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Clinical paper

A comparison of metropolitan vs rural major trauma in Western Australia☆

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ABSTRACT

Background: Metropolitan and rural Western Australia (WA) major trauma transport times are extremely different. We compared outcomes from these different systems of care.
Methods: Major trauma (Injury Severity Score, ISS > 15) data from the Royal Flying Doctor Service (RFDS) and Trauma Registries, 1 July 1997–30 June 2006. Two groups were studied: Metro (metropolitan major trauma transported directly to a tertiary hospital), and Rural (rural major trauma transferred by the RFDS to a tertiary hospital in Perth). The primary endpoint was death. We used logistic regression and multiple imputation.
Results: 3333 major trauma patients were identified (mean age 40.1 ± 22.6 yrs; Metro = 2005, Rural = 1328). The rural patients were younger, had a larger proportion of motor vehicle crashes, and higher median ISS (25 vs 24, $p < 0.001$). Mean times to definitive care were 59 min versus 11.6 h, respectively ($p < 0.0001$). After adjusting for age, injury severity and the effect of time with the initial rural deaths, there was a significantly increased risk of death (OR 2.60, 95% CI 1.05–6.53, $p = 0.039$) in the Rural group. For those rural patients who reached Perth, the adjusted OR for death was 1.10 (95% CI 0.66–1.84, $p = 0.708$).
Conclusion: There is more than double the risk of major trauma death in rural and remote WA. However, if a major trauma patient survives to be retrieved to Perth by the RFDS, then mortality outcomes are equivalent to the metropolitan area.

1. Introduction

The conventional paradigm of trauma care is that it is a time critical condition.[1] Hence, the ideal system for managing trauma patients is one in which the time from injury to definitive care is minimised.[2] However, time from injury to definitive care for rural trauma patients is prolonged.[3] As such, the 'golden hour' of trauma care has little relevance for this population, especially in rural and remote Western Australia (WA).

Mortality from rural trauma increases with delays until discovery of the victim or delays in accessing the trauma system.[3] We have previously quantified the direct relationship between remoteness and trauma deaths in WA.[4] We found that the death rate in very remote areas is over four times the rate in major cities.

This study describes the epidemiology and outcomes of major trauma patients transferred from rural and remote WA by the Royal Flying Doctor Service (RFDS). These data are compared to metropolitan major trauma patients in a population based study. The transport times for these two groups of patients are extremely different and we compared the mortality of these two groups of patients, for those who survive long enough to reach a hospital of definitive care in Perth.

2. Methods

2.1. Study design

We obtained data from the RFDS database, on all their major trauma (Injury Severity Score, ISS > 15) transfers to Perth from 1 July 1997 to 30 June 2006. Additional data from the state's Trauma Registries was also obtained, including metropolitan major traumas. The two databases were linked by the WA Data Linkage Branch. Additional data was obtained from the Death Registry and the Australian Bureau of Statistics.

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The cohort was divided into two groups. Metro patients were metropolitan Perth major trauma patients who were transported directly to a tertiary hospital. Rural patients were rural and remote major trauma patients who were transferred by the RFDS to a tertiary hospital in Perth.

2.2. Setting

WA has an area of 2.5 million km^2 with a population density of 0.8 people per square kilometre. The population at the 2001 census was 1.9 million, with 69.7% in Perth. Severely injured rural patients require transfer to Perth, as there is very limited specialist expertise in rural and remote WA, such as surgery and intensive care.[5] It is noteworthy that there are only 14 surgeons working in rural WA, of whom 6 are in Bunbury, 185 km south of Perth.[4]

The initial care of rural trauma patients may include first aid at a remote mine site, nursing post or small rural hospital.[5] Occasionally, initial care will be given by a member of the lay public being advised by the RFDS using a radio or satellite telephone. The injured patient is then transported by road or air to a regional hospital. These hospitals do not have the capacity for thoracic surgery, neurosurgery or intensive care, so patients are then flown to Perth, with another road ambulance transport to a tertiary hospital.[5]

With the scarce staff and resources in rural and remote WA, it has been stated that "the patient has undergone a trial of survival before reaching any medical facility".[5] Transport distances can be over 2000 km, thus adding to the burden of time. Trauma represents the largest transfer group for the RFDS, comprising 27% of all patients carried.

The RFDS maintains an extensive retrieval database. Data extracted for this study comprised all patients with a diagnosis coded within the Injury and Poisoning chapter of ICD 9. As poisonings were not relevant to this study, all cases with a code of 960.0 and above (poisoning by drugs, medicinal and biological substances) were excluded, thus leaving trauma patients only.

Perth is remarkable for its isolation from other major cities. Its population in the 2001 census was 1.4 million and the metropolitan area is about 5000 km^2. There is a single emergency ambulance service for the metropolitan area. There are trauma registries which cover each tertiary hospital and use identical databases and data definitions.

It is important to highlight that deaths that occurred at the rural hospital prior to transfer are excluded in the rural group. Further, major trauma patients who exclusively attend a rural hospital are not captured by the Trauma Registries. Using Death Registry data from our previous work[4], we identified 185 deaths that occurred at rural hospitals prior to transfer to Perth. These were independently assessed by the Royal Perth Hospital Trauma Registry to determine if they would have been eligible for inclusion into the Trauma Registry as a major trauma. However, these patients are not the focus of this study and are reported simply to describe the method of obtaining the correct numbers.

Approval for the study was by the ethics committee of the University of Western Australia, and the Western Australian Department of Health, Human Research Ethics Committee.

2.3. Statistical analysis

Data were analysed using SPSS (version 16; SPSS Inc, Chicago, IL, USA) and Stata (Release 11: StataCorp LP, College Station, TX, USA). Descriptive statistics were used to describe the cohort, including the arithmetic mean, Student's *t*-test and ANOVA (for normal data) and median, inter-quartile range (IQR), geometric mean and Chi square, Kruskal–Wallis and Mann–Whitney tests for non-normal data. Where appropriate, corrections for multiple comparisons were applied for univariate tests using the sequential rejection method of Holm.[6]

Table 1
Demographic and injury data.

	Metro n = 2005	Rural n = 1328	p-Value
Mean age (yrs ± SD)	43.9 ± 24.3	34.2 ± 18.3	<0.001*
Sex (male)	1425 (71%)	979 (74%)	0.09
Cause			
MVC	918 (45.8%)	676 (62.5%)	
Falls	593 (29.6%)	73 (6.8%)	<0.001*
Other[a]	494 (24.6%)	332 (30.7%)	
Mean initial RTS	6.85	7.04	0.05
95% CI	6.76–6.94	6.87–7.20	
Mean RTS on arrival at tertiary hospital	6.85	7.63	<0.001*
95% CI	6.76–6.94	7.57–7.68	
Median ISS (IQR)	24 (17–29)	25 (18–29)	0.001*
Range	16–75	16–75	

MVC: motor vehicle crash; RTS: revised trauma score; ISS: injury severity score; IQR: interquartile range.
* Remains significant after correction for multiple comparisons.
[a] Other includes: struck by object, stabbing, fire, gunshot, recreational, crushing, electrical, explosion.

The primary outcome for this study is death in hospital, so the analysis was conducted using univariate and multivariate linear logistic regression analysis to describe the association of variables with the risk of death and to create a multivariable model of risk of death. We used the Hosmer and Lemeshow goodness-of-fit test[7] to check that the models were valid, and the area under the ROC curve to describe concordance between model prediction and observed data. We validated the models using bootstrap estimation of the standard errors to provide robust estimates of 95% confidence intervals and p-values. We regarded a p-value < 0.05 as statistically significant.

A major statistical and interpretational challenge for this dataset is the presence of selection bias as a consequence of missing observations. These fall into two categories and different approaches were adopted to deal with them. The first category concerns missing observations of variables. This is particularly obvious for the time variables but also applies to some other variables which relate to the episode before attendance at the tertiary hospital, e.g. Revised Trauma Score (RTS). We used Heckman selection models[8] to assess the nature of the missing data and multiple imputation using the Stata statistical analysis package with 40 imputed data sets. We also used the user-written ICE package[9] to examine the sensitivity of the imputation. Analysis of the multiple imputation dataset used methods that applied 'Rubin's Rules'[10] to adjust the degrees of freedom for the estimation of p-values. We used the user-written MIM package[11] for analysis of multiply imputed data. Interaction terms for time and injury severity were used in the modelling.

The second category of missing data concerns cases missing because they died prior to arrival of the RFDS. Imputation is not suitable in this case because all we know about the missing cases is that they are dead and they belong to the Rural group. We used weighted logistic regression analysis of the imputed data set to address this selection bias. The weights were based upon the inverse of the probability of dying before Emergency Department attendance as shown in Table 3: metro deaths: 1.0; rural deaths: 2.04.

3. Results

There were 3333 major trauma patients identified in the nine years of the study. Table 1 describes the demographic and injury data which are significantly different for age, cause and severity. Note that while the rural patients had a higher median ISS, the improved RTS reflects the longer time interval from trauma

Table 2
Injury severity score (ISS) severity categories.

ISS	Metro	Rural	Total
16–24 Moderate 95% CI	1046 (52.2%) 50.0–54.4	610 (45.9%) 43.2–48.7	1656 (49.7%)
25–49 Severe 95% CI	827 (41.2%) 39.1–43.4	663 (49.9%) 47.2–52.6	1490 (44.7%)
50+ Critical 95% CI	132 (6.6%) 5.6–7.8	55 (4.1%) 3.2–5.4	187 (5.6%)

Chi square = 29.6 p-value < 0.0001.

Table 4
The key time variables for each group. Observed time data, reported as geometric mean (95% CIs).

	Metro	Rural	p-Value
Time 1	18 min (17–19)	55 min (48–63)	<0.001
Time 2	43 min (41–45)	10.1 h (9.6–10.7)	<0.001
Time 3	59 min (57–61)	11.6 h (11.2–12.1)	<0.001

Time 1: time of trauma to time of first provider input (usually ambulance). Time 2: time of first provider input (usually ambulance) to time of arrival at tertiary hospital. In the Rural group, this time includes prehospital care, rural hospital care and RFDS retrieval care. Time 3: time of trauma to time of arrival at tertiary hospital Emergency Department. Note that time 3 does not equal the sum of times 1 and 2 because of different numbers of missing values.

event to arrival in Perth with the associated period of resuscitation. There were no differences between the groups for anatomic region injured. There was a larger proportion of chest injuries in the Rural group (721, 54.3% vs 1001, 49.9%; $p = 0.015$) but this was not significant after correction for multiple comparisons. Importantly, the total number with greater than 4 anatomic regions injured in the Rural group was significantly greater (168, 12.6% vs 197, 9.8%; $p < 0.0001$). Table 2 highlights the different patterns of injury severity.

Table 3 reports the outcome data and highlights further differences between the groups, especially for the proportion admitted to ICU, the length of stay in hospital and the deaths in each group. The longer length of stay in the Rural group is influenced by the longer time it takes to repatriate rural patients. Review of the Death Registry data resulted in an additional 115 deaths in the Rural group that were assessed as major trauma deaths.

The time intervals are significantly different for each group, consistent with the different processes of care and the distances involved (Table 4). Time data is the most frequently missing, due to the unpredictable nature of trauma. There were 1928 (57.8%) missing values for time 1, 1016 (30.5%) missing for time 2, and 1381 (41.4%) missing for time 3. The Heckman selection models indicated that missing time data were, at worst, missing at random[9] (p-values for the inverse Mill's ratio were: time 1, $p = 0.880$; time 2, $p = 0.212$; time 3, $p = 0.495$), and this did not alter the results of the primary analysis. The imputed time interval data were not significantly different to the observed data.

Table 5 reports the logistic regression model for death in the Rural group compared to the Metro group, after using imputed data and weighting the analysis for the rural hospital deaths. This demonstrates that the predictor variables for death are age, ISS, ISS^2, RTS and total number of regions injured. However, pre-tertiary hospital time was not included in this model.

3.1. Effect of time

We used logistic regression to examine the effects of time on risk of death for the entire cohort, weighted to correct for the deaths that occurred prior to the arrival of the RFDS. The model included times 1 and 2, age, ISS, ISS^2 and interaction terms between ISS and times 1 and 2. This demonstrated a 19% increased risk of death per hour of time 1 (OR 1.19, 95% CI 1.03–1.39, $p = 0.02$) and the interaction between ISS and time 1 (OR 0.99, 95% CI 0.99–1.00, $p = 0.056$) approached significance. So the longer it takes for the ambulance to arrive, the risk of death increases, and this is likely to be influenced by injury severity. Time 2 is associated with a decreased risk of death of 17% per hour, which is equivalent to 60% of the risk for time 1 (OR 0.83, 95% CI 0.71–0.97, $p = 0.02$), but there was no significant interaction with ISS ($p = 0.138$). So once the ambulance arrives, the risk of death decreases, and injury severity is not relevant. These results are after adjusting for age and injury severity.

We then compared the Metro and Rural groups in the model, and also weighted it for the deaths that occurred prior to the arrival of the RFDS. After adjustment for age, ISS and the interaction terms, there was a significantly increased risk of death (OR 2.62, 95% CI 1.05–6.53, $p = 0.039$) in the Rural group. When times 1 and 2 were replaced by time 3 (i.e. total pre-tertiary hospital time), total time was not a significant predictor ($p = 0.302$). So if the patient survives to be transported to Perth by the RFDS, time does not matter, and this is not influenced by injury severity (interaction term $p = 0.836$); (OR for death in Rural group = 0.99, 95% CI 0.57–1.72, $p = 0.972$).

In summary, time prior to ambulance arrival is a significant predictor of the risk of death, after adjusting for age and injury severity. There is a significant negative interaction between the time prior to ambulance arrival and injury severity. This suggests that the influ-

Table 3
Outcome data.

	Metro $n = 2005$	Rural $n = 1328$	p-Value
Admitted (ICU)	744 (37.1%)	703 (52.9%)	<0.001*
Median ICU LOS (days) (IQR) Range	4 (2–10) 1–51	5 (2–11) 1–56	0.001*
Median hospital LOS (IQR) Range	9 (3–19) 0–742	12 (6–24) 0–282	<0.001*
Initial TRISS 95% CI	0.811 0.795–0.827	0.882 0.865–0.898	
Death in tertiary hospital	395 (19.7%)	111 (8.4%)	<0.001*
Deaths at referring hospital included 95% CI	395 (19.7%) 18.0–21.5%	226(15.7%) 13.8–17.7%	0.002*

ICU: intensive care unit; LOS: length of stay; IQR: interquartile range; TRISS: trauma revised injury severity score; initial TRISS: the first calculated TRISS in the pre-tertiary hospital phase.

* Remains significant after correction for multiple comparisons.

Table 5
Multivariable logistic regression for death by group (Metro group is reference) using imputed data, weighted by selection fraction. This table corrects for the selection bias that results from the deaths that occurred prior to transfer to the tertiary hospital of definitive care as well as bias from missing values, but does not include time in the model.

Variable	OR	95% CI	p-Value
Rural group	1.10	0.66–1.84	0.71
Age	1.06	1.05–1.07	<0.001
ISS	1.17	1.08–1.27	<0.001
ISS^2	1.00[a]	1.00–1.00	0.04
RTS	0.44	0.38–0.50	<0.001
Total number of anatomic regions injured	0.73	0.65–0.92	0.001

Hosmer–Lemeshow $p = 0.953$. Area under receiver operator curve = 0.92. ISS: injury severity score; RTS: revised trauma score.

[a] OR = 0.9990 (95% CI 0.9979–0.9999).

ence of higher injury severity occurs at earlier rather than later times. This indicates that when critical injuries are influenced by the time to first prehospital care, they cause death quickly.

4. Discussion

This population based study reports a comparison between the conventional urban trauma paradigm of the 'golden hour' and the unique geographic isolation of rural and remote WA that requires prolonged transport times for definitive care. In general terms, the mortality outcomes reflect age, injury severity and location. However, if a major trauma patient survives to be transferred to Perth by the RFDS, their mortality is equivalent, partly reflecting the 'self-selection' that occurs.[12,13]

There have been few population based studies of major trauma.[14–17] They are often limited by failures to account for interhospital transfers, prehospital deaths, or referrals from outside the base population.[17] Comparisons can be difficult because of variability of definitions of severe trauma and methodologic inconsistencies.[17] A strength of this study is the use of multiple data sources that were linked using a data linkage system. This enabled the cohort to truly reflect population based data over a substantial period of time. The major weakness is the limited data available from the Death Registry. This could be addressed by routine data sharing between the Death Registry and the Trauma Registry, which would allow for collection of improved descriptive data such as time intervals and injury severity. This would better inform the rural trauma system.

While the organisation of the process of trauma care delivery is crucial to optimise outcomes, there is much regional and international variation in trauma care delivery.[18] The ideal system for management of major trauma remains controversial, especially in relation to pre-hospital care and regionalisation of trauma care delivery.[18] For patients who survive long enough to receive RFDS care, the benefits of the resuscitation care provided, together with the role of the rural hospitals, appear to be significant in our study. This is consistent with the report by Gomes et al., that pre-trauma centre interventions may significantly decrease mortality.[19] These processes represent local solutions to a complex organisational problem.[18]

Nathens et al. argue that the importance of time in the context of an organised trauma system is overstated.[18] Our findings are in keeping with this statement and recent work that time may be less crucial than once thought.[19–21] Our more detailed data indicates, however, that time from the trauma to initial prehospital care is very important and influenced by injury severity. The 'golden hour' phrase might be better stated as 'time is traumatic.' This highlights the importance of quickly getting into a system of care for those who are critically injured, which is obviously more difficult in a rural environment. Our results also show that more time after ambulance arrival is approximately 60% less hazardous than time from trauma to ambulance arrival. So prevention remains the biggest opportunity for large improvements in trauma outcomes.

Missing data are a frequent complication of any real world study.[22] The unpredictable nature of trauma means that essential data such as times and some of the physiologic data will be missing. Multiple imputation procedures that handle missing data now exist and were employed for this study. These procedures make outcomes stronger by not excluding important observations.[23] Our results demonstrate the use of this approach and found that imputation decreased the bias from missing values. The selection bias produced by missing patients because of early mortality (i.e. the deaths that occurred prior to arrival at the hospital of definitive care) was corrected by using weighted analysis. There are limitations to the use of multiple imputation.[24] Missing data creates problems because of selection bias and loss of efficiency. No other method has been developed to address these issues with a valid underlying statistical theory.

5. Conclusion

In conclusion, we found that there is more than double the risk of major trauma death in rural and remote WA. However, if a major trauma patient survives to be retrieved to Perth by the RFDS, then mortality outcomes are equivalent to the metropolitan area.

Conflicts of interest

There are no conflicts of interest to declare.

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