Major Trauma Patients Transferred From Rural and Remote Western Australia by the Royal Flying Doctor Service

Daniel M. Fatovich, MBBS, FACEM, Michael Phillips, BSc (Hons), MMedSci, Ian G. Jacobs, BAppSc, RN, PhD, and Stephen A. Langford, MBBS, FAFPHM, FRACGP, MRACMA, DipRACOG

Background: The "golden hour" of trauma care is irrelevant in rural areas. We studied the effect of distance and remoteness on major trauma patients transferred by the Royal Flying Doctor Service from rural and remote Western Australia.

Methods: The Royal Flying Doctor Service retrieval and Trauma Registry databases were linked for the period of July 1, 1997, to June 30, 2006. Major trauma was defined as Injury Severity Score (ISS) >15. Remoteness was quantified using the Accessibility/Remoteness Index of Australia (ARIA) classes: inner regional, outer regional, remote, and very remote. The primary outcome was death.

Results: Among 1328 major trauma transfers to Perth, mean age was 34.2 years ± 18.3 years (range, 0–87 years) and 979 (73.7%) were male. Over half were motor vehicle crashes. Mean transfer time was 11.6 hours (95% confidence interval [CI], 11.2–12.1). The median ISS was 25 (interquartile range [IQR], 18–29), and there were no differences within the ARIA classes for cause and injury patterns. After adjusting for ISS, age, and time, the risk of death increases as remoteness increases: outer regional odds ratio (OR), 2.25 (95% CI, 0.58–8.79); remote, 4.03 (95% CI 1.04–15.62); and very remote, 4.69 (95% CI, 1.23–17.84). Risk increases by 87% for each 1,000 km (OR, 1.87; 95% CI, 1.007–3.48; $p = 0.05$) flown. Despite long retrieval times, there were no deaths in flight.

Conclusion: There is an excess of a fourfold increase in the risk of major trauma death in patients transferred to Perth from remote and very remote Western Australia. Remoteness, as measured by the ARIA, is more important than distance, in the risk of death.

Key Words: Major trauma, Remoteness, Rural, Royal Flying Doctor Service, Retrieval.

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From the Department of Emergency Medicine (D.M.F.), University of Western Australia; Western Australian Institute for Medical Research (M.P.), University of Western Australia; Discipline of Emergency Medicine (D.M.F., I.G.J.), University of Western Australia; and Department of Medical Services (S.A.L.), Royal Flying Doctor Service Western Operations, Western Australia, Australia.
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Address for reprints: Daniel M. Fatovich, MBBS, FACEM, Department of Emergency Medicine, Centre for Clinical Research in Emergency Medicine, Western Australian Institute for Medical Research, Royal Perth Hospital, Box X2213 GPO, Perth, Western Australia 6847, Australia; email: daniel.fatovich@health.wa.gov.au.

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The Royal Flying Doctor Service (RFDS) was the first comprehensive aerial medical organization in the world, commencing in 1928.[1] Its work is woven into the fabric of life in outback Australia, providing a range of primary health care and emergency services across extensive areas of rural and remote Australia.[1] Trauma represents their largest transfer group, comprising 27% of all patients carried.[2] In Western Australia (WA), the most commonly transferred injuries are major head injury and thoracic trauma.[3]

The conventional urban trauma paradigm is that the time from injury to definitive care should be minimized. However, time to definitive care for rural trauma patients is prolonged.[4] As such, the "golden hour" of trauma care[5] is irrelevant for this population, especially in WA, which is predominantly rural and has a vast expanse of remoteness.

We have previously quantified the direct relationship between remoteness and all trauma deaths in WA regardless of severity using Death Registry and population data.[6] In a separate study using linked Trauma Registry and RFDS data, we found that if a major trauma patient survives to be retrieved to Perth by the RFDS, their mortality is equivalent to a major trauma in the Perth metropolitan area, partly reflecting the "self-selection" that occurs.[7] However, the issue of remoteness and major trauma was not specifically studied. This article provides a detailed description and examination of the effects of distance and remoteness on major trauma patients transferred by the RFDS from rural and remote WA.

MATERIALS AND METHODS

An extensive retrieval database is maintained by the RFDS. Data were extracted for the period of July 1, 1997, to June 30, 2006. This consisted of all patients with a diagnosis coded within the Injury and Poisoning chapter of International Classification of Diseases 9. All cases with a code of 960.0 and above (poisoning by drugs, medicinal, and biological substances) were excluded, leaving trauma patients only.

Major trauma is defined as an Injury Severity Score (ISS) >15.The trauma registries at the tertiary hospitals use identical databases and data definitions. Additional data, such as the distance flown by the RFDS, was obtained from the RFDS database. The two databases were linked by the WA Data Linkage Branch.[8] The variables of interest included demographic data, cause, remoteness location of the trauma, distance flown, ISS, outcome data, and time data. ISS was

categorized using the classification by Sampalis et al.[9]: ISS, 15–24 (moderate); ISS, 25–49 (severe); and ISS ≥50 (critical). Approval for the study was provided by the ethics committee of the University of Western Australia and the Western Australian Department of Health, Human Research Ethics Committee.

Setting—Western Australia

WA is a state with an area of 2.5 million km^2, and at the time of the study had a population of 2 million people with one major metropolitan area (Perth) of 1.4 million. Perth has been described as the most remote city on earth.[10] The only tertiary hospitals in the state are in Perth. Transferring trauma patients for definitive care over distances of up to 2,500 km is required.

We have previously described the rural trauma system in WA.[6] In summary, there is limited specialist expertise in rural and remote WA, and the rural hospitals do not have the appropriate resources to provide definitive care of major trauma patients. Hence, major trauma patients require transfer to one of the four tertiary hospitals in Perth. About two thirds of these are treated at Royal Perth Hospital. This study is focused on those rural and remote major trauma patients who survive long enough to reach the hospital of definitive care in Perth. Major trauma patients who die before transfer are not the subject of this article. 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."[11]

The vast distances to be traveled to receive tertiary trauma care in Perth are unique, and the RFDS provides the required interhospital transfers. Such transfer distances are at odds with the conventional approach to trauma that the "golden hour" is critical to patient outcome.[12] Rather than reaching definitive care within 1 hour, patients from rural and remote WA take a mean of 11.6 hours (95% CI, 11.2–12.1) to arrive at the hospital of definitive care in Perth.[7]

Accessibility/Remoteness Index of Australia

To quantify remoteness, we used the Accessibility/Remoteness Index of Australia (ARIA). ARIA was developed by the National Centre for Social Applications of Geographic Information Systems, as a standard national measure of remoteness.[13] Accessibility and remoteness are two ends of a continuum, which describes the ease or difficulty that one can access a range of services.[13] Some services available in larger centers are not available in smaller centers. As a geographic accessibility index, it reflects the ease or difficulty people face in accessing services in nonmetropolitan Australia.[13] ARIA excludes any consideration of socioeconomic status, rurality, and population size factors; it is purely a geographic measure of remoteness.[13] ARIA is used by the Australian Bureau of Statistics.

The ARIA is classified into five discrete remoteness classes, termed remoteness areas.[13] These are major cities, inner regional, outer regional, remote, and very remote. The proportions of WA's geographical area in each of these remoteness classes are as follows: 0.07%, 0.71%, 3.42%, 9.99%, and 85.81%, respectively.[14] Hence, WA is predominantly very remote. The proportions of the WA population at the time of the study, in each of these remoteness classes was 69.77%, 11.86%, 9.64%, 5.28%, and 3.45%, respectively.[15] This study uses these remoteness area categories to describe the location of the trauma event. (It is not the location of the airstrip that the RFDS collected the patient from.) For ease of writing, whenever we use the term ARIA, we are referring to the ARIA+, which is the updated version. Our previous article displays the ARIA map of WA.[6]

Statistical Analysis

Data were analyzed using Stata (Version 11.1; StataCorp LP, College Station, TX) and SPSS (Version 17; SPSS, Chicago, IL). The primary outcome was death in hospital. The primary methods of univariate analysis were the χ^2 test for dichotomous independent variables such as gender and the Wilcoxon independent samples rank-sum test (Mann-Whitney U test) for continuous or ordinal variables. The time intervals and distance flown by patients transported by the RFDS follows a skewed lognormal distribution and consequently the geometric mean was used as an unbiased estimate of the average. Estimates of the risk of death were based on the OR, and multivariable logistic regression analysis was used to adjust the estimates for age and gender and to examine the role of other variables as effect modifiers or confounding factors; 95% CIs were calculated. The adequacy of the models was assessed using the Hosmer and Lemeshow[16] goodness-of-fit test, and predictive power was assessed by the area under the receiver operator characteristics curve. Significance was set at 0.05.

Age was standardized by subtraction of the mean for all subjects so that the constant in the multivariable regression models shows the risk of dying for an average aged person rather than the risk for a person aged zero. Similarly, the ORs and coefficients for age relate to the difference in risk for each year over the mean age.

RESULTS

There were 1,328 major trauma patients in the 9 years of the study. Their mean age was 34.2 years ± 18.3 years (range, 0–87 years) and 979 (73.7%) were male. There were no deaths during RFDS transfer. A detailed description of the mechanism of injury is reported in Table 1. Over half resulted from a motor vehicle crash. Only 22 cases (2.2%) resulted from penetrating trauma. Table 2 provides a more detailed description according to the ARIA category. This highlights that age decreases as remoteness increases. The overall median ISS was 25 (IQR, 18–29). We found no differences within the ARIA categories for cause, body region injured, or total number of body regions injured. Moreover, there was no confounding by age, ISS, ARIA category or distance, and the ISS was the same in each ARIA category ($p = 0.52$). There were no significant differences with those who had missing ARIA data, except that the missing data had an increased proportion of deaths (40 of 340, 11.8%, $p = 0.04$).

Table 3 reports the important time intervals and mean distance flown according to ARIA category, reported as geometric mean. The overall median distance flown was 383 km (IQR, 217-1037 km). Table 4 reports the logistic regres-

sion model for death. This model correctly identifies the outcome for 94% of cases with an area under the receiver operator characteristics curve of 0.82 (95% CI, 0.79–0.84).

There was no significant interaction between distance and time, ARIA and time, and distance and ARIA. After adjusting for ISS, age, and time, the risk of death increases as remoteness increases. As expected, the critically injured (ISS ≥50) had the greatest risk of death. Age is also important, with each year above the mean age increasing the risk of death by 2.4%. Distance and ARIA are colinear and therefore cannot be included in the same model. The pattern of risk increasing with increasing remoteness shown with the ARIA model is confirmed by a model with distance, where risk increases by 87% for each 1,000 km (OR, 1.87; 95% CI, 1.007–3.48; $p = 0.05$) flown.

However, this is an underestimate when compared with the effect of remoteness. The decreased risk of death with longer pretertiary hospital time is a reflection of the self-selection that occurs in this cohort.

Clinical Scenario

The following case is illustrative of some of the issues in relation to remoteness, distance, and time: A 24-year-old male tourist motorbike rider in very remote WA swerved to avoid an object on the road. He lost control, skidded on gravel, and rolled several times before being thrown off. The bike landed on top of him. He was not discovered for 15 hours, but was conscious when found. The ambulance transported him to the local district hospital, where his initial observations were as follows: pulse 68 bpm, blood pressure not recordable, and Glasgow Coma Scale score 12. He spent 4 hours there before the RFDS retrieved him 632 km to Perth, arriving 22.8 hours after injury, in a periarrest state. Despite resuscitative thoracotomy in the emergency department, he died 23 minutes after arrival. His ISS was 21 and he had the following injuries: bilateral hemothoraces, bilateral pulmonary contusions, cardiac contusion, mediastinal hemorrhage, fractured scapula, thermal burns to the arm, and multiple abrasions and contusions.

TABLE 1. Mechanism of Injury for Major Trauma Patients Transferred by the Royal Flying Doctor Service to Perth

Cause	n (%)
MVC driver	257 (26.4)
MVC front passenger	109 (11.2)
MBC rider	108 (11.1)
Struck by object	96 (9.9)
MVC—back passenger	89 (9.2)
Pedestrian	51 (5.2)
Fire	40 (4.1)
Fall from standing	38 (3.9)
Fall >3 m	31 (3.2)
Fall ≤3 m	24 (2.5)
Miscellaneous other*	129 (13.3)
Total	972 (100)

MVC, motor vehicle crash; MBC, motor bike crash.
* Includes stabbing, explosives, pedal cyclists, machinery, gunshot, burns, and sports.
Data are missing for 356 (26.8%) cases.

DISCUSSION

This cohort of major trauma transfers by the RFDS is remarkable and unique for the magnitude of times and distances involved. We have shown that remoteness, as measured by the ARIA, is more important than the distance patients are flown by the RFDS, for the outcome of death. Obviously, ARIA, distance, and time are all interrelated. This study quantifies the relative importance of these, after controlling for age and ISS.

These findings are consistent with our previous Death Registry study on all trauma deaths in WA.[6] However, this study highlights the greater magnitude of this remoteness effect on death from major trauma. This is to be expected because of the reduced accessibility to "normal" emergency and health services, mainly from the prolonged times but also the reduced capacity of these services. Clinically, this results in a greater physiologic derangement, such as acidosis, hypoxemia, and coagulopathy. Although not specifically studied, the role of the rural hospitals and the resuscitation and transfer care provided by the RFDS seem to be clinically significant. This is highlighted by the fact that there were no deaths during retrieval.

It is important to note that major trauma patients who die before RFDS transfer are not included in this analysis, because these data are unavailable. However, they underscore the importance of prevention and using systematic means to decrease this remoteness effect. Prevention represents the

TABLE 2. Descriptive Data According to ARIA Remoteness Class

	Inner Regional	Outer Regional	Remote	Very Remote	*p*
n*	118 (12.0%)	255 (25.8%)	196 (19.8%)	419 (42.4%)	
Mean age (yr)	35.1 ± 22.8	34.6 ± 19.7	32.4 ± 16.7	32.0 ± 16.0	0.02
Sex (male)	87 (73.7%)	198 (77.6%)	150 (76.5%)	290 (69.2%)	0.07
Median ISS (IQR)	24 (18–33)	25 (19–29)	25 (19–34)	25 (18–29)	0.52
Admitted ICU	69 (58.5%)	128 (50.2%)	106 (54.1%)	219 (52.3%)	0.50
Median days ICU (IQR)	5 (2–10)	6 (2–12)	6 (2–15)	4 (2–10)	0.38
Median LOS (d IQR)	12 (8–24)	11 (5–21)	12 (7–29)	12 (6–24)	0.44
Death (95% CI)	7 (5.9%) (2.6–12.3)	17 (6.7%) (4.1–10.6)	20 (10.2%) (6.5–15.5)	27 (6.4%) (4.4–9.4)	0.33

RTS, Revised Trauma Score; ICU, intensive care unit; LOS, length of stay in hospital.
* Three hundred forty (25.6%) did not have an ARIA category determined because of missing data on the precise location of the trauma event.

TABLE 3. Mean Time and Distance Data According to ARIA Remoteness Class

	Inner Regional	Outer Regional	Remote	Very Remote	*p*
n	118	255	196	419	
Time from trauma to first provider (95% CI)	29 min (21–39)	34 min (26–45)	1.0 h (0.75–1.4)	1.2 h (0.9–1.5)	<0.001
Time (h) from first provider to arrival at Perth ED (95% CI)	8.6 h (7.4–10.0)	9.5 h (8.2–10.9)	8.9 h (7.9–10.1)	12.3 h (11.1–13.6)	<0.001
Time (h) from trauma to arrival at Perth ED (95% CI)	9.8 h (8.8–10.9)	10.3 h (9.6–11.1)	9.9 h (9.1–10.7)	14.3 h (13.5–15.1)	<0.001
Mean kilometers flown (95% CI)	151 (148–154)	271 (258–285)	449 (404–499)	1, 109 (1, 055–1, 165)	<0.001

ED, emergency department.

TABLE 4. Logistic Regression Model Reporting Risk of Death in Major Trauma Patients Who Survive to be Transferred by the RFDS to Perth (Inner Regional and Moderately Severe ISS, 15–24 Are Reference)

Variable	OR	95% CI	*p*
ARIA remoteness class			
Outer regional	2.25	0.58–8.79	0.24
Remote	4.03	1.04–15.62	0.04
Very remote	4.69	1.23–17.84	0.02
Injury Severity			
ISS 25–49 (severe)	6.08	2.33–15.83	<0.001
ISS ≥50 (critical)	47.45	15.28–147.35	<0.001
Total time	0.92	0.86–0.99	0.03
Age standardized	1.02	1.01–1.04	0.005

Total time: time from trauma event to arrival at tertiary hospital in Perth.

biggest opportunity for large improvements in survival from major trauma. Specifically, this study highlights the very large proportion of motor vehicle crashes that were the cause of injury. Efforts to address this might include the use of technology, such as automatic crash notification systems that use car sensors and the global positioning system to signal local rural emergency services that a crash has occurred, together with the precise location.[4,17,18]

Mandatory training in first-aid and resuscitation (as part of the driver licensing system) would increase the pool of helpers at rural crash scenes and could ameliorate slower rural response times.[17] Indeed, our previous work highlights that the time from trauma to first provider input is the most important time interval in the rural trauma chain of survival, there being a 19% increased risk of death per hour.[7] Rural and remote road major trauma is a serious problem across Australia, and a national effort is required to address it.[17] The vastness of WA magnifies the major problems confronting rural trauma care viz access to the system and lack of resources. More specifically, they are as follows: victim discovery to begin system access, manpower, communications, transport facilities, and education and maintenance of skills.[19] However, we share the frustrations of others in this field in identifying recommendations that can make an impact. This reflects the complexity of trauma as a disease of society.

There were limitations to this study. Missing data are a frequent complication of major trauma studies because of the unpredictable nature of trauma.[20] However, our results show that the characteristics of those patients without ARIA data were similar to those with the ARIA data, except for a higher proportion of deaths. There are also concerns about the completeness, quality, and limitations in coverage of Trauma Registry data.[21] However, we used an established WA data linkage technique. This is one of only a handful of information-rich environments worldwide that have been constructed from the linkage of multiple, large, population-based, administrative datasets.[22]

CONCLUSION

There is in excess of a fourfold increase in the risk of major trauma death in patients transferred to Perth from remote and very remote WA. Remoteness, as measured by the ARIA, is more important than distance in the risk of death.

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