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The relationship between patient volume and mortality in NSW major trauma service hospitals

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ABSTRACT

Introduction: Conventional wisdom is that Major Trauma Services (MTS) treating larger volumes of severe trauma patients will have better outcomes than lower volume centres, but recent studies from Europe have questioned this relationship. We aimed to determine if there is a relationship between patient volume and outcome in New South Wales (NSW) MTS hospitals.
Materials and Methods: Retrospective observational study using data from the NSW State Trauma Registry from 2010 to 2019 inclusive. Adult patients with Injury Severity Score >15 transported directly to a NSW MTS were included. Outcome measures were mortality at hospital discharge, and intensive care unit and hospital length of stay. Generalised estimating equation models were created to determine the adjusted relationship between patient volume and the main outcome measures.
Results: The mean annual patient volume of the MTS ranged from 127.4 to 282.0 patients whilst the observed mortality rates p.a. ranged from 10.4 % to 17.19 %. Multivariate analysis, using low volume MTS as the reference, did not demonstrate a significant difference in mortality between high and low volume MTS (adjusted OR: 1.14 95 % CI: 0.98–1.25, $P = 0.087$). There was however a significant correlation between volume and length of hospital stay (adjusted β; 0.024, 95 % CI, 0.182 – 1.089, $P = 0.006$).
Conclusions: There was no mortality difference between high and low volume MTS demonstrated. Length of hospital stay significantly increased with increasing volume however.

Introduction

Trauma is the most common cause of death in first world jurisdictions for people under 45 years of age. In Australia road trauma and self-harm were both amongst the top ten causes of years of life lost in 2013 [1]. Systems of trauma care which decrease mortality are therefore important public health measures. Based on systems originally developed in the United States in the 1970s and 1980s modern trauma systems designate specialist centres for the management of severely injured patients as this has been associated with lower mortality [2]. Non-specialist facilities are bypassed by emergency medical services (EMS) with patients transported directly to the dedicated trauma centres wherever possible.

These specialist centres (known as Level 1 or Major Trauma Services - MTS) have all facilities required to immediately manage a critically injured patient available 24hours a day. An area of ongoing controversy however is the number of severely injured patients required for MTS to maintain expert capability and whether larger patient volumes result in better patient outcomes where capabilities between MTS are otherwise equivalent. Two systematic reviews [3,4] as well as a recent meta-analysis [5] conducted to evaluate the relationship between trauma centre volume and mortality were able to identify at best a modest relationship between trauma centre volume and mortality. Since publication of the meta-analysis in 2018, studies from England [6] (28 MTS) and the Netherlands [7] (13 MTS) have both failed to demonstrate an association between volume and mortality. The English system is

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notable for the degree of variation in size with centres ranging from 69 to 781 severely injured patients with injury severity score (ISS)>15 per year. Both studies concluded that centres with similar structure and processes of care can achieve comparable outcomes regardless of patient volume.

In Australian trauma system design the relationship between volume and outcome for MTS has been assumed in system design. In New South Wales (NSW) for example the number of MTS was actively reduced in 2009 to concentrate numbers at a smaller number of larger volume centres, despite the directing plan noting the supporting literature to be equivocal [8]. There is no previously published report examining the relationship between volume and outcome for MTS in any Australian jurisdiction. The aim of this project is to determine if there is a relationship between patient volume and outcome (mortality and process of care measures) at MTS in NSW.

Methods

Design

This study is a retrospective observational study and conforms to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for reporting of observational data [9]. The study was approved by the NSW Population and Health Service Research Ethics Committee, Project Identifier: 2020/ETH02623.

Setting

Patient data was obtained from the NSW Institute of Trauma and Injury Management's (ITIM) state wide trauma registry. The registry includes all patients with major trauma admitted to MTS and Regional Trauma Service (RTS) hospitals in NSW. The NSW Trauma Registry [10] at a minimum includes patients who were admitted to a Trauma Service within seven days of sustaining an injury, and who:

- Had an ISS > 12 (moderate to severely injured); or
- Died in hospital irrespective of ISS following injury, except those with an isolated fractured neck of femur injury sustained from a fall from standing height (<1 metre); or
- Admitted to the Intensive Care Unit (ICU) irrespective of ISS

In NSW all MTS are major teaching hospitals but no formal system wide trauma accreditation process for the hospitals was in place during the years of the study. System wide verification against Royal Australasian College of Surgeons Committee on Trauma verification guidelines was commenced the year following the study period with all MTS being assessed against the Level 1 standard.

Participants

Data was abstracted from the ITIM Registry for patients where:

- Age ≥16 years
- Injury occurred between the 1st January 2010 and 31st December 2019 inclusive
- ISS>15, and
- Patient was transferred directly from the incident scene to a NSW MTS.

Transferred cases were excluded from analysis. Inter-hospital transfers of severe trauma patients typically take greater than 8.5hours in NSW [11] whilst most trauma deaths occur in the first 1–2 h post injury [12,13]. Patients who survive long enough to be successfully transferred from a lower level facility may therefore bias apparent survivor rates in MTS that receive larger numbers of transferred cases.

Data abstraction

Data abstracted from the Registry on patients that met the inclusion criteria included:

- Treating facility and admission date
- Patient age, gender and mechanism of injury
- Total prehospital time (in minutes)
- Glasgow Coma Score (GCS), respiratory rate (RR), and systolic blood pressure (SBP) on arrival at the MTS
- Revised Trauma Score (RTS), ISS, New Injury Severity Score (NISS), Trauma Score-Injury Severity Score (TRISS) and Abbreviated Injury Scale (AIS) for head region
- Intubation prior to or during admission and ventilation days
- Hospital and Intensive Care Unit (ICU) Length of Stay (LOS)
- In hospital mortality

Outcome measures

The primary outcome measure is mortality at hospital discharge. The secondary outcome measures are ICU and hospital LOS.

Statistical analysis

Hospital volume was calculated for each MTS as an average of the severely injured patients (ISS>15) per hospital per year. Hospitals were then split into low and high-volume groups with a total of 6917 patients in the low volume (MTS $n = 4$) and 7656 patients in the high-volume hospitals (MTS $n = 3$) based on the median value of 212 patients per year. Normality of continuous data was checked by plotting histogram and variables with non-normal distribution were standardised using Z scores. Categorical data between low and high volume was compared by using Chi Square test while the continuous data was compared using independent samples *t*-test for normally distributed data and Mann Whitney *U* test for data with non-normal distribution. Multiple imputation was used to impute missing data for the analytic portion, assuming that Missingness occurred at random (MAR) as Missing Completely at Random (MCAR) was ruled out with Little's MCAR test being significant ($P < 0.001$). All variables with missing values were imputed using Fully Conditional Specification (FCS) method within the SPSS software. Within this method Markov Chain Monte Carlo (MCMC) technique was automatically selected to handle missing data. Five imputed datasets were created and pooled using Rubin's Rules (See supplementary Table 2) and a complete case analysis was carried out as well. Interaction terms were introduced to account for the interplay between the effects of age and gender and between the effects of age and GCS. Unadjusted volume-outcome relationships were assessed by plotting in-hospital mortality against hospital volume for all MTS. Generalised estimating equation models were created with binary in hospital mortality as the dependent variable and hospital length of stay as outcome variables. The low volume MTS group was used as reference for comparison with high volume group. The models were adjusted for patient age, gender, ISS, =AIS head region ≥ 3, SBP, GCS, RR, and penetrating mechanism. Inclusion of variables in the models was based on a-priori. All data analysis was conducted with IBM SPSS Statistics 26 (SPSS Inc., Chicago). Odds ratios presented are calculated per 50 additional patients. Results were considered statistically significant if the p-value was < 0.05.

Results

14,573 patients met the inclusion criteria after exclusions (Fig. 1).

The mean annual patient volume of the MTS for patients meeting the inclusion criteria ranged from 127.4 to 282.0 patients per year. The observed mortality rates of the trauma centres ranged from 10.4 % to 17.19 %. Characteristics and outcomes of all patients, and by low and

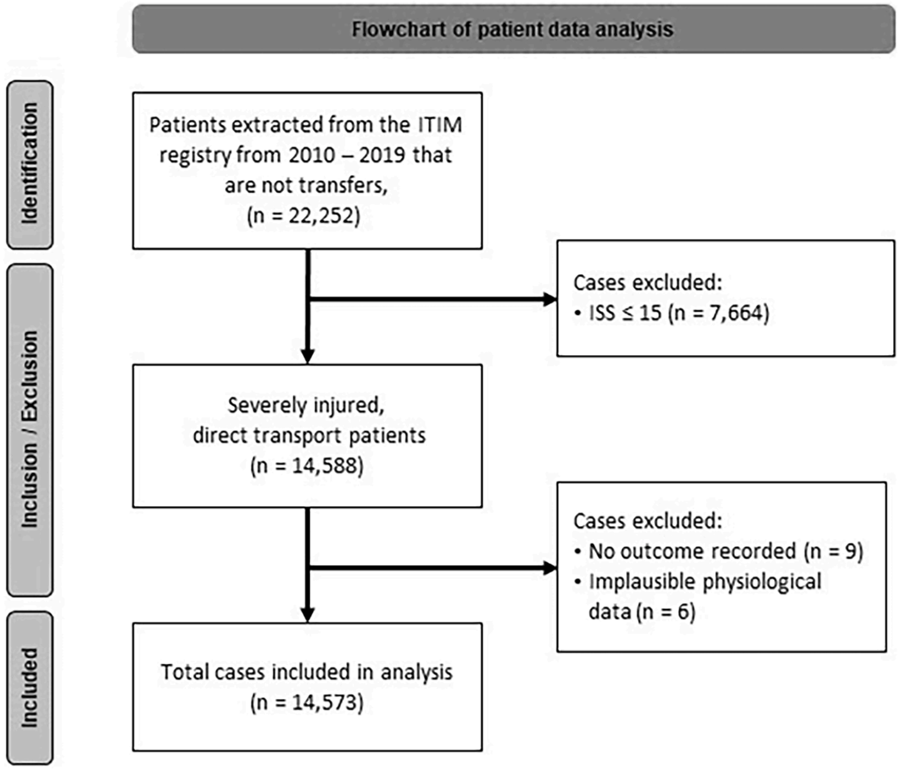

Fig. 1. Flowchart of inclusions and exclusions.

high hospital volume groups are detailed in Table 1. Details of mechanism of injury are available in Supplementary Table 1, and characteristics of the imputed data set in Supplementary Table 2.

A plot of the observed mortality rate versus annual volume for each MTS per year is shown in Fig. 2.

Primary outcome

Univariate analysis, using the low volume MTS group as the reference, demonstrated a marginally significant higher mortality in the high volume MTS group (OR: 1.10 (95 % CI:1.03–1.21, $P = 0.046$). The adjusted analysis is reported in Table 2. This demonstrated in-hospital mortality was not significantly lower in high volume hospitals compared to low volume hospitals (OR: 1.14 95 % CI: 0.98–1.25, $P = 0.087$). Sensitivity analysis did not demonstrate any significant difference in the ISS>24, isolated severe head injury (AIS for head region >4 and ISS < 35), or Age<65 years subgroups in the adjusted analysis, although a mortality effect was observed in the subgroups of patients with complete data, and in those with severe head injury (AIS ≥ 3 for head region) (Table 2).

Table 1
Characteristics and outcomes of patients, overall, low and high hospital volume.

	Total *n* = 14,573	Low Volume (≤ 212) *n* = 6917 (47.1%)	High Volume (>212) *n* = 7656 (52.5%)	P value	% Missing
Number of MTS	7	4	3	0.295[1]	0
Age, mean (SD)	53.3 (23.3)	53.51 (23.09)	53.11 (23.53)	0.305[2]	0
Male, n (%)	10,403 (71.4)	4944 (71.5)	5459 (71.3)	0.792[1]	0
Penetrating Injury, n (%)	665 (4.6)	360 (5.2)	305 (4)	<0.001[1]	0.1
Prehospital time (mins), median (IQR)	77 (54–126)	69 (49–113)	85 (60–136)	0.046[3]	8
GCS, median (IQR)	14 (9–15)	14 (10–15)	14 (8–15)	0.505[3]	9.8
SBP < 90 mmHg, n (%)	1119 (7.7)	491 (7.1)	628 (8.2)	0.429[1]	9.7
AIS score head region ≥ 3, n (%)	8561 (58.7)	4086 (59.1)	4475 (58.5)	0.449[1]	0
Respiratory rate, mean (SD)	18.9 (6.2)	19.3 (6.7)	18.6 (5.8)	<0.001[2]	11
ISS, median (IQR)	22 (17–26)	21 (17–26)	22 (17–26)	0.04[3]	0
NISS, median (IQR)	27 (21–34)	27 (21–34)	27 (21–34)	0.08[3]	0
RTS, median (IQR)	7.841 (6.171–7.841)	7.841 (6.376–7.841)	7.841 (5.967–7.841)	0.708[3]	12.3
Probability of Survival by TRISS, median (IQR)	0.928 (0772–0.978)	0.930 (0784–0.978)	0.928 (0.767–0.976)	0.786[3]	13.6
Prehospital Intubation, n (%)	2106 (14.4)	1166 (16.9)	940 (12.3)	<0.001[1]	0
ICU Admission, n (%)	6410 (44)	2975 (43.0)	3435 (44.9)	0.023[1]	0
ICU Length of Stay, >7 days	1912 (13.1)	864 (12.5)	1048 (13.7)	0.034[1]	0
Ventilation days for intubated patients, median (IQR)	3 (2–8)	3 (2–8)	3 (2–9)	0.642[3]	0
Length of Hospital Stay (days) median (IQR)	9 (4–19)	8 (3–19)	9 (4–20)	0.014[3]	0
In-hospital Mortality, n (%)	2129 (14.6)	968 (14.0)	1161 (15.2)	0.046[1]	0

P values derived from 1=Chi Square test, 2=Independent Samples *t*-test, 3=Mann Whitney U test. ICU length of stay threshold calculated from median and IQR values.

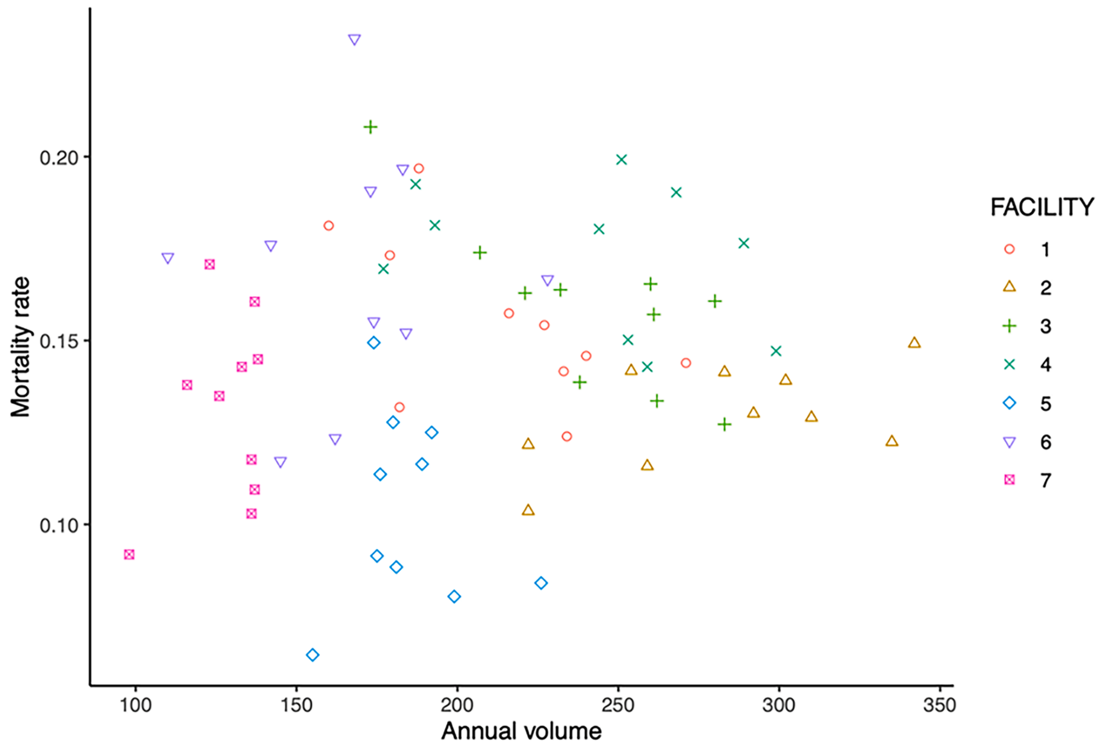

Fig. 2. Observed mortality rate versus annual volume for each MTS per year.

Table 2
Unadjusted and adjusted effect of hospital volume on in-hospital mortality.

	OR per 50 additional patients per year (95 % CI)	P value
Unadjusted	1.10 (1.00–1.20)	0.046
Adjusted	1.14 (0.98–1.25)	0.087
Complete case analysis adjusted (n = 10,400)	1.19 (1.02–1.28)	<0.02
ISS>24 subgroup		
Unadjusted	1.05 (0.94–1.18)	0.385
Adjusted	1.07 (0.94–1.22)	0.311
AIS≥3 Head Region subgroup		
Unadjusted	1.09 (1.00–1.20)	0.0463
Adjusted	1.14 (1.01–1.30)	0.03
AIS >4 Head Region and ISS<35 subgroup (isolated severe head injury)		
Unadjusted	1.25 (1.06–1.48)	0.01
Adjusted	1.16 (0.96–1.40)	0.125
Age<65 years		
Unadjusted	1.03 (0.90–1.19)	0.589
Adjusted	1.00 (0.83–1.21)	0.954

Models adjusted for sex, age, age x sex, GCS, respiratory rate, SBP, Heart Rate, prehospital intubation, AIS head region, year of admission, and penetrating injury.

A sensitivity analysis excluding the outlier site (Site 5) is included in the supplementary materials (Supplementary Table 3).

Median prehospital time was 77 mins (IQR=54–126) with significantly shorter prehospital time intervals for low volume hospitals (median=69, IQR: 49–113) compared to high volume hospitals (median 85, IQR: 60–136, $P < 0.001$)). Additionally median prehospital time was significantly lower (71 mins, IQR: 52–115) for those who died compared to those who survived (78 mins, IQR:54–128, $P < 0.001$). Prehospital time was not significantly associated with mortality in the adjusted model with time treated as a continuous ($P = 0.567$) or a binary variable (<60 mins vs ≥ 60mins) ($P = 0.386$).

Secondary outcomes

The adjusted model results for ICU and hospital LOS are detailed in Table 3. The high volume group was significantly associated with ICU and overall hospital LOS, with the significantly positive adjusted beta value indicating higher volume being associated with longer LOS in both instances.

Discussion

Using state-wide trauma registry data from the NSW Trauma System we were unable to demonstrate a survival benefit for severely injured adults transported directly from the scene to the three highest volume adult MTS when compared with the four lower volume MTS. This is consistent with the findings of another recent analysis of the NSW trauma system [14] in which the adjusted risk of mortality across MTS was not significantly different. We did however identify a significant relationship between increasing MTS volume and increased length of ICU and hospital stay.

This report evaluates a statewide system with seven total MTS. It is possible that a larger sample of MTS may have shown a volume outcome relationship. The trend towards lower mortality in the smaller volume centres appears to have been driven by one outlying centre as indicated

Table 3
The adjusted linear regression model results for ICU and hospital length of stay for the high volume group compared with the low volume group as the reference.

	Unstandardised B	*Standardised Beta*	*95 % CI for B*	*P value*
ICU Length of Stay	0.497	0.027	0.216–0.779	<0.001
Hospital Length of Stay	1.310	0.030	0.643–1.977	<0.001

ICU, Intensive Care Unit.

by a sensitivity analysis excluding this centre (Supplementary Table 3). However, the smallest centre having the lowest mortality inherently does not support the volume outcome theory.

Prehospital time in our study was significantly shorter in the lower volume centres, although shorter prehospital times were also associated with lower survival but were not significant in the adjusted analysis. The observed relationship between shorter prehospital times and lower survival on univariate testing possibly reflects prehospital clinicians expediting the transport of physiologically unstable patients. Another plausible reason is that the registry excludes prehospital deaths that were not transported to a trauma service hospital. Hence some high risk patients who would have died if their transport time was longer, may receive sufficiently rapid transport to arrive at hospital and be recorded in the registry. Prehospital intubation rates were also higher in the low volume centres although this has been associated with higher mortality in severe head injury [20] and trauma in general [21], and was hence included in the adjustment variables.

Although there is no significant association between mortality and hospital volume we noted significant results for length of stay in both ICU and total duration of hospital stay which were longer in the higher volume hospital group. Increased length of stay has implications for burden on healthcare, and efficiency and cost effectiveness of high-volume trauma centres. Further investigation is required to determine the causes for this observed difference.

The current NSW Trauma Plan [8] was introduced in 2009 and included a reduction in the number of MTS in Sydney with the rationale that concentrating numbers in larger centres would result in improved outcomes although it was noted that evidence for a volume outcome relationship at that time was equivocal. The most recent systematic review (and only meta-analysis) published in 2018 [5] found that there was still only modest evidence for an association between trauma centre volume and survival with most supporting studies coming from the United States, but very limited evidence from other jurisdictions.

Since the publication of this review, new studies examining the trauma systems in England and Wales [6], and the Netherlands [7] have found no relationship between volume and outcome for MTS. This was particularly striking across the 28 MTS in the English system where annual volume of patients with ISS>15 ranged from 69 to 781. After adjustment for patient factors there was a very small mortality difference between centres (tau-squared = 0.006, 95 % range of centre effects of 0.99–1.01). In the Netherlands MTS volume ranged from 120 to 410 patients with ISS > 15 per annum with no difference in mortality between high and low volume centres identified.

Also published since the 2018 systematic review is a study utilising the Japan Trauma Data Bank published in 2020 [15]. It included nearly 75,000 patients with ISS > 15 treated in 213 centres and demonstrated lower mortality in high volume centres where high volume was defined as greater than one hundred ISS > 15 patients per annum. Similarly, a 2015 study utilising the German national trauma registry [16] with nearly 40,000 patients with ISS >15 found a strong correlation between volume and outcome, but similarly the highest volume centres were defined as treating greater than one hundred patients per annum. There was also some evidence that as few as forty severely injured patients per annum was beneficial for survival. This suggests that there may be a ceiling effect in non-US jurisdictions beyond which mortality outcomes are independent of volume, perhaps around the one hundred patients per annum mark. All MTS in our study treated more than the one hundred patient threshold suggested by these studies.

The pattern of outcome in these recent publications may parallel other changes in trauma centres and trauma management more generally. In most developed jurisdictions trauma patients are older than previously, more likely to have significant medical comorbidities and increasingly likely to be injured by falls rather than motor vehicle incidents. In developed jurisdictions with low rates of penetrating trauma, maturation of trauma systems combined with these changes in the demographics of trauma may mean the traditional notion of concentrating large numbers of severely injured patients in a small number of large volume centres is no longer justified [17]. The long transport times that result for many patients from this system design compared with transporting patients to closer hospitals of similar capability that meet a minimum threshold of 100 patients per annum appears difficult to justify given the results of the current study and recent international data. Indeed, this study indicates that such a policy may result in increased costs (from longer lengths of stay) given the observed performance of lower volume centres in NSW.

Recent data from Afghanistan has also led to questioning of the policy of longer transport to a more distant facility compared with earlier treatment at forward surgical units in the military context. Politically directed changes to the US military field triage policy in 2009 routed injured combatants away from rear echelon hospitals to closer small surgical facilities in order to achieve a time from injury to surgical facility less than 60 min. This resulted in a sustained decrease in observed mortality contrary to predictions of trauma systems experts. The killed in action rate decreased significantly from 16 % to 9.9 % whilst the case fatality rate decreased from 13.7 % to 7.6 % [18]. Other potentially confounding changes in system design and treatment were unable to account for these observed differences [19].

Strengths and limitations

The NSW Trauma Registry is prospectively collected by trained coders and research nurses ensuring consistency of data input. Although we have included all available relevant variables in our adjusted model, the analysis was however limited by the variables available from the registry dataset and differences in case-mix may account for the observed mortality and length of stay outcomes. The registry does not include a co-morbidity measure as previously noted. We are therefore unable to exclude co-morbidity differences as the reason for the observed outcomes although we extensively adjusted for other potential case mix differences in the data set. Similarly, the registry does not include a measure of long-term functional outcome or cause of death which could also vary by centre volume. Upgrades to the NSW registry which are currently underway will make this type of analysis feasible in the future. Additionally, the relatively small range of volumes amongst NSW trauma centres may be insufficient to detect a benefit of much larger volume centres. Some American researchers [22] cite a minimum of 650 severely injured patients per annum as the definition of a high volume centre. No NSW centre currently treats such numbers and major re-arrangement of the trauma system would be required to achieve similar volumes in a single NSW centre. Given the recent study of the England and Wales trauma system did not identify a mortality benefit in the 14 centres with volumes greater than 500 ISS > 15 patients per annum it is difficult to sustain an argument for such a re-arrangement in NSW which has similar injury patterns however.

Conclusion

In this analysis of ten years of state-wide trauma registry data from NSW we were unable to demonstrate a mortality benefit for severely injured patients transported directly to the three MTS with the highest annual volume compared with treatment at the four lower volume centres. There was however a significant relationship between increasing MTS volume and increased length of ICU and hospital stay. This report adds to recent international data from similar jurisdictions questioning the volume outcome relationship for MTS.

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CRediT authorship contribution statement

Alan A Garner: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Leela Sai Krishna Suryadevara:** Writing – original draft, Methodology, Investigation, Formal analysis. **Charlie Sewalt:** Writing – original draft, Validation, Methodology, Investigation, Conceptualization. **Stuart Lane:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Formal analysis, Conceptualization. **Rajneesh Kaur:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Methodology, Formal analysis.

Declaration of competing interest

None declared by any author.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2024.111506.

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