality rate per 100,000 PY (denominator = person-time at risk from population estimates) and adjusted OR	Pre-hospital injury-related deaths from MVC in Sweden	All ages	3,107	Population density	Residence

		In-hospital	Morality rate (per 100,000 PY); Adjusted OR	Death from MVC where the patient was a vehicle occupant with serious injuries and hospitalised > 1 day		832		
TAIWAN	Huang et al. 2017 [36]	In-hospital	Adjusted OR and % mortality	Hospital admissions for accidental falls in Taiwanese databases	≥ 65	9,438	Rural = Yilan County; Non-rural = other Taiwan	Residence
NORWAY	Kristiansen et al. 2014 [37]	Overall	Annual mortality rate (per 100,000); Denominator = Census population estimates	All injury-related deaths in Norway	16-66	8,466	Population density	Residence
		Pre-Hospital	% pre-hospital deaths	All injury-related pre-hospital deaths in Norway		6,589		
GUYANA	McWade et al. 2016 [38]	Overall	Mortality OR	Fatal MVC identified by police reports in Guyana	All ages	275	Not stated	Injury
SUDAN	Abdalla et al [39]	Overall	Age and gender adjusted SMR (per 100,000); Denominator = Census population estimates	All cause injury related mortality	≥ 5	~33,400	Other country specific	Injury
FINLAND	Raatiniemi et al. 2015 [40]	In-hospital	30-day mortality OR	All major trauma (ISS > 15) patients survived to hospital admission	All ages	472	Other country specific	Injury
SOUTH AFRICA	Sherriff et al. 2015 [41]	Overall	Age-SMR per 100,000 and RR; Denominator = population estimates	Unintentional (non-transport) injury-related mortality	All ages	17,289	Urban province = Gauteng; Rural province = Mpumalanga	Injury
		Overall	Age-SMR per 100,000 and RR; Denominator = population estimates.	Transport-related injury mortality				

RUCC = Rural-Urban Continuum Codes; UIC = Urban Influence Codes; ASGS RA = Australian Statistical Geographical Standard Remoteness Area; ARIA = Accessibility/Remoteness Index of Australia; MIZ = Metropolitan Influence Zones; SMR = Standardised Mortality Rate; NW BC = North West British Colombia; MVC = Motor Vehicle Crash; OR = Odds ratio; RFDS = Royal Flying Doctor Service; NSW = New South Wales; ED = Emergency Department

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Of all studies reporting mortality outcomes (n = 35), ten did not adjust for any potential confounding factors [13,15,32,33,41,43–47]. A number of papers adjusted for age (n = 8) [11,12,17,39,48–51]; age and gender (n = 5) [9,14,18,52,53]; and age, gender and injury severity (n = 3) [40,54,55]. One study adjusted for age and injury severity [56]. Nine studies adjusted for age as well as three or more additional confounders including injury severity, speed, time of day, comorbidities, socioeconomic status, time to first responder input and alcohol [37,38,40,42,57–61] (see Supplementary Material Table 1 for specific details).

In summary, despite variation in the mortality statistics reported, a significantly higher risk of mortality was reported for rural populations and this was particularly notable in regards to pre-hospital mortality statistics.

Other in-hospital outcomes

Eight studies reported in-hospital outcomes other than mortality (Table 3; for expanded tables with additional details such as full results, confounders adjusted for, data sources and classification methods see Supplementary Material). Hospital length of stay was the most commonly reported hospital-related outcome (n = 7); two studies found that rural patients experienced longer hospital stays [35,58], three studies found no differences between groups [33,54,62], and three studies reported a shorter hospital length of stay for rural residents [38,62,63]. Sukumar and colleagues [38] investigated patients older than 65 years, who were hospitalised for fall-related injuries, and found that although the hospital length of stay was shorter for rural residents, this group had a higher 28-day hospital readmission rate. Within studies that investigated other in-hospital outcomes there was little consistency in findings regarding geographic variation.

Two studies reporting in-hospital outcomes did not state whether confounders had been adjusted for [35,62], one study adjusted for age only [63] and five studies adjusted for age and other potential confounding factors [33,38,54,56,58] (see Supplementary Material Table 2 for full details).

Recovery outcomes

Twelve studies were identified which reported outcomes relating to recovery following injury (see Table 4; for expanded tables with additional details such as full results, data sources and classification methods see Supplementary Material). A wide variety of outcome measures, assessing a number of constructs, were captured at differing time points ranging from hospital discharge [35,55,64] to four years following injury [65]. Half of these studies reporting recovery outcomes did not adjust for confounders or did not state whether this was done [35,62,64,66–68]. Of the other six studies, various confounding factors were taken into consideration in the results including age, gender, occupation and post-traumatic amnesia [55,65,69–72] (see Supplementary Material Table 3 for full details).

All three studies which reported on disability at hospital discharge found poorer outcomes for rural patients [35,55,64], despite studying different populations. When patients were assessed at least 12 months following injury, no significant differences between rural and urban groups were found in seven of nine studies [62,65,66,68–71]. The two studies reporting worse post-discharge outcomes for rural patients included patients with traumatic brain injury (TBI); one dichotomised the Disability Rating Scale (DRS) into fully independent or dependent and found that a greater proportion of rural patients were dependent compared to urban counterparts [67], and the other reported rural patients to have significantly higher mental health illness and reduced social participation levels following brain injury [73]. Notably, two-thirds of the studies (n = 8) which investigated recovery outcomes in specific groups of injured patients such as TBI [62,64,66,67,69,69,70,71,73] and spinal cord injury (SCI) [62]. Two studies included all mechanisms of injury [55,65], however, only one of these explored outcomes beyond hospital discharge, and only included patients who required outpatient rehabilitation services [65].

Discussion

The aim of this review was to explore the association between geographic location and outcomes following injury. Most of the included studies focused on injury-related mortality outcomes, particularly in relation to road trauma, with a small number of studies also reporting other hospital-related and recovery outcomes. Our findings suggest that there is a greater risk of fatality in rural areas overall and in the pre-hospital phase. However, if the patient survives to hospital admission, rurality appeared to be less relevant to in-hospital mortality. In the small number of studies that reported outcomes other than mortality, the results did not conclusively suggest that rural patients experienced more or less favourable outcomes than the urban group. Within these studies however, a key finding that affected the interpretation of our results was the inconsistency and variability in the measurement and statistical reporting of outcomes, limiting the comparability between studies.

The papers included in this review suggest that geographic location may have an impact on injury mortality. The overall mortality findings of this study were consistent with general Australian population data which reported that between 2012-13 there was an increased age-standardised injury death rate with increasing remoteness [74]. Explanatory factors proposed for the increased mortality in rural areas following serious injury have included greater injury incidence, injury severity, longer emergency services response times and distance to health services, particularly specialised trauma centres [15,41,75]. Most recently, it was shown that distance to the nearest trauma centre was associated with an 8% increase in odds of death for every five-mile increase in distance, in addition to the effect of increased pre-hospital time [76]. Crash characteristics including high-speed collisions, head-on collisions, collisions involving a single vehicle with a stationery object, increased alcohol use, greater involvement of trucks and reduced occupant restraint use [16,43,77] have also been more commonly attributed to collisions in rural environments and potentially contribute to the increased risk of death in rural areas following injury, especially in the pre-hospital phase.

Our findings have highlighted the paucity of literature available and variable conclusions on the impact of geographic location on non-mortality hospital related outcomes. Inconsistency in findings

Table 3
Other in-hospital outcomes - Urban Vs Rural.

Country	Author(s)	Measures reported	Population Studied	Age (years)	n	Rurality Classification	Rurality Classified By
AUSTRALIA	Fatovich et al. 2011 [23]	Hospital LOS, ICU admission and ICU LOS	Patients admitted to metropolitan trauma centre following major trauma (ISS > 15)	All ages	3,333	ASGS RA	Injury
	Mitchell & Lower 2018 [65]	Hospital LOS and 28-day readmission	Patients in NSW admitted to hospital following injury	All ages	709,464	ASGS RA	Residence
	Sukumar et al. 2016 [25]	28 day re-admission	Fall-related injury hospitalisations in rural vs urban elderly populations	≥ 65	256,536	ASGS RA dichotomised	Residence
		Hospital LOS					
FINLAND	Raatiniemi et al. 2015 [40]	ICU LOS	Major trauma (ISS > 15) patients survived to hospital admission	All ages	472	Other country specific	Injury
USA	Mazurek, M.O. et al. 2011 [42]	SCI/TBI acute hospital LOS and TBI rehabilitation hospital LOS.	TBI/SCI patients enrolled in the Missouri Model SCI System and Missouri Model TBI System databases	≥ 18	152 TBI; 149 SCI	Population	Residence
		SCI rehabilitation hospital LOS					
	McCowan et al. 2007 [13]	Hospital LOS	Patients transported by HEMS following blunt trauma	≥ 15	412	Population density	Injury
TAIWAN	Chiang et al. 2006 [43]	Hospital LOS	Head injured adolescents in Taiwan with inpatient hospital stay	13-18	600	Other country specific	Injury
SCOTLAND	McGuffie et al. 2005 [32]	Hospital LOS and ICU LOS	All moderate and major trauma patients (ISS > 8) admitted to hospital for more than two days	All ages	4,636	Population density	Injury

Better outcomes for rural patients
No difference
Worse outcomes for rural patients

TBI: traumatic brain injury; SCI = spinal cord injury; LOS= length of stay; ASGS RA = Australian Statistical Geographical Standard Remoteness Area

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between studies reporting hospital length of stay may reflect the wide variation in methodology used [33,35,38,54,58]. A longer hospital length of stay was reported for rural patients in the studies that involved major trauma (ISS > 15) [58] and TBI populations [35]. This finding may be due to limited availability and access of inpatient rehabilitation or outpatient services required to facilitate discharge for more complex patients, resulting longer inpatient hospital stays for rural patients. Additionally, challenging home environments or a lack of alternate and accessible accommodation options may also create barriers for early hospital discharge as opposed to a patient in a metropolitan area who may have access to a wider range and number of services after discharge.

Traumatic injury is difficult to manage and effectively study due to the heterogeneity of the condition and the disparities that arise due to how the injured patient interacts with their social environment and health care system [78]. However, the management of an injured patient within a trauma system should involve coordinated efforts along the entire patient pathway from pre-hospital care to rehabilitation and community reintegration, to optimise outcomes [21,22]. Understanding potential disparity across distinct phases of trauma systems is important to ensure processes and interventions adequately meet patients' needs across the continuum of care [78]. In this review, studies measuring functional status at hospital discharge reported poorer outcomes for rural patients. However, at 12 months or more following injury there was minimal difference in outcomes between rural and urban patients. Of the studies that investigated outcomes beyond hospital discharge, the majority focussed on TBI [35,62,66,67,69–71,73] and spinal cord injury (SCI) [62] with only one study reporting longer term outcomes following all injuries [65] and one that was limited to patients following bone fracture due to workplace injury [72]. Despite being multi-site studies, all of the TBI/SCI cohorts investigated were sampled from well-established brain or spinal cord injury rehabilitation programs. This may represent a sample of patients who received a high standard of initial and follow-up care from specialised healthcare services. The fact that these groups have been investigated more frequently is also a reflection of the ongoing involvement they have with health professionals, and the availability of specific services to manage this population over longer periods following injury.

Given that the concept of geographic location or place is inextricably linked to the social determinants of health [79] it is also important to appreciate that factors such as socio-economic status, environmental factors, access to health services, risk-taking behaviours and in the case of traumatic injury, insurance status, are all likely to be contributing an individual's recovery following injury [78]. Whilst some studies have controlled for these potential confounders using multivariable analysis to isolate rurality or place as the primary variable of interest, where not controlled for, these factors can bias results. Due to the heterogeneity of populations studied and the paucity of the literature, it is unclear whether geographic location is a significant factor that impacts on long-term health outcomes following injury.

An important limitation of the literature included in review was the heterogeneity of the measures used to determine the degree of rurality in study populations. To understand the relationship

Table 4
Recovery outcomes - Rural vs Urban.

Country	Author (s)	Measures Reported	Population Studied	Time Post-Injury	Age (years)	n	Rurality Classification	Rurality Classified By
USA	Gontkovsky et al. 2006 [44]	Disability (DRS); Medical Complications	Patients admitted for TBI inpatient rehabilitation (single site)	12 months	≥16	111	Other country specific	Residence
	Johnstone et al. 2003 [45]	Successful employment; financials spent in vocational rehab	Patient with TBI who sought vocational rehabilitation services in Missouri	Mean = 9 years	18-57	78	Other country specific	Residence
	Mazurek et al. 2011 [42]	Disability (FIM), QoL (SWLS), alcohol use	Missouri Model SCI System and Missouri Model TBI System databases	12 months	≥ 18	152 TBI; 149 SCI	Population	Residence
	Schootman M et al. 1999 [46]	Disability (DRS dichotomised)	TBI patients recruited from Iowa Central Registry	12-18 months	≥ 18	292	Population density	Residence
	Sihler et al. 2009 [18]	Disability (FIM)	Patients admitted to hospital for injuries from 904 hospitals in the US	Hospital Discharge	All ages	34,933	UIC	Injury
	Young et al. 2008 [47]	Work disability -time off work (days) in 2yrs following injury; OR likelihood of being off work > 1 week	Injured workers seeking compensation for fracture from a USA insurance company (8-10% of US workers' compensation claims)	24 months	Working age	5,618	Population density	Residence
AUSTRALIA	Harradine et al. 2004 [48]	Disability (DRS); Adaptability (MPAI), Psychosocial Reintegration (SPRS), Medical outcomes (MOS-SF), General health (GHQ)	Patients referred to NSW BIRP (11 sites) with severe TBI (as measured by post traumatic amnesia (PTA) ≥ 1 day, and/or a Glasgow Coma Scale ≤ 8).	18 months	18-65	198	ARIA	Residence
	Ponsford et al. 2010 [49]	SOQ, GOS -E, SIP, CHART, Alcohol use, Anxiety & depression (HADS), Drug abuse (DAST)	TBI patients admitted to metropolitan (single site) inpatient rehabilitation	24 months	≥ 18	959	Other country specific	Residence
	Simpson et al. 2016 [50]	Mental Health (HONOS-ABI); Social participation (SPRS-2) Disability (DRS), Challenging behaviours (OBS), Care needs (CANS)	Patients referred to NSW BIRP (11 sites) with severe TBI (as measured by PTA ≥ 1 day, and/or a Glasgow Coma Scale ≤ 8).	24 months	18-65	503	ASGS RA	Residence
TAIWAN	Chiang et al. 2006 [43]	Disability (GOS)	Patients hospitalised following TBI in a rural and urban Taiwanese county	Hospital Discharge	13-18	600	Other country specific	Injury
	Kuo et al. 2017 [51]	Disability (GOS)	Cyclists admitted to hospital with a traumatic brain injury	Hospital Discharge	All ages	812	Other country specific	Injury
CANADA	Sirois et al. 2009 [52]	Physical health (aSF12), Disability (FIM)	Trauma patients admitted to level I/II trauma centres in Quebec requiring rehabilitation following hospital discharge.	24-48 months	18-65	435	Other country specific	Residence

Better outcomes for rural patients
No difference
Worse outcomes for rural patients

GOS (-E) = Glasgow Outcome Scale (-Extended); DRS = Disability Rating Scale; FIM = Functional Independence Measure; MPAI = Mayo-Portland Adaptability Index; GHQ = General Health Questionnaire; MOS = Medical Outcomes Scale; SPRS (-2) = Sydney Psychological Reintegration Scale (-2); QoL = Quality of Life; HADS = Hospital Anxiety and Depression Scale; AUDIT = Alcohol Use Disorders Identification Test; SWLS = Satisfaction With Life Scale; CHART = Craig Handicap Assessment and Reporting Technique; DAST = Drug Abuse Screening Test; CANS = Care and Needs Scale; HONOS-ABI = Health of the Nation Outcome Scale-Acquired Brain Injury; aSF12 = Adjusted Short Form 12; TBI = Traumatic Brain Injury; ISS = Injury Severity Scale; SOQ = Structured Outcome Questionnaire; UIC = Urban Influence Codes; ASGS RA = Australian Statistical Geographical Standard Remoteness Area; ARIA = Accessibility/Remoteness Index of Australia; BIRP = Brain Injury Rehabilitation Program

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between differing levels rurality on health outcomes, 'rurality' must be defined and the consistent methods used to classify this construct used in the literature. Of the 47 studies included in this review, there were 14 different classifications of rurality. Population density was the most commonly reported method of classification however within this measure, there was significant inconsistencies in the population considered to be 'rural'. Population density also only measures a single construct, population, and doesn't take into consideration other factors associated with location that may impact health outcomes. Although more widely used in the literature, without consistent definitions of what population figures should be considered 'rural', comparison of findings across studies using population density to classify rurality remains difficult.

The ASGS RA [34] was referenced in most of the include papers from Australia. Whilst more consistently used in Australia studies, like population density, the ASGS RA only measures a single attribute for a construct that is multifactorial. An alternative measurement scale, the Index of Rural Access, was developed in Australia and combines the key elements of access to primary health services in rural areas, spatial accessibility, population health needs and mobility [80]. This measure provides a more sensitive classification method [80] and has the ability to identify access differences within rural populations at a much finer geographical level. Another key consideration regarding rurality classification methods is the variation in the size of the area each classification area represents and that often studies are reporting outcomes in broad regions dichotomised into 'rural' and 'urban' groups. For example, classifications of population density are examined at the county level and ASGS RA classifications are by postal code, each of which are relatively broad and encompass a variety of populations and services within each classification category. To improve the specificity of measurement across different spatial areas, a distance-based approach to analysis may be more beneficial. In the recent study by Jarman et al. [76], they effectively utilised a distance-based geospatial method to evaluate the association between distance to the nearest trauma centre and odds of death. With advances in geospatial methods, spatial analyses have been used increasingly in public health research as an effective method to explore patterns of injury and evaluate the spatial organisation and accessibility of acute trauma care systems [76,81–87]. Future research utilising geospatial methods to explore to the impact of location on healthcare service utilisation and longer-term outcomes following injury may be beneficial in this cohort.

There were also variations in the mortality statistics reported in the literature and in particular methods used to calculate mortality rates. Although SMR was most commonly used, it is a population based estimate and lacks specificity. Denominators used such as the Emergency Medical Services (EMS) attended population [44] and number of licenced drivers [57] in road trauma cohorts may provide more specific insight into variations in mortality rates. There was also large variation in the study population sizes which we were unable to account for when drawing conclusions due the heterogeneity of the literature and inability to conduct a meta-analysis.

Another limitation of the available literature was the heterogeneity of the study populations in regards to age group and injury profile. Traumatic injury is an inherently difficult area of research due to the heterogeneity of the condition, however, without further research on targeted groups of patients following traumatic injury, such as head injury and orthopaedic trauma, it is difficult to make inferences from the data. Furthermore, with the rapidly increasing number of older major trauma patients experiencing poor long-term outcomes [48], it may also be important to give further consideration and priority of research to geographic variation in outcomes following traumatic injury in older adults.

Finally, despite the majority of the world's burden of injury being borne by low and middle income countries (LMIC) [88] where the impact of rurality is likely to be amplified due to poverty and limited health care, there has been little research carried out on the impact of geography in these countries, highlighting another important area for future research.

As well as the limitations of the literature included in this review, other limitations of this scoping review must be considered. Firstly, although multiple databases were searched using broad search terms, there is always the possibility that not all relevant articles were identified by this strategy. Whilst there was only one reviewer conducting the review of available literature and data extraction, any papers where there was uncertainty in methodology or reporting of results were discussed with all authors until a consensus was reached. Additionally, because scoping reviews do not typically include a quality assessment of included studies, data synthesis and interpretation may be limited [89,90]. A strength of this paper however was the robust search strategy and identification of three major groups of outcomes explored in the literature. Thus, even if a relevant article was missed, it is unlikely that any other significant category of outcome was excluded from this review.

Conclusion

This review suggests that the overall and pre-hospital risk of death following injury is higher for rural patients. However, once admitted to hospital, there appears to be no difference in mortality. There was a paucity of data regarding the impact of geography on non-mortality outcomes and significant inconsistency in findings in the available literature related to the types of outcomes being reported, and time points after injury at which these are assessed. There was a paucity of data regarding the impact of geography on non-mortality outcomes and significant inconsistency in findings amongst available literature such as the types of outcomes being reported and time points after injury at which these are assessed. These inconsistencies need to be further explored to better understand whether rurality may influence longer term recovery outcomes following injury.

Furthermore, without consistent methods of classifying rurality and measures reported following injury it is difficult to make inferences from the already limited literature. Researchers may wish to consider the use of geographic information systems to develop a more specific and consistent international classification method to determine the impact of place on outcomes. Most importantly, additional research is necessary to develop a larger evidence base to enhance the understanding of geography on acute and long-term outcomes following injury.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.injury.2019.07.013.

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