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Comparing the outcomes of isolated, serious traumatic brain injury in older adults managed at major trauma centres and neurosurgical services: A registry-based cohort study

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ABSTRACT

Background: The incidence of older adult traumatic brain injury (TBI) is increasing in both high and middle to low-income countries. It is unknown whether older adults with isolated, serious TBI can be safely managed outside of major trauma centres. This registry based cohort study aimed to compare mortality and functional outcomes of older adults with isolated, serious TBI who were managed at specialised Major Trauma Services (MTS) and Metropolitan Neurosurgical Services (MNS).

Method: Older adults (65 years and over) who sustained an isolated, serious TBI following a low fall (from standing or $\leq$ 1 m) were extracted from the Victorian State Trauma Registry from 2007 to 2016. Multivariable models were fitted to assess the association between hospital designation (MTS vs. MNS) and the two outcomes of interest: in-hospital mortality and functional outcome, adjusting for potential confounders. Functional outcomes were measured using the Glasgow Outcome Scale Extended at six months post-injury.

Results: From 2007–2016, there were 1904 older adults who sustained an isolated, serious TBI from a low fall who received definitive care at an MTS (n = 1124) or an MNS (n = 780). After adjusting for confounders, there was no mortality benefit for patients managed at an MTS over an MNS (OR = 0.84; 95% CI: 0.65, 1.08; P = 0.17) or improvement in functional outcome six months post-injury (OR = 1.13; 95% CI: 0.94, 1.36; P = 0.21).

Conclusion: For older adults with isolated, serious TBI following a low fall, there was no difference in mortality or functional outcome based on definitive management at an MTS or an MNS. This confirms that MNS without the added designation of a major trauma centre are a suitable destination for the management of isolated, serious TBI in older adults.

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Introduction

Traumatic Brain Injury (TBI) is a leading cause of trauma related morbidity and mortality [1]. Approximately 39% of patients die following a severe TBI, and 60% suffer an unfavourable functional outcome [2]. In older adults, outcomes following a TBI are substantially poorer [3–5]. The most common mechanism leading to a severe TBI in an older adult is a low fall [6]. In high-income countries, the older adult population is rising with increasing life expectancies [7]. Concurrently, the incidence of TBI in older adults is increasing at a rate that cannot be attributed to the aging population alone [8,9]. Further, the aging population trends currently observed in high-income countries are expected to extend into the low-middle income countries in the future [10]. If

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these predictions are correct, the global public health burden of TBI in older adults will increase significantly. Optimising outcomes for older patients with TBI should therefore be a public health and social priority.

It is well established that major trauma patients have better outcomes if they receive definitive care at a specialised trauma centre over a non-trauma centre [11–13]. However, there is evidence to suggest that older adult major trauma patients can be safely managed outside of level-1 trauma centres [11,14]. Further, it is unknown as to whether the benefit of trauma centre management is applicable to patients with single system injuries, including isolated head injuries. Older adults with isolated, serious TBI may therefore not achieve an additional benefit from management at specialised trauma centres over neurosurgery-enabled facilities (without the designation of major trauma centre). In traumatic brain injury, functional outcomes are arguably of equal importance to mortality, given the high rate of disability in survivors [8].

The aim of this study was to compare the in-hospital mortality and 6-month functional outcomes of older adults with an isolated, serious TBI from a low fall managed at specialised major trauma centres and neurosurgical services without the designation of a major trauma centre in a mature, inclusive trauma system.

Ethics

Ethics approval was provided by the Department of Health and Human Services Human Research Ethics Committee (HREC), all trauma-receiving hospitals, and the Monash University HREC.

Methods

A registry-based cohort study of older adult (65 years and over) patients who sustained an isolated, serious TBI following a low fall (from standing or $\leq$ 1 m) was conducted.

Setting

The state of Victoria is the second most populous state in Australia with a population of 6.1 million. The Victorian State Trauma System (VSTS) is an inclusive, regionalised trauma system established in 2000, with the aim of delivering the "right patient to the right hospital by the fastest and safest means" [15]. Of the 138 trauma-receiving hospitals in the state, two adult hospitals are designated as 'major trauma services' (MTS) (The Alfred Hospital and Royal Melbourne Hospital), which are essentially Level 1 trauma centre equivalent. The MTS provide 24 -h trauma reception teams, on-site neurosurgical and intensive care services [15]. The major trauma service classification was restricted to ensure that a high-case load of major trauma patients consistently receive definitive care at an MTS institution. In 2007, three metropolitan trauma services with neurosurgical capabilities were designated as 'metropolitan neurosurgical services' (MNS) (Monash Medical Centre, The Austin and St Vincent's Hospital Melbourne). They were approved to provide definitive care to a subset of major trauma patients – older adults who have sustained an isolated TBI following a low fall. The MNS provide essentially the same tertiary level services as the MTS. However, between the two designations, there is a significant difference in terms of case volume and clinical exposure in favour of the MTS. This creates a difference in orientation, skill and clinical competence across all clinical specialties, ranging from those in the emergency department through to the rehabilitation services. For this study, outcomes are compared between the two MTS and the three MNS. These five institutions are the only hospitals in the state of Victoria accredited to provide neurosurgical operative management.

The Victorian State Trauma Registry

The Victorian State Trauma Registry (VSTR) is a population-based trauma registry, established in July 2001 to collect data from all hospitalised major trauma patients [16]. The VSTR collects extensive pre-hospital, in-hospital and long-term patient-reported outcomes data. The VSTR uses an opt-out consent process. All eligible major trauma cases are included, provided with information about the registry and then given the opportunity to be removed. The opt-out rate is less than 0.5%, which ensures almost complete capture of major trauma cases in the state [17]. A case is included on the VSTR if they meet any of the following criteria: 1) Death due to injury; 2) an Injury Severity Score (ISS) > 12 as determined by the Abbreviated Injury Scale (AIS 2005, Update 2008); 3) Admission to an intensive care unit (ICU) for at least 24 h and requiring mechanical ventilation whilst there; and 4) Urgent surgery [18]. All adult survivors to discharge have been followed up by telephone interview at 6 months post injury since July 2005.

Participants

Cases were extracted from the registry with a date of injury from the 1st January 2007 to the 31st December 2016 inclusive. Cases were included in the study providing they met all of the following criteria: 1) Age $\geq$ 65 years; 2) Mechanism of injury was a low fall (from standing or $\leq$ 1 m); 3) Patient had an isolated serious TBI, defined by an AIS severity score $\geq$ 3 in the head region and no other AIS body region with a severity score > 1; and 4) Patients were definitively managed at either an MTS or an MNS. Patients who were injured outside the state of Victoria, but were cared for in Victoria were excluded from the study.

Procedures

For eligible patients, demographic variables, injury event details, trauma system level of designation (MTS or MNS), inter-hospital transfer details, clinical observations, in-hospital outcomes and 6-month functional outcomes were extracted from the VSTR for analysis. The comorbid status of the patient was quantified using the Charlson Comorbidity Index (CCI). The Charlson Comorbidity Index (CCI) includes 19 diseases that are weighted based upon their association with mortality [19], and these were mapped from the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification (ICD-10-AM) codes related to the patient's admission. A score of zero indicates that the patient had no coded CCI conditions during their admission. The AIS score is an anatomically based scoring system for injury [20]. A score of $\geq$ 3 indicates an anatomical injury with a rating of serious or higher. Cases were considered compensable if the funding for their treatment came from the Transport Accident Commission or from WorkSafe Victoria, the third party no-fault insurers for transport and work-related injury, respectively. Transfer status refers to whether the patient received at least one inter-hospital transfer during their management. The Glasgow Coma Scale (GCS) is a measure of the level of consciousness which includes three components – the motor, eye opening and verbal responses – which are combined to give a total GCS score ranging from 3 to 15 with a higher scored representing a greater level of consciousness [21]. The motor score is recommended for use in TBI studies over the total GCS score [22–24]. A patients GCS score was deemed missing (n = 94) if any of the following criteria were met: (1) No GCS score was recorded; (2) A GCS score was recorded, but there was no recording of the where that score was recorded (pre-hospital, primary hospital or definitive hospital); and (3) The patient had a pre-existing neurological deficit. A missing GCS score

was not deemed to necessitate exclusion from analysis as the inclusion criteria for this study used head AIS scores as a marker of injury severity, rather than the GCS - patients missing a valid head AIS score were not included in the analysis. When possible, the GCS score was recorded on arrival at the first hospital the patient presented to (n = 1,624). If this was invalid due to the patient being intubated prior to arrival, then the corresponding GCS score recorded by the paramedics was used (n = 125). If the pre-hospital GCS score was also invalid, then the corresponding definitive hospital observations were used (n = 40). If the pre-hospital, primary hospital and definitive hospital scores were all invalid, then the case was automatically assigned a total GCS score of 3 and a GCS motor score of 1 (n = 21).

Functional outcomes

Functional outcomes were measured using the Glasgow Outcome Scale – Extended (GOS-E) at six-months post injury. The GOS-E is an extension of the Glasgow Outcome Scale (GOS) [25]. It is a hierarchical scale, consisting of 10 main questions and 3 subsidiary questions [26]. The questions of the GOS-E are administered via telephone interview and can be completed by a proxy if the patient is unable to provide the answers themselves, be that a carer or a next of kin. The questionnaire consists of measures of self-care, community participation, activities of daily living, relationships, social and leisure activities, cognition and work. Responses to the interview enable classification of the patient's level of function into one of eight categories; GOS-E 1 represents death, 2 indicates a vegetative state, 3 indicates lower severe disability, 4 indicates upper severe disability, 5 indicates lower moderate disability, 6 indicates upper moderate disability, 7 indicates lower good recovery and 8 indicates upper good recovery [25]. The GOS-E is recommended as a measure of functional outcome for patients with TBI [26,27].

Data analysis

Summary statistics were used to compare cases definitively managed at an MTS with cases managed at MNS hospitals (Table 1). Age and CCI were categorised for analysis due to skewed distributions, and for ease of interpretation.

The outcomes of interest were in-hospital mortality and the GOS-E score at six months post-injury. Multivariable models were fitted to assess the association between level of designation in the trauma system (MNS vs. MTS) and the outcome of interest, adjusting for potential confounders of this association. Variables were considered confounders if they differed between the trauma system level of designation ($p < 0.1$) and the variable was also associated with the outcome of interest ($p < 0.1$). Age group was included in all models. The variables quantifying ICU admission, the number of days spent in the ICU and the discharge destination were not considered for analysis, as these variables were deemed to lie on the causal pathway. TBI severity, represented by the categorised GCS, was not included in the models as the motor score is recommended for use in TBI studies over the total score [22–24].

The association between definitive hospital designation and in-hospital mortality was assessed using a binary logistic regression model. Adjusted and unadjusted odds ratios (OR) and the corresponding 95% confidence intervals (CI) were reported. The association between definitive hospital designation and the GOS-E at six months post-injury was assessed using a mixed effects ordinal logistic regression model with a random effect to adjust for excess correlation between patients treated at the same hospital [28]. In-hospital deaths were included in this model as a GOS-E of 1. Due to a large number of empty cells that appeared when the GOS-E was cross tabulated with the GCS motor score, the GOS-E was collapsed to 4 categories (1–2, 3–4, 5–6, 7–8) and the GCS motor was collapsed into 4 categories (1, 2–4, 5 and 6) for analysis. The collapsed GOS-E reflects the original Glasgow Outcome Scale (GOS) but with vegetative state and death combined into a single category [29]. Adjusted and unadjusted ORs, and the corresponding 95% CIs were reported. Sensitivity analyses with a seven category GOS-E (GOS-E 1 and 2 collapsed into a single category), GOS-E dichotomised as 'good recovery' (GOS-E 7–8) vs. 'less than a good recovery' (GOS-E 1–6), GOS-E dichotomised as 'independent living' (GOS-E 5–8) vs. 'not independent living' (GOS-E<5), and the 6 category GCS motor score, were conducted (see Supplementary

Table 1
Profile of older adult isolated serious TBI cases following low falls in Victoria (2007–2016), stratified by definitive hospital designation.

	MTS	MNS	p-value
Number of cases:	1124	780	
Age (years)			0.76
65-74	265 (23.6%)	176 (22.6%)	
75-84	490 (43.6%)	353 (45.3%)	
85+	369 (32.8%)	251 (32.2%)	
Sex			0.17
Male	610 (54.3%)	448 (57.4%)	
Female	514 (45.7%)	332 (42.6%)	
Intent			0.15
Unintentional	1118 (99.5%)	779 (99.9%)	
Other	6 (0.5%)	1 (0.1%)	
Fund[a]			0.66
Non-compensable	1110 (99.5%)	761 (99.6%)	
Compensable	6 (0.5%)	3 (0.4%)	
Charlson Comorbidity Index			<0.001
None	467 (41.5%)	413 (52.9%)	
1 or more	657 (58.5 %)	367 (47.1%)	
TBI Severity (GCS)[b]			0.15
Severe (3-8)	138 (13.0%)	82 (10.9%)	
Moderate (9-12)	129 (12.2%)	78 (10.4%)	
Mild (13-15)	791 (74.8%)	592 (78.7%)	
GCS motor score[c]			0.05
1	81 (7.3%)	35 (4.5%)	
2	20 (1.8%)	6 (0.8%)	
3	12 (1.1%)	11 (1.4%)	
4	42 (3.8%)	27 (3.5%)	
5	102 (9.2%)	71 (9.1%)	
6	848 (76.7%)	626 (80.7%)	
Head AIS			0.003
3	61 (5.4%)	68 (8.7%)	
4	499 (44.4%)	302 (38.7%)	
5	564 (50.2%)	410 (52.6%)	
Place of Injury			0.04
Home	658 (58.5%)	479 (61.4%)	
Road, street or highway	77 (6.9%)	48 (6.2%)	
Residential care facility or institution	172 (15.3%)	138 (17.7%)	
Other or unknown	217 (19.3%)	115 (14.7%)	
Transfer Status			<0.001
Patient was never transferred	636 (56.6%)	510 (65.4%)	
Patient was transferred	488 (43.4%)	270 (34.6%)	
Discharge Destination[d]			0.01
Home	240 (29.1%)	203 (34.7%)	
Rehab	408 (49.5%)	245 (41.9%)	
Nursing Home	20 (2.4%)	27 (4.6%)	
Other	28 (3.4%)	27 (4.6%)	
Hospital for Convalescence	129 (15.6%)	83 (14.2%)	
ICU Admission			<0.001
No	845 (75.2%)	646 (82.8%)	
Yes	279 (24.8%)	134 (17.2%)	
Number of days spent in the ICU[e]			<0.001
None	845 (75.2%)	646 (83.0%)	
1-10	257 (22.9%)	123 (15.8%)	
11-20	16 (1.4%)	8 (1.0%)	
> 20	6 (0.5%)	1 (0.1%)	

Missing data for Table 1: (a) n = 24; (b) n = 94; (c) n = 23; (e) n = 2. Note: (d) discharge destination only includes patients who survived to discharge. Comparisons between cases definitively managed at an MTS and an MNS were made using the using the chi-square test.

Material). All statistical analyses were performed using STATA Version 15 (StataCorp, College Station, Texas, USA).

Results

Overview of the patients

From the 1st January 2007, to the 31st December 2016, there were 1904 patients aged 65 years or greater who sustained an isolated serious TBI in a low fall who received definitive care at an MTS (n = 1,124) or an MNS (n = 780).

Profile of cases

Cases definitively managed at an MTS had a higher prevalence of comorbidities, had a more serious TBI as indicated by the TBI severity (GCS categorised), GCS motor and head AIS score, a lower proportion sustained the injury at home, a higher proportion underwent an inter-hospital transfer, a higher proportion were admitted to the ICU and a higher proportion were discharged to in-patient rehabilitation (Table 1). There were no patients transferred from an MNS to an MTS, or from an MTS to an MNS. Of the 1904 patients included in this study, in-hospital mortality status was recorded for all patients, and 1788 (93.9%) patients had a valid 6-monthly GOS-E score. Of the 116 lost to follow up, 53 were definitively managed at an MTS and 63 at an MNS suggesting no differential loss to follow-up.

In-hospital mortality

Of the 1904 older adults with an isolated, serious TBI, 494 died whilst in hospital, 299 at the MTS (60.5%) and 195 at the MNS (39.5%) (Table 2). The overall mortality rate was 25.9%. Without adjusting for confounders, the odds of in-hospital mortality for patients definitively managed at an MTS was not different to patients definitively managed at an MNS (OR = 0.92; 95% CI: 0.75, 1.13; P = 0.43). After adjusting for age group, the CCI, GCS motor score, head AIS score, place of injury and transfer status, the adjusted odds of in-hospital mortality was not different for patients definitively managed at an MTS compared to an MNS (OR = 0.84; 95% CI: 0.65, 1.08; P = 0.17) (Table 3).

Six-month GOS-E

The distribution of GOS-E scores six months post injury is presented in Table 4. Without adjusting for confounders, the odds of achieving a higher four-category GOS-E score (1–2, 3–4, 5–6, 7–8) was not different for patients definitively managed at an MTS compared to an MNS (OR = 1.08; 95% CI: 0.91, 1.29; P = 0.38). After adjusting for age, CCI, GCS motor score (collapsed), head AIS score, place of injury and transfer status, the adjusted odds of achieving a higher four-category GOS-E score was not different for patients definitively managed at an MTS compared to an MNS (OR = 1.13; 95% CI: 0.94 1.36; P = 0.21) (Table 5). This finding was consistent in all sensitivity analyses undertaken (see Supplementary Material).

Table 2
Mortality status of patients at discharge, stratified by hospital designation (MTS vs. MNS).

	MTS N = 1,124	MNS N = 780	Total N = 1,904
Dead	299 (26.6 %)	195 (25.0%)	494
Alive	825 (73.4 %)	585 (75.0%)	1,410
Total	1,124 (100 %)	780 (100 %)	1,904

Table 3
Multivariable logistic regression examining the association between definitive hospital service level and in-hospital mortality. Note that the greater the odds ratio the greater the odds of surviving.

In-hospital Mortality	Odds Ratio (95 % CI)
Definitive Hospital Service Level:	
MNS (reference)	1.00
MTS	0.84 (0.65, 1.08)
Age:	
65-74 (reference)	1.00
75-84	0.59 (0.42, 0.84)
85+	0.41(0.28, 0.59)
Charlson Comorbidity Index:	
CCI = 0 (reference)	1.00
CCI = 1 or more	1.02 (0.79, 1.31)
GCS Motor Score:	
1 (reference)	1.00
2	0.76 (0.23, 2.50)
3	1.07 (0.34, 3.38)
4	2.46 (1.22, 4.98)
5	4.80 (2.70, 8.55)
6	13.7 (8.37, 22.56)
Head AIS score:	
3 (reference)	1.00
4	6.49 (4.05, 10.42)
5	1.56 (1.02, 2.40)
Place of Injury:	
Home (reference)	1.00
Road, street or highway	1.40 (0.80, 2.45)
Residential care facility or institution	0.92 (0.66, 1.28)
Other or unknown	0.98 (0.69, 1.39)
Transfer status:	
Patient was never transferred (reference)	1.00
Patient was transferred	2.38 (1.81, 3.13)

Discussion

In our study, comparing the outcomes of older adults with isolated, serious TBI following a low fall in a mature, inclusive trauma system, there was no difference in mortality or functional outcome for patients definitively managed at specialised major trauma services when compared to neurosurgical services. This result confirms that older adults with isolated, serious TBI can be safely managed at metropolitan neurosurgical services without the added designation of a major trauma centre. Whilst only two hospitals had the additional designation of major trauma centre, all hospitals included in this study were neurosurgical centres. As our study exclusively focused on single system injuries, and all patients were managed at neurosurgical-enabled facilities, the finding of comparable outcomes across hospital designations is not surprising.

Only one study has previously explored the specific association of trauma centre designation and outcome in older adults with isolated, serious TBI [30]. In a large multicentre study, Kaufman et al. found that initial presentation to level I or II trauma centres over neurosurgery capable non-trauma centres in the United States (US) reduced in-hospital mortality for patients aged 65 years or older with isolated, serious TBI [30]. The authors observed no such benefit on functional outcome, which was dichotomised as a favourable discharge home over residential care.

A number of additional studies have explored the association of trauma centre designation and outcome in older adults, albeit without restricting the injury to isolated TBI and only focusing on mortality [11,14,31]]. Meldon et al. found that for patients aged 80 years or older with major trauma not limited to isolated TBI, definitive management at US Level I or II trauma centres over non-trauma centres reduced the odds of in-hospital mortality 31]. In contrast, MacKenzie et al. showed in a multicentre study that for patients aged 55 years or older with major trauma not limited to isolated TBI, treatment at level-1 trauma centres over non-trauma

Table 4
GOS-E scores six months after the injury, stratified by hospital designation (MTS vs. MNS).

GOS-E Scores 6 months after the injury	MTS N = 1,071	MNS N = 717	Total N = 1,788
1	435 (40.6 %)	295 (41.1 %)	730
2	4 (0.4 %)	2 (0.3 %)	6
3	243 (22.7 %)	184 (25.6 %)	427
4	79 (7.4 %)	54 (7.5 %)	133
5	28 (2.6 %)	14 (2.0 %)	42
6	50 (4.6 %)	30 (4.1 %)	80
7	114 (10.6 %)	76 (10.5%)	190
8	118 (11.0 %)	62 (8.6 %)	180
Total	1,071 (100 %)	717 (100 %)	1,788

Table 5
Mixed effects ordinal logistic regression model, assessing the impact of definitive hospital designation (MTS vs. MNS) on GOS-E scores (collapsed into four categories) six months post injury. Note that the greater the OR the greater the odds of the patient moving up a category in the collapsed GOS-E, and the better the patients functional outcome.

GOS-E Scores Six Months Post-Injury	Odds Ratio (95 % CI)
Definitive Hospital Service Level:	
MNS (reference)	1.00
MTS	1.13 (0.94, 1.36)
Age:	
65-74 (reference)	1.00
75-84	0.48 (0.38, 0.60)
85+	0.28 (0.22 0.36)
Charlson Comorbidity Index:	
CCI = 0 (reference)	1.00
CCI = 1 or more	0.73 (0.61, 0.88)
GCS Motor Score:	
1 (reference)	1.00
2–4	1.22 (0.61, 2.46)
5	3.99 (2.19, 7.28)
6	10.93 (6.47, 18.45)
Head AIS score:	
3 (reference)	1.00
4	1.81 (1.23, 2.68)
5	0.95 (0.64, 1.39)
Place of Injury:	
Home (reference)	1.00
Road, street or highway	1.48 (1.02 2.13)
Residential care facility or institution	0.38 (0.29, 0.50)
Other or unknown	0.91 (0.71, 1.16)
Transfer status:	
Patient was never transferred (reference)	1.00
Patient was transferred	1.52 (1.25, 1.84)

centres in the US did not produce a benefit with respect to in-hospital mortality [11]. Similarly, Staudenmayer et al. determined from a multicentre study that the 60-day mortality rate for severely injured patients (ISS > 15) aged 55 years or older with any injury not limited to isolated TBI was the same whether they were managed in level I or II trauma centres or non-trauma centres 14]].

Overall, direct comparison of the findings from our study with the previous literature is challenging, primarily due to differences in the study population, namely heterogeneity in the type of injury sustained and the definition of an older adult. Comparisons are limited even further due to differences in trauma centre designation and verification processes across studies. All previous studies were conducted in the US and used varying methodologies to explore the relationship between level of care and outcome in older adults. Nevertheless, our finding that definitive management at a specialised major trauma centre over a neurosurgical service did not yield a benefit on mortality or functional outcome for adults aged 65 or older who sustained a isolated, serious TBI following a low fall, broadly supports the findings of these studies.

Strengths

There are clear strengths to the study. The VSTR has near complete capture of cases within the state of Victoria. This avoids the typical selection bias that is observed in studies with opt-in consent processes. The use of the GOS-E is highly advantageous as exclusions are not required for language barriers, cognition or other similar reasons as the GOS-E can be administered to the patient via a proxy [25]. Additionally, the rate of follow-up was high. Only 116 (6.1%) patients were missing a valid GOS-E score six months post injury.

Limitations

This study focuses on a single, mature trauma system in the Australian state of Victoria. In the Victorian State Trauma System, neurosurgical management is centralised and restricted to five institutions, which are all fully equipped to treat neurosurgical emergencies. Modern trauma systems will likely have guidelines stipulating that serious head injuries should be managed at neurosurgery-enabled facilities. Therefore, the findings here should be generalisable to most mature, inclusive trauma systems. However, we acknowledge that there are significant differences in the provision of trauma care across jurisdictions. In many parts of the world, neurosurgical management is not centralised and instead is provided across a much larger number of institutions. Furthermore, in some jurisdictions, neurosurgical emergencies are not definitively managed by neurosurgeons. In such settings, the generalisability of our findings are limited. Additionally, while a wide variety of potential confounders to the association between level of care and outcome were considered, we were limited to the variables available in the VSTR. As the study was observational, causation cannot be confirmed and this should be considered when interpreting the findings. Additionally, detailed pre-morbid functional status was not available necessitating reliance on self-reported pre-injury functional levels in the GOS-E interviews and the consideration of this in the scoring algorithms. Further, clinician triage involves numerous unmeasurable variables, including social setting, family values and clinician gestalt. It is possible that the patients transferred to an MTS over an MNS were those that the clinician deemed more likely to achieve a positive outcome. Hence, there may be variables that we were unable to account for. Nevertheless, approximately one-third of the 780 patients who were definitively managed at an MNS were transferred there, rather than being transferred directly to an MTS. Additionally, in this study we are retrospectively classifying a patient as an ‘isolated head injury’. At a systems level, these patients may be assigned as multi-traumas following clinical review and treated as such until they undergo a comprehensive assessment. Similarly, they may be initially classified as an “isolated” head injury and treated as such until additional injuries are identified by secondary or tertiary surveys. Furthermore, we

were not able to explore the accuracy of diagnosis or triage of an isolated head injury within the pre-hospital setting. Additionally, despite a reasonable sample size, there is a possibility that the study was simply underpowered to detect a significant difference in outcome across hospital designations.

Conclusion

We observed no difference in mortality or functional outcome for older adults with isolated, serious TBI sustained in low fall events managed at specialised major trauma centres and neurosurgical services in a mature, inclusive trauma system. This result confirms that metropolitan neurosurgical services, without the added designation of a major trauma centre, are a suitable destination for the management of isolated, serious TBI in older adults.

Competing interests

There are no conflicts of interest.

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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.2019.06.012.

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