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THE UNIVERSITY OF SYDNEY

Submission to the Independent Hospital Pricing Authority on the Pricing Framework for Australian Public Hospital Services 2020–21

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Introduction

This submission discusses several key issues surrounding the currently proposed addition to the Pricing Guidelines for 2020–21; with an agreement that pricing should seek to promote value in public hospital services.

We offer evidence about treatment of people with traumatic spinal cord injury (TSCI). This is from our population based health and costing data linkage analyses, conducted with the objective of describing health service pathway efficiency and variation across the state of NSW and its relation to patient outcomes.

We further aimed to investigate the sufficiency of reimbursement at the hospital level, for block funded episodes for patients with TSCI, in comparison with the actual costs of care, analysed using the NSW District Network Return data.

The Consultation Paper proposes 'one addition' to the Pricing Guidelines for 2020–21, namely, that pricing should seek to promote value in public hospital services. Our submission covers equally the overarching guidelines of the Pricing Guidelines, specifically the intent to provide 'timely-quality care', and the policy intent that the ABF should 'ensure a sustainable and efficient network' of public hospital services.

In summary we recommend:

Further research, should explore whether the gaps in funding found in this NSW study can also be detected in other States. Our study suggests that continuing attention is required to ensure that funding for high resource groups such as patients with SCI is appropriate and adequate for the specialised units that deliver these services, and to ensure modifications designed to incentive quality don't further disadvantage these groups.

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Consultation Questions

1. Are the Pricing Guidelines still relevant in providing guidance on IHPA's role in pricing Australian public hospital services?

We recommend that the Pricing Guidelines continue to provide guidance to IHPA's role, however that they additionally seek comparisons, similar to what we are providing here, of the variability in actual costs of caring for particular patient populations in the acute care setting, to ensure that:

a. the service provided within state based health care settings is consistent with evidence based clinical practice guidelines; and,
b. the reimbursement for highly complex, resource intensive patients is sufficient for the actual costs of their care.

We propose that failure to address these two key aspects within the context of the overarching guidelines of pricing guidelines and their policy intent, will hamper efforts to deliver efficient quality care that is focussed on patient outcomes.

2. Does the proposed addition to the Pricing Guidelines appropriately capture the need for pricing models to support value in hospital and health services?

We have conducted analyses using population based record linkage data (Ambulance, EDDC, APDC, RBDM, COD-UR) to investigate the patient healthcare pathways for patients with traumatic spinal cord injury (TSCI). A study across NSW using linkage data for the period 2006-2009 (Sharwood, Boufous et al. 2017)(Appendix A), showed that less than 60% of patients with acute TSCI experienced any acute care in a specialist spinal cord injury unit (SCIU- Royal North Shore Hospital or Prince of Wales Hospital). Of these, only 73% were transferred to an SCIU within 24 hours from injury. Hypothesising that this could lead to poorer and more costly outcomes for patients with TSCI, we repeated this study using more recent record linkage data, also linking with the NSW-DNR. Analysis of these data showed that again, for the period 2013-16, only 60% of all patients with acute TSCI, had any acute care in a SCIU. We ***confirmed*** with this study that TSCI patients who experienced direct transfer to a SCIU, had lower treatment costs, shorter lengths of stay and *less costly* complications (e.g. urinary tract infection, pressure injury, respiratory complication etc.). We conducted scenario modelling and showed that optimising patient care pathways (i.e. reducing indirect transfers to SCIU), was able to offer significant cost savings (Vaikuntam, Middleton et al. 2019)(Appendix B).

Findings of less favourable outcomes according to the level of service provider, have also been identified in studies of trauma patient outcomes across the regionalised trauma system in NSW. Gomez et al (Gomez, Sarrami et al. 2018)(Appendix C) showed that definitive care at an MTS was associated with a 41% lower likelihood of death compared to definitive care at an RTS (OR 0.59 95%CI 0.35-0.97), for patients with major trauma, treated within the trauma network hospitals of NSW.

In summary, we recommend that additional considerations, such as the extent of adherence to best practice guidelines for specific patient populations, must be included in any improvement to

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the Pricing guidelines, if they are to support value in hospital and health services to the fullest extent possible.

3. What should IHPA prioritise when developing AR-DRG Version 11.0 and ICD-10-AM/ACHI/ACS Twelfth Edition?

We do not have relevant data findings to make an informed response to this question.

4. Are there other priorities that should be included as part of the comprehensive review of the admitted acute care classification development process?

As we have demonstrated for TSCI, we propose that there are likely to be similar concerns and discrepancies for people with extremely severe and high resource injuries, such as severe burns and moderate to severe traumatic brain injury. These would most certainly include patients requiring substantial time in intensive care, including the need for invasive ventilation.

Particularly, and again with reference to healthcare pathways for individuals with serious injury, it has been shown that, within the complex regionalised trauma system within NSW, there are varied pathways from the point of injury to definitive care. Patients with serious injury do not receive the same quality of care, with the same outcomes across this complex system. While there are particular specialist services provided for the acute care of patients with identified needs (such as acute spinal cord injury, acute traumatic brain injury and burns), there is sufficient evidence demonstrating system inefficiency and therefore delayed or absent access to the specialist services.

5. Are there any impediments to implementing pricing using the AECC Version 1.0 for emergency departments from 1 July 2020?

We do not have relevant data findings to make an informed response to this question.

6. Are there any impediments to implementing pricing for mental health services using AMHCC Version 1.0 from 1 July 2020?

We are currently undertaking a body of work to understand the impact of mental health diagnoses on resource use in admitted patient populations for individuals with either TSCI and/or traumatic spinal fractures (TSI). This work is ongoing, therefore final data will not be available for this submission, however, early findings show clearly that in this injury population, those with comorbid mental health and/or substance use disorders (ICD10-AM diagnoses), experience *twice* the length of hospital stay and subsequently *twice* the cost of those with these injuries but without additional mental health diagnoses. We propose that particular attention should be paid to resource intensive patient populations who have comorbid mental illness in the Pricing Framework. The following tables show the findings currently in the Draft manuscript; we would be happy to provide further information once the work is completed and submitted for publication.

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Table 1: Comparison of characteristics of individuals with Mental Illness Disorder (MID) or Substance Use Disorder (SUD) who sustained acute TSI, June 2013-June 2016.

Variable	Categories	MID or SUD		p_value
		No N (%) (n = 10657)	**Yes** N (%) (n = 2832)	
Sex	**Female**	4779 (44.8)	1197 (42.3)	0.014
	Male	5878 (55.2)	1635 (57.7)	
Seifa index (quintiles)	**0 (Unknown)**	189 (1.8)	45 (1.6)	0.944
	1 (Lowest)	1855 (17.4)	492 (17.4)	
	2	2189 (20.5)	585 (20.7)	
	3	2170 (20.4)	560 (19.8)	
	4	1256 (11.8)	338 (11.9)	
	5 (Highest)	2998 (28.1)	812 (28.7)	
Charlson index	**0**	9606 (90.1)	2037 (71.9)	<0.001
	1	909 (8.5)	671 (23.7)	
	2+	142 (1.3)	124 (4.4)	
Location of injury	**1: Neck**	2650 (24.9)	871 (30.8)	<0.001
	2: Thorax	3639 (34.1)	912 (32.1)	
	3: Lumbar	4112 (38.6)	993 (35.1)	
	4. Unspecified	256 (2.4)	56 (2)	
Died within 7 days	**No**	10454 (98.1)	2769 (97.8)	0.277
	Yes	203 (1.9)	63 (2.2)	
External cause	**Transport (V00-V99)**	3256 (30.5)	608 (21.5)	<0.001
	Falls(W00-W19)	5911 (55.5)	1847 (65.2)	
	Mechanical forces (W2)	402 (3.8)	47 (1.7)	
	Drowning (W65-W74)	35 (<1)	5 (<1)	
	Suffocation (W75-W84)	7 (<1)	5 (<1)	
	Forces of nature (X30)	11 (<1)	0 (<1)	
	Overexertion (X50-X57)	273 (2.6)	39 (1.4)	

	Intentional self-harm	15 (<1)	79 (2.8)	
	Assault (X85-Y09)	104 (<1)	45 (1.1)	
	Other and unspecified	643 (6)	157 (5.4)	
ICISS	**< 0.7**	410 (3.8)	266 (9.5)	<0.001
	0.7 to <0.83	726 (6.8)	335 (11.8)	
	0.83 to <0.89	794 (7.5)	281 (9.9)	
	0.89 to <0.95	2451 (23)	680 (24)	
	0.95 to 1.00	6276 (58.9)	1270 (44.8)	
Other major injuries (Head/Chest/Abdomen)	**No**	9995 (93.8)	2450 (86.5)	<0.001
	Yes	662 (6.2)	382 (13.5)	
Cord injury	**No**	10195 (95.7)	2662 (94)	<0.001
	Yes	462 (4.3)	170 (6)	
MID+SUD	**No**	10657 (100)	2587 (91.3)	<0.001
	Yes	0	245 (8.7)	

Table 2: Measures of resource and complications in acute care setting

Variable	**MID [N (%)]**		**SUD [N (%)]**		**MID+SUD [N (%)]**	
	No	**Yes**	**No**	**Yes**	**No**	**Yes**
	n = 11475	**n = 2014**	**n=12426**	**n=1063**	**n=13244**	**n=245**
Length of stay (days) median (IQR)	5 (2;10)	13 (6;23)	5 (2;12)	8 (3;17)	5 (2;12)	15 (7;30)
Length of stay (days) mean (SD)	8.2 (12.1)	19.0 (20.4)	9.5 (13.8)	13.5 (17.9)	9.6 (13.9)	21.7 (21.7)
Cost (acute care) median (IQR)$	5558 (1902;13,624)	15,590 (7076;36,300)	6316.5 (2170;15,554)	11,298 (3889;29,286)	6,438 (2203;15,919)	21,338 (8800;54,810)
Cost (acute care) mean (SD)$	14,480 (35,262)	36,092 (66,449)	16,652 (39,231)	30,030 (66,223)	17,119 (40,058)	49,479 (100,270)
Hospital acquired complications = yes	2170 (18.9)	1097 (54.4)	3022 (24.3)	245 (23.0)	3159 (23.8)	108 (44.1)

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7. Are there adjustments for legitimate and *unavoidable cost variations* that IHPA should consider for NEP20?

Whilst the objective of specialist hospitals is to achieve greater efficiency, quality and responsiveness, treatment costs are not necessarily lower than non-specialist hospitals. Specialist hospitals have higher treatment costs due to higher staffing levels, more specialised and expensive facilities. In the UK, top-up payments are provided for children's, orthopaedic, spinal and neurosciences specialised services, albeit to eligible providers. Specialist units treating conditions such as spinal cord injuries may not receive many patients nationally, however, if the best practice policy recommendations guide most of these patients to be treated at the few specialist units, their ability to provide quality care and financial viability will be considerably affected.

Hospital characteristics must also be considered in addition to patient level characteristics in the determination of adjustments for unavoidable cost variations, unless such hospitals housing specialist units are complemented by other forms of funding such as top-up payments for eligible providers.

We have conducted a study of patients were aged 16 years or older, who sustained an incident Traumatic Spinal Cord Injury (TSCI) between June 2013-2016 in NSW. Patients were identified in from record linked health data. Costs were estimated using two approaches, first using the District Network Return (DNR) data and second based on National Weighted Activity Units (NWAU) assigned to Activity-Based Funding activity. The funding gap in acute-care treatment costs for TSCI patients was determined as the difference in cost estimates between both approaches.

Five hundred and thirty-four patients with an acute incident TSCI were identified between June 2013 and June 2016 from the record linked data, accounting for 811 acute-care treatment separations within their index episodes. The majority were male (74%), with a mean (SD) age of 54 (22) years. Half of the patients (n=268) sustained injuries concomitant to TSCI, and 32 patients (6%) died in the hospital within the first seven days. Over half of all patients (n=283, 53%) sustained other complications within their acute-care hospital stay; pressure injuries the most common (n=106, 20%).

For the 534 patients with TSCI, using the DNR costing method the total acute-care treatment cost was estimated at $40.5 million ; the mean (SD) per patient cost was $72,246 ($94,894). Using the WAU costing method the total cost was $29.9 million; mean (SD) $58,793 ($63,227). The mean (SD) gap in cost per patient estimated using the two approaches was $13,349 ($61,432).

For the 654 separations included in the analysis, the mean (SD) cost per separation and the total costs (95% CI) were $56,489 (84,097) and $36.9 (32.7 – 41.2) million respectively using the DNR approach. The mean (SD) cost per separation and the total cost (95% CI) were $49,098 (59,853) and $32.1 (29.1 – 35.1) million respectively using the WAU approach.

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The study analysed the extent to which prices reflect the costs incurred by the hospitals for providing acute-care treatment for patients with TSCI in NSW, Australia over a 3-year study period. The results suggest a shortfall under activity-based funding for resource-intensive care provided to patients treated in public hospitals following TSCI. Specifically, depending on the classification system, the Principal Referral Hospitals, the SCIU co-located with a major trauma centre and stand-alone SCIU were under-funded by around 5.3 million dollars over the study period, whilst non-specialist hospitals were over-funded for acute care of patients with TSCI. Principal Referral Hospitals treat the bulk of resource intensive patients with TSCI. The shortfall is equivalent to a deficit of between $9,756 - $21,000 per acute-care separation at the specialist and Principal Referral Hospitals. Similar discrepancies have been previously identified, using a former State-specific cost model.5 However, this study provides evidence taking into account more recent national funding reforms.

The National Health Reform Agreement (2011) introduced the most significant reforms to public hospital funding system since the introduction of Medicare in Australia. The reforms introduced a nationally consistent activity-based hospital funding system based on a periodically calculated and updated efficient price, where LHNs receive the funds equivalent to the price paid for each separation. Since the price weights are based on national hospital cost data collection, the difference in cost estimates described in this study might be explained by inter-state cost variability not captured in the price weights.

** *Vaikuntam B, Middleton JW, McElduff P, Walsh J, Pearse J, Connelly L, Sharwood LN. Gap in funding for specialist hospitals treating patients with TSCI under an Activity-based funding model in New South Wales, Australia. Aust Health Rev. (in press July 2019)*

Further research, should explore whether the gaps in funding found in this NSW study can also be detected in other States. This study suggests that continuing attention is required to ensure that funding for high resource groups such as patients with SCI is appropriate and adequate for the specialised units that deliver these services, and to ensure modifications designed to incentive quality don't further disadvantage these groups.

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Bojke, C, Grašič, K, Street, A. How should hospital reimbursement be refined to support concentration of complex care services? Health Economics. 2018; 27: e26- e38. https://doi.org/10.1002/hec.3525

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8. Is there any objection to IHPA phasing out the private patient correction factor for NEP20?

We do not have the relevant data to comment on this.

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9. Do you support IHPA making the NBP publicly available, with appropriate safeguards in place to protect patient privacy?

We would only support public availability of hospital cost/activity and complications data when there is a national agreement on the scope and manner of presenting this data.

10. Would you support the introduction of an incentive payment or other mechanism to assist in covering these costs for a limited time period?

We do not have relevant data findings to make an informed response to this question.

11. What initiatives are currently underway to collect PROMs and how are they being collated?

The 2016 ITIM report recommendation to "Establish a standardised post-discharge follow-up process for trauma patients" (NSW Institute of Trauma and Injury Management 2016) prompted the initiation of the NSW Trauma Outcomes Registry and Quality Evaluation (TORQUE), which, once established, will commence interviewing trauma patients at 1, 6 and 12 months post discharge. While the future availability of patient report outcome measures aligned with inpatient treatment records offers a potential measure of service experience by this patient population, it will not report on important efficiency measures including shorter term patient outcomes (such as unplanned readmissions and secondary complications) and costs.

12. Should a national PROMs collection be considered as part of national data sets?

Yes, we believe this would assist in conducting routine review using national administrative data sets that could more easily and effectively evaluate patient care outcomes alongside measures of healthcare efficiency.

13. Are there impediments to shadow pricing the 'fixed plus variable' model for NEC20?

We do not have relevant data findings to make an informed response to this question.

14. Are there any additional alternative funding models IHPA should explore in the context of Australia's existing NHRA and ABF framework?

The current funding model in Australia, does not directly compensate for organisational characteristics. In some countries, hospitals incorporating specialist units receive additional funding by way of top-ups or extra funds to allow for the higher costs of specialist care. This suggests that international funding models have adjusted in recognition of the costs of providing specialised care (in addition to the existing adjustments for patient characteristics) to ensure fair and appropriate reimbursements commensurate with service provision. The additional healthcare costs from top-up

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payments or adjustments for specialist hospitals would contribute towards the value-based care initiatives focussing on specific population segments as they encourage adherence to best practice care recommendations for optimal patient outcomes. Additionally, these additional costs can be offset by health system level cost savings/cross-subsidisation from cheaper treatment costs, lower incidence of complications and subsequent lower-complexity episodes.

15. IHPA proposes investigating bundled payments for stroke and joint pain, in particular knee and hip replacements. Should any other conditions be considered?

We do not have relevant data findings to make an informed response to this question.

16. Is IHPA's funding approach to HACs improving safety and quality, for example through changing clinician behaviour and providing opportunities for effective benchmarking?

The episode level approach implemented by IHPA from 1 July 2017 penalises hospitals for each episode of Hospital Acquired Complication (HAC) at patient level. These funding adjustments reduce the NWAU for each episode incurring a HAC by a risk adjusted percentage reduction based on relative patient complexity for equitable adjustment between hospitals. However, the complexity of patient cohorts with complex needs such as spinal cord injury patients might not be adequately captured using the Charlson index and other patient characteristics currently being considered for risk adjustment. Hospitals housing specialist units treating the majority of such patient cohorts would be further financially disadvantaged if penalised based on the current risk adjustment model. Review of the impact of these adjustments across the hospital network will be vital to understand the limitations and impact on specific patient cohorts with complex resource-intensive needs.

17. What should IHPA consider to configure software for the Australian context that can identify potentially avoidable hospital readmissions?

We recommend software that will identify 'at risk' patients on admission to an acute care episode, whereby appropriate attention can be paid to ensuring necessary and evidence based referrals (e.g. allied health etc), prior to the end of the acute care episode. Discharge planning should involve consideration (from the beginning of an episode) of the potential risk factors already evident.

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Health Service Pathways Analysis as Evidence Base for Trauma Policy Change: A Retrospective Study of Patients with Traumatic Spinal Cord Injury

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Abstract

Background: Addressing policy change in traumatic injury care demands a strong evidence base from which to inform necessary amendments, and measure the impact of any change. Current recommendations for acute traumatic spinal cord injury include admission to a specialist Spinal Cord Injury Unit within 24 hours from injury. This study aimed to document pathways for patients with traumatic spinal cord injury across a state-wide Health Service in a historical cohort, prior to and in order to inform trauma policy changes.

Methods: Retrospective analysis of a large Ambulance Service record-linked dataset, containing 2.04 million Ambulance records linked with hospital and death records (2006-09). Incident cases of traumatic spinal cord injury were identified using ICD-10-AM codes. Multivariate analysis aimed to identify factors associated with admission to specialist units within 24 hours.

Results: Of 311 patients with confirmed traumatic spinal cord injury, 177 (56.9%) were admitted to a specialist Spinal Cord Injury Unit, with 130 of these (73.4%) being within 24 hours post injury. The remaining 47 (26.6%) had up to several months delayed transfer to SCIU. Patients were significantly more likely to have timely admission to SCIU with a cervical level cord injury (OR 2.05), aeromedical transfer to a specialist unit (OR 2.5), outer regional geographic location of injury (OR 2.05), or a surgical spinal procedure within 24 hours (OR 3.1). Patients were significantly less likely to be admitted to a specialist unit within 24 hours were those who experienced more than one hospital transfer (OR 0.28), and patients >75 years (OR 0.35).

Conclusion: Historically across this state-wide Health Service, patients with traumatic spinal cord injury did not experience consistent treatment pathways. Publication of this study importantly provides a baseline from which changes to clinical policies that have occurred since 2009 can be evaluated.

Keywords: Spinal cord injuries; Standards of care; Delayed diagnosis; Multiple trauma; Clinical pathways

Introduction

Traumatic spinal cord injury (TSCI), whilst relatively uncommon with an incidence of approximately 300 new TSCI cases per year in Australia, causes devastating changes in functioning, as well as substantial social and financial burden, with lifetime costs being estimated previously at $5 million for a young person with paraplegia and $9.5 million for tetraplegia [1]. It has long been recognised that management of the patient with acute TSCI in the earliest phase of care has a critical impact on outcomes in terms of impairment of severity and functional recovery, acute mortality, length of stay and occurrence of secondary complications [2-6]. Recent work has further strengthened the key concept of a time-critical window in which to intervene with neurosurgical decompression [7-9], as well as emerging pharmacologic and other therapies to enhance neuroprotection and improve the possibility of recovery of function [10-12].

Delayed transfer (greater than 24 hours from time of injury) to a specialist spinal cord injury unit (SCIU) has been the topic of previous research [2,3] with Amin et al. [2] reporting that the principal reason for delay between injury and SCIU referral related to the treatment of concurrent injuries, even where patients had sustained complete spinal cord injury. Similarly, Middleton et al. [13] found that multiple trauma patients were more likely to experience delays in transfer than patients with an isolated TSCI. These authors also established that patients who took longer than 24 hours to reach a SCIU were 2.5 times more likely to develop a secondary complication (95% CI 1.51–4.17, p<0.001), confirming earlier findings by Barr [14] in the United Kingdom (UK), who demonstrated that delay from time of injury to admission to a

SCIU increased complication risk on admission. Recently, Wilson et al. [15] reported on factors that caused delays in the care pathway to definitive treatment and timely surgery post SCI in a population-based cohort in Ontario, Canada, using linked administrative health data. They found older age, increased number of inter-hospital transfers; higher comorbidity and fall-related etiology were associated with increased time to arrival at a tertiary or quaternary hospital providing definitive SCI care. For surgery, increased age and number of inter-hospital transfers were associated with greater odds of late surgery (performed more than 24 hours after injury).

International Clinical Practice Guidelines (CPGs) for the early management of adults with TSCI state that early and rapid access to a Level 1 trauma hospital with a team that includes specialists in spine and brain injury is critical and that there should be clinical liaison with the designated SCIU as soon as possible; preferably within 24 hours of injury [16]. Furthermore, the CPGs recommend expeditious transfer of the patient with TSCI to a SCIU equipped to provide comprehensive, state-of-the-art care by an expert interdisciplinary team be considered when the patient is "sufficiently medically stable". Evidence suggests variation in practice exists among centres, and that not all patients with an acute TSCI are being referred to a SCIU for specialist care. For example, a report from the UK found that only 17% of patients with an acute TSCI were referred to a SCIU within 24 hours of injury, and 21% were not referred within one month. Forty one percent of those ultimately receiving care in a SCIU were admitted more than one month after injury [14]. Optimal treatment therefore depends on having an effective and well-coordinated health care system capable of quickly recognising and managing all patients with suspected TSCI as medical emergencies, employing spinal precautions and rapidly and directly transporting them to a SCIU [17].

The aims of this study were to (i) describe state-wide pathways of care for patients sustaining acute TSCI in a historic cohort (ii) investigate factors determining admission to a SCIU within 24 hours from injury, compared with delayed or no admission to specialist care, and (iii) inform trauma policy amendment and document the baseline against which such changes can be evaluated.

Methods

Setting

The Australian state of New South Wales (NSW) has a population of approximately 7 million and covers an area over 800,000 km^2 including suburban, rural and very remote areas. The state is serviced by one state government funded emergency medical service - Ambulance Service of NSW (ASNSW). Patients are transported via road, fixed wing or helicopter depending on injury severity and geographic location.

In NSW, there are currently six strategically located major trauma services (MTS) and ten regional trauma services (RTS). Currently, and at the time of this study (from 2006-2009), there are two acute care specialist SCIUs, both located in metropolitan Sydney; those being the Royal North Shore Hospital, which is also a MTS, and the Prince of Wales Hospital, a non-trauma designated hospital. Around 200 other non-trauma designated hospitals are located across all metropolitan and regional health districts in NSW. ASNSW protocols for the management of spinal, major trauma or head injuries that were applied to patients with TSCI during the study period included direction to immobilise the spine applying a rigid cervical collar, using a spine board or scoop stretcher, along with use of straps and sandbags (equivalent to heavy-duty supports). Patients with suspected spinal cord injury are classified as a 'major trauma' case, and as such, at the time of this study, were required by the NSW Department of Health to be transported to a designated trauma service within a transport time of 30 minutes from the scene. Patients who were assessed at the scene by an ASNSW aeromedical retrieval physician to have an isolated TSCI, were to be transported directly to a SCIU hospital, whilst patients with TSCI in the presence of comorbid injuries, could be flown to either a regional or MTS. In cases of severe trauma, patients injured in rural or remote areas of NSW may have been transported to a small rural hospital before inter-hospital transfer to MTS. In instances where there was also a TSCI, once stabilised, the patient may require further transportation to a SCIU in Sydney. The recommendation from the State Spinal Cord Injury Service was that transfer to a SCIU should ideally occur within 24 hours from injury.

Ambulance service of NSW linked dataset and data sources

This study utilised a dataset containing approximately 2.04 million ASNSW records for dispatch information and EMS patient health care reports linked with four other state wide data sources (emergency department data, hospital inpatient data and two death registries) for the period from June 2006 to July 2009. The ASNSW Linked Dataset was originally created for the Australian Prehospital Outcomes Study of Longitudinal Epidemiology (APOSTLE) Project by the NSW Ministry of Health Centre for Health Records Linkage employing deterministic and probabilistic record linkage techniques, and have previously been fully described elsewhere [18]. A review of linkage integrity found the overall prehospital-hospital linkage rate was 97.2% [19,20]. While rates of non-linkage to hospital records, where expected, tended to decrease with patient age, for all other variables, expected and unexpected linkages were indiscriminate. This linked dataset enables researchers to examine the patient's entire journey through the health care system, from the initial emergency call to the emergency department (ED) and hospital inpatient setting, through to discharge or death.

ASNSW data are comprised of operational information captured at the time of the 'Triple Zero (0-0-0)' call recorded in the Computer Aided Dispatch (CAD) dataset and also clinical data documented by NSW Ambulance paramedics in the paper Patient Health Care Record (PHCR). Portions of the PHCR information are transcribed by trained coders into an electronic format. CAD data includes important time markers (e.g. times of ambulance dispatch, paramedic arrival at a scene), dispatch priority, and incident location information. The NSW Emergency Department Data Collection (EDDC) and Admitted Patient Data Collection (APDC) provided the in-hospital data. Inpatient episodes such as acute admissions, readmissions, rehabilitation admissions and discharge events all have discrete codes within the APDC data, enabling journey mapping and acute length of stay to be derived. Survival status (fact of death) information was obtained from the NSW Registry of Births, Deaths and Marriages and the Australian Bureau of Statistics datasets.

Case finding and data management

Incident cases of TSCI captured within the ASNSW Linked Dataset during the 2006-09 financial years were identified using a discrete list of relevant ICD codes from the 10th Revision of the International Classification of Diseases, Australian Modification (ICD-10-AM) for all APDC separation fields (Appendix 1 for SCI-specific ICD-10-AM codes used). Patients aged 16 years or more were included only. Flags were created for all patients with any of the codes, firstly as a primary diagnosis, or within an admission following an injury event. Initial cleaning of the APDC records commenced with exclusion of all patients with diagnosis codes commencing with the letter 'Z'; these are related to allied health services as opposed to an acute admission. Cases in the latter months of the dataset were excluded if they did not have a date of separation from acute care, or entry into rehabilitation, as their entire acute care stay was unavailable for comparison. Data cleaning, separation and re-linking were performed using the statistical software package SAS v.9.2.

Where there were concerns regarding combinations of codes; for example, whether the coding rules had been correctly applied or there were very short lengths of stay, a process of individual case review of all linked records in the dataset was undertaken to determine case inclusion or exclusion. This was done taking the following 'data features' into consideration:

- Time in hospital – length of acute care, whether the person was transferred and if so where, mode of admission and separation;
- Presence of a relevant functional code where the level of the cord injury was categorised as 'unspecified' (i.e., S14.10 or S24.10) in the unit record data. For example, one unspecified TSCI injury code (e.g. S14.10), paired with an unspecified functional code (S14.70) may be indicative of a suspected case only, requiring review of all linked record data to decide whether this represents a true case;
- Presence of another neurological code (not from the ICD-10 injury chapter) to indicate a deficit, such as cord compression from cervical stenosis and there was no external cause of injury to indicate traumatic rather than non-traumatic etiology.

Once cleaned, the APDC data were merged onto the prehospital, EDDC and death records, to create a final dataset permitting mapping of the patient journey from the time of injury through to rehabilitation or death. The time of the '0-0-0' call was used to approximate the time of injury, and other time interval information including paramedic response times were obtained from the CAD data. Hospital data recorded patient arrivals, discharges and admissions, including dates, times and the destination location for each event.

This project was approved by the Cancer Institute NSW (NSW Cancer Institute, NSW Population and Health Services Research Ethics Committee reference number: 2012/09/420).

Variable definitions

Variables included age, gender, geographic location and time of injury, retrieval mode, use of spinal precautions and pre-hospital protocols, mechanism of injury, type of neurological impairment, type and time of diagnostic imaging, ambulance and hospital triage and prioritisations, transfers and admissions and length of hospitalisation prior to rehabilitation or discharge. The neurological level of injury and severity (complete or incomplete lesion) were determined by examining the specific ICD-10-AM code/s for each patient as described in Appendix I. It should be noted, however, that detailed clinical information from neurological examination consistent with the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) was not contained in any of the linked health data sources available for this study [21].

The linked dataset did not contain a standard injury severity measure such as the Abbreviated Injury Score (AIS) or Injury Severity Score (ISS). Length of acute hospital stay of the 'incident episode' was used as one proxy for injury severity [22] this did not exclude time in rehabilitation. This was categorised for addition to the final model; stay lengths were <7 days, 8-30 days, 31-90 days or >90 days/death within 24 hours. The longest stay group included the deaths that occurred within the first 24 hours from injury, considering that an injury severe enough to cause death within 24 hours to be equivalent to injuries severe enough to cause the longest acute care hospital stays.

During analyses, the documentation of cervical collar application, other spinal immobilisation and/or documentation of the use of TSCI related protocols by paramedics were taken to indicate that spinal precautions were initiated during prehospital care. Injury combinations were explored, comparing patients who had sustained isolated TSCI and those with multiple comorbid injuries, including traumatic brain injuries (TBI). Isolated TSCI was defined as a TSCI at a cervical, thoracic or lumbar level (sometimes dual spinal levels), with no associated injuries to any other body regions. Multiple injuries/TBI were defined as having any level TSCI plus injury to two or more body regions, or any level TSCI plus a TBI. These definitions were chosen to reflect the complexity of multiple trauma management and/or life threatening injuries requiring immediate trauma care and stabilisation [23].

Statistical analyses

All statistical analyses were performed using STATA version 14.0 (version 14.0 STATA Corporation, College Station, TX, USA). Standardised reporting of demographic and other variables, as recommended by De Vivo et al. was followed where possible [24]. Descriptive analyses were performed on demographic, injury and health systems operational and time-related data to examine the clinical characteristics and time variables for different groups of clinical interest that may potentially follow different care pathways. The time and admission location variables defined above were used to generate a 'time of injury to time of arrival at a SCIU' variable. Data was divided firstly into three groups for descriptive analysis: patients admitted to SCIU within 24 hours of injury, patients admitted to SCIU greater than 24 hours post-injury, and patients who were not admitted to SCIU at all. Descriptive analyses were also performed with data grouped into patients with an isolated TSCI and those with TSCI combined with multiple injuries or TBI. Categorical data frequencies were tested for statistical significance using Chi-squared or Fishers exact tests, with the latter being used when cell sizes were small. Kruskal-Wallis one-way ANOVA by ranks was used to test differences for the time variables. P values <0.05 were considered statistically significant.

Backward regression was used to determine the factors that contributed to admission to SCIU within 24 hours – that is, we started with a full model of potential predictors, based on univariate analyses, and variables were eliminated from the model in an iterative process. This full enter model commenced with the variables age (forced), gender (forced), aeromedical retrieval and location of injury incident by ARIA category (considered together), number of inter-hospital transfers, length of stay as proxy for injury severity, spinal surgery within 24 hrs and spinal injury level. A p-value of 0.025 was used as the exit criterion for removal of a variable from the model. The final model, which contained only independent variables that significantly contributed to admissions SCIU within 24 hours, was reached when no more variables could be eliminated.

While three distinct groups (i.e., SCIU<24 hrs, SCIU>24 hrs, no SCIU) are presented for descriptive analysis, the primary objective of the analysis was to consider those factors associated with CPG recommended transfer time to SCIU within 24 hours from injury. Further, the 'late arrivals' to SCIU were notably fewer in number; and a multinomial model would have certainly been over-fitted.

Results

Within the ASNSW linked dataset, 311 patients were identified with the diagnosis of an acute TSCI from ICD-10 codes. Seventy-four percent were male, with a mean age of 48.7 years (SD 21.7). Eighty-nine patients (28.6%) sustained an isolated TSCI; while a further 168 (54%) patients had two or more additional injuries (multi-trauma) that may have included a TBI. Table 1 describes factors that were significantly associated with either admission to a SCIU within 24 hours of injury (n=130), admission to a SCIU but beyond 24 hours of injury (n=47) or those not admitted at all to a SCIU (n=134).

Characteristics	SCIU <24 hrs N=130, N (%)	SCIU >24 hrs N=47, N (%)	No SCIU N=134, N (%)	Chi sq/ exact	P-value
Age in years n (%)				**38.32**	<0.001
16 - 30	44 (33.8)	13 (27.7)	21 (15.6)		
31- 45	35 (26.9)	10 (21.2)	25 (18.6)		
46 - 60	24 (18.4)	7 (14.8)	29 (21.6)		
61- 75	16 (12.3)	13 (27.7)	18 (13.4)		
76 +	11 (8.4)	4 (8.5)	41 (30.6)		
Sex n (%)				11.15	0.004
Male	109 (83.8)	37 (78.7)	89 (66.4)		
Female	21 (16.1)	10 (21.2)	45 (33.5)		
Mechanism of injury*				3.5	0.74
Falls	57 (43.8)	14 (29.8)	56 (41.8)		
Transport	53 (40.8)	22 (46.8)	56 (41.8)		
Other	20 (15.4)	11 (23.4)	22 (16.4)		
Cervical level injury				13.75	0.001
Yes	87 (66.9)	33 (70.2)	63 (47.0)		
No	43 (33.1)	14 (29.8)	71 (53.0)		
Multiple injury#/TBI				13.2	0.001
Yes	79 (60.7)	32 (68.1)	57 (42.5)		
No	51 (39.2)	15 (31.9)	77 (57.4)		
Time of day of incident				5.24	0.51
0-6:00 am	15 (11.5)	8 (17.0)	11 (8.2)		
6:01-12 am	39 (30.0)	8 (17.0)	39 (29.1)		
12:01-6 pm	49 (37.7)	20 (42.5)	53 (39.5)		
6:01-12 mn	27 (20.8)	11 (23.4)	31 (23.1)		
Incident location				12.31	0.05
Sydney Metropolitan	65 (50.0)	33 (70.2)	71 (53.0)		
Inner Regional	32 (24.6)	11 (23.4)	42 (31.3)		

Outer Regional	22 (16.9)	2 (4.3)	12 (9.0)		
Missing	11 (8.5)	1 (2.1)	9 (6.7)		
Aeromedical retrieval				33.38	<0.001
Yes	54 (41.5)	12 (25.5)	14 (10.4)		
No	76 (58.4)	35 (74.5)	120 (89.5)		
ASNSW Protocol Usage[Ɏ]					
Cervical collar use recorded	62 (47.7)	26 (55.3)	60 (44.8)	1.55	0.46
Spinal Protocol use recorded	82 (63.1)	22 (46.8)	57 (42.5)	11.69	0.003
Major Trauma Protocol use recorded	97 (74.6)	31 (65.9)	83 (61.9)	4.94	0.084
Head Injury Protocol use recorded	19 (14.6)	9 (19.5)	21 (15.6)	0.53	0.76
No Protocol Identified	24 (18.4)	13 (27.6)	38 (28.3)	3.91	0.14
Any spinal precautions [ɎɎ]	106 (81.5)	34 (72.3)	95 (70.9)	4.35	0.11
Diagnostic imaging <24 hrs (=yes)	127 (97.7)	45 (95.7)	111 (82.8)	19.3	<0.001
Spinal Procedure <24 hrs (=yes)	82 (63.0)	20 (42.5)	28 (20.9)	23.6	<0.001
Number of hospital transfers					
None				59.04	<0.001
One	65 (50)	0 (0)	82 (61.2)		
Two or more	59 (45.4)	36 (76.6)	39 (29.1)		
Vital Status	6 (4.6)	11 (23.4)	13 (9.7)		
Alive	122 (93.8)	43 (91.5)	98 (73.1)		
Died within 7 days	5 (3.8)	1 (2.1)	22 (16.4)		
Died >7 days	3 (6.4)	3 (2.3)	14 (10.4)	24.95	<0.001
Rehab. Admission (= yes)	90 (69.2)	39 (82.9)	41 (30.6)	57.6	<0.001

[*]As defined by CAD problem and/or APDC External Cause Codes, [#]Any level TSCI + 2 or more body regions injured, [Ɏ]In Ambulance Service of NSW data – individual binary variables listed, [ɎɎ]Either/or/and protocols, collar, spinal immobilisation documented

Table 1: Characteristics of patients with TSCI in the NSW Ambulance Linked Dataset, 2006-09.

From a total of 177 (56.9%) patients with TSCI who received any acute care in a SCIU during the study period, just over one-third 37% (n=66) were transported directly to SCIU; 58% (n=38) being taken there by road ambulance and 42% (n=28) by air. Just over half (54%, n=95) had one transfer to another hospital before admission to a SCIU, with the remaining 10% of patients (n=17) having two or three transfers to other hospitals before reaching the SCIU. The number of inter-hospital transfers a patient experienced significantly impacted their ability to reach an SCIU within 24 hours from injury; those experiencing two or more transfers were more than three times less likely to achieve this (OR 0.28, p=0.02).

Patients were significantly more likely to be admitted to a SCIU within 24 hours in cases where paramedics had recorded use of spinal precautions compared to those where no spinal precautions were documented (OR 1.78, p=0.04).

When examining the pathways for patients from the first hospital type to which they were taken by the NSW Ambulance Service, patients first taken to a MTS were less likely to be transferred elsewhere in comparison to those initially transported to a metropolitan (non-trauma designated) hospital (36% vs. 75%). Where a transfer occurred from a major trauma centre, it was predominantly to a SCIU (78%). Approximately one-third (32%) of patients transferred from a metropolitan hospital were admitted to a SCIU, which occurred more than 24 hours following injury in 40% of these instances.

Early arrival at a SCIU was associated with rurality in univariate analysis – those injured in an outer regional area were 2.57 times more likely to be admitted to a SCIU within 24 hours compared to those injured in a metropolitan area (p=0.01). Aeromedical retrieval in the prehospital phase was associated with a fourfold increase in the likelihood of timely admission to a SCIU (p<0.001), with patients in outer regional areas being 2.6 times more likely to have aeromedical retrieval than patients in a metropolitan area (OR 2.62, p=0.039). Sixty percent of the patients with TSCI first transported to a Regional Trauma Service (RTS) were later transferred elsewhere for their acute care and approximately half of these patients (49%) were transported to a SCIU, with 25% arriving more 24 hours from the time of injury. Regional/district hospitals (non-trauma designated services) transferred out 86.7% of patients arriving with TSCI. None of these patients were transported to a SCIU, while 46% were transferred to a trauma service.

Characteristics	Isolated TSCI (n=89) N (%)	Multiple injury/TBI (n=168) N (%)
Age years, x̅ (SD)	50.8 (22.7)	46.2 (20.4)
Sex		
Male	69 (77.5)	127 (75.6)
Female	20 (22.5)	41 (24.4)
Cervical collar use recorded	37 (41.5)	88 (52.3)
Any spinal precautions	58 (65.1)	141 (83.9)
ED Triage Category		
Resuscitation	12 (15.2)	87 (56.8)
Within 10 mins	34 (43.0)	42 (27.4)
Within 30 mins	23 (29.1)	21 (12.5)
Within 2 hours	10 (11.2)	3 (1.8)
Missing	10 (11.2)	15 (8.9)
Diagnostic imaging <24 hrs	74 (83.1)	161 (95.8)
Spinal Procedure <24 hrs	35 (39.3)	76 (45.2)
SCIU <24 hrs	31 (34.8)	79 (47.0)
First hospital of transport		
SCIU*	17 (19.1)	37 (22.0)
Major trauma service**	28 (31.4)	59 (35.1)
Regional Trauma Service	15 (16.8)	33 (19.6)
Non-trauma designated metropolitan/rural services	29 (32.5)	39 (23.2)
Vital Status		
Alive	74 (83.1)	143 (85.1)
Died within 7 days	6 (6.7)	16 (9.5)
Died >7 days	9 (10.1)	9 (5.3)

*SCIU = Royal North Shore hospital or Prince of Wales hospital, **Major trauma service other than Royal North Shore hospital

Table 2: Injury epidemiology and treatment -isolated TSCI vs. TSCI with multiple injury/TBI.

Over half of all patients sustained multiple injuries, with 44% of these injuries including a TBI. Comparisons between patients sustaining TSCI associated with multiple injuries/TBI versus those with an isolated TSCI at any level are shown in Table 2. A greater proportion of patients with TSCI and multiple injuries that may have included a TBI required Emergency Department (ED) resuscitation compared to those with an isolated TSCI (57% vs. 15%, p<001). Compared to those with isolated TSCI, a greater proportion of those with multiple injuries/TBI were admitted to a SCIU within 24 hours (47% vs. 35%, p<001). Table 2 does not include the 54 patients who sustained a TSCI at any level with only 1 other injury. Transfer to a SCIU and/or time to spinal surgery were delayed in the majority of cases, even in the isolated TSCI group (65% and 60%, respectively).

Table 3 compares a range of times for the three groups (SCIU <24 hrs, SCIU >24 hrs and no SCIU) presented in Table 1. The median time that patients spent in the ED (of around 6.5 hours) did not differ between groups, although nine patients spent more than 24 hours in the ED with seven of these delays occurred in a MTS other than Royal North Shore hospital. Patients arriving at a SCIU were more likely to be admitted to a rehabilitation facility than those not admitted to a SCIU (72.9% vs. 30.6%), and of the patients who were admitted to a SCIU those admitted within 24 hours of injury commenced their rehabilitation on average 30 days earlier than patients admitted later.

Median (IQR) times	SCIU <24 hrs	SCIU >24 hrs	No SCIU	Kruskal Wallis-rank test	p-value
	N=130	N=47	N=134		
Ambulance response time (mins)* (n=259)	12 (9-23)	12 (10-18)	14 (9-23)	1.59	0.45
Total time to ED arrival (min) (n=281)	82.5 (53.5-124)	66.5 (50-82)	61 (45-78)	15.64	<0.001
Total ED time (hrs) (n=282)	6.4 (4.5-8.9)	6.2 (3.9-9.6)	6.6 (4.5-9.9)	0.93	0.62
Total of acute care stay (days) (n=311)	25 (13-40)	16 (8-29)	20.5 (7-49)	82.68	<0.001

Time to rehab (days) (n=170)	30 (17-50.1)	60 (26-90)	25 (15-43)	15.93	<0.001
*From '000' call time to scene arrival time.					

Table 3: Comparison of time intervals. *From '000' call time to scene arrival time.

Patients over sixty years of age spent more time in an ED than their younger counterparts, with those more than 76 years of age spending a median of 8 hours (IQR 5.9-14.4) in an ED compared with 5.5 hours (IQR 3.8-7.7) for those aged between 16-30 years (p<0.001).

Table 4 presents the results of the backward multivariate logistic regression analysis, exploring factors associated with patients being admitted to an SCIU within 24 hours of TSCI. Univariate analysis showed these variables to be significantly predictive of admission to SCIU within 24 hours and this association remained after adjusting for multiple confounders; gender was retained by force into the model (Table 4). Aeromedical retrieval was associated with geographic location of injury and as such was considered jointly within the model.

Patients were more than three times as likely to have early spinal surgery for decompression and stabilisation if they were admitted to a SCIU within 24 hours (p<0.001). Thirty-one percent of patients having timely surgery were directly transported by NSW Ambulance to a SCIU, while a further 32% were transferred to a SCIU within 24 hours for this procedure.

Of the remaining patients who had surgery within 24 hours, most (89%) received this at a MTS hospital other than RNSH. Patients with higher level injury (cervical cord), regardless of multiple trauma or head injury, were over two times more likely to be admitted to a SCIU within 24 hours, compared to patients with lower level injuries (involving thoracic/lumbar cord) (p=0.016). Mode of transport within the pre-hospital care phase, as well as the initial transport destination, also significantly influenced the likelihood of a patient with TSCI being admitted to a SCIU in accordance with current recommendations.

	SCIU < 24 hrs N=130 N (%)	**SCIU >24 hrs or no SCIU N=181 N (%)**	**OR**	***Adjusted 95% CI**
Gender (male)	108 (83.7)	127 (69.8)	1.57	0.82-2.97
Age categories				
16-30	44 (33.8)	34 (18.8)	1	
31-45	35 (26.9)	35 (19.3)	0.86	0.41 – 1.80
46-60	24 (18.4)	36 (19.9)	0.68	0.31 - 1.49
61-75	16 (12.3)	31(17.1)	0.57	0.24 – 1.34
76+	11 (8.4)	45 (24.8)	0.35	0.14 - 0.88
Aeromedical transport	54 (41.5)	26 (14.3)	2.5	1.33-4.69
Geographic location				
Metropolitan	65 (50)	104 (57.4)	1	
Inner regional	32 (24.6)	53 (29.2)	0.83	0.44 – 1.58
Outer regional	22 (16.9)	14 (7.7)	2.62	1.05 – 6.53
Missing	11 (8.4)	10 (5.5)	1.02	0.36 – 2.87
Inter-hospital transfers				
0	65 (50.0)	82 (45.3)	1	
1	59 (45.4)	75 (41.4)	0.99	0.619 – 1.59
2+	6 (4.6)	24 (13.3)	0.28	0.09 – 0.82
Spinal surgery <24 hrs	82 (63.1)	48 (26.5)	3.1	1.78 – 5.26
Cervical level injury	87 (66.9)	96 (53.0)	2.05	1.17 – 3.58
*Adjusted for age, gender (forced), (aeromedical retrieval and location of injury incident by ARIA category), type of hospital first attended, length of stay as proxy for injury severity, diagnostic imaging within 24 hrs, spinal surgery within 24 hrs, spinal injury level, pre hospital spinal precautions.				

Table 4: Predictors of admission to SCIU within 24 hours of injury for patients with TSCI (pseudo R2=0.46).

Patients who had aeromedical transport were 2.5 times more likely to arrive at SCIU within 24 hours than those who did not and in particular from outer regional areas. Patients experiencing two or more inter-hospital transfers were less likely to arrive at a SCIU than those who were either taken directly there, or had only one transfer (OR 0.28, p=0.021). Older patients (>60 years) were also less likely to experience timely transfer to SCIU compared with their younger counterparts (OR 0.25, p=0.012).

Discussion

In this study we examined a large dataset of approximately 2 million NSW Ambulance records that had been linked to four external datasets for the period June 2006 to July 2009, to determine predictors of expeditious transfer (within 24 hours from injury) to a specialist SCIU for patients with acute TSCI. It builds on previous work [13], which showed that delays to SCIU admission increased the incidence of secondary complications for individuals with TSCI. Also, the impact of delays to intervention such as time critical surgical decompression to reduce secondary cord damage and extent of permanent impairment have previously been shown to be substantial, affecting the achievement of maximum mobility and function for these patients [8].

The results presented here demonstrated that for those admitted to a SCIU within 24 hours of injury compared to those who experienced delays or were not admitted to a SCIU at all, the likelihood of spinal surgery occurring within 24 hours of injury increased three-fold. The prioritization of time to specialist treatment has been previously demonstrated to have significant impact on patient outcomes including mortality, for those with acute ischemic stroke [25] and acute myocardial infarction [26]. The healthcare system therefore has a responsibility to its patients to optimize their chances for the best possible outcome despite incurring significant injury.

Patients admitted to a SCIU within 24 hours from injury were not only more likely to have a subsequent rehabilitation admission, but this was achieved earlier on average than those with delayed or no SCIU admission. The shorter acute length of stay in this latter group may imply a lesser injury severity, and that these patients required less equipment or care, however, this was not conclusive in the data. It may be that from within a SCIU, the referral, access and transfer processes required for admission to rehabilitation are more easily streamlined. These factors were not able to be explored within this current study, neither the policy, clinician or resource level factors influencing referral or delays to SCIUs from other healthcare services.

Patients aged 60 years or more were at least four times less likely to be admitted to a SCIU within 24 hours of injury in comparison to those aged 16-30 years. This is consistent with previous research showing that older patients sustaining falls were less likely to have their TSCI identified early and were subsequently less likely to receive in-line cervical spine stabilization at the scene of the injury [13,15]. Failure to suspect TSCI affects triage and transfer decisions, as well as the application of appropriate spinal precautions in the field. Further research should investigate attitudes of emergency clinicians towards older patients with traumatic injury and their treatment decisions. In this study, older patients experienced longer periods in the ED, possibly in order to ensure the patient was stable enough for inter-hospital transportation, however, this was not investigated specifically. Other research has demonstrated that even with lower injury severity, older trauma patients experience worse outcomes than younger patients, including lengthier hospital admissions and higher mortality rates [27].

Early pathways of care for trauma patients are subject to guidelines and protocols that are implemented based upon the paramedic's clinical assessment of the patient, as well as factors such as time and distance to a trauma service or the availability of aeromedical physician assistance. At the time of the study, for multiple injury TSCI patients in rural or remote areas, one or even two inter-hospital transfers may have been necessary before reaching a SCIU in Sydney – depending on the severity of other life threatening conditions and the time required to stabilize the patient. The 30 minute travel time restriction for paramedics to reach the nearest trauma service (major or regional) with a major trauma patient has since been extended to 60 minutes, under policy changes disseminated in the 2009 NSW Trauma Plan. Notably there are some exceptions to this rule, which permit medical retrieval services (with an accompanying medical doctor) to transport the patient with a primary isolated TSCI directly to a designated SCIU. The policy further states that "In primary cases of a combined severe trauma and acute spinal cord injury in the greater Sydney metropolitan area, where a helicopter with accompanying doctor has responded, then these patients may be transported directly to Royal North Shore Hospital (where MTS is collocated with SCIU) if considered clinically appropriate" [28]. Geographic limitations may still prohibit paramedics from direct transport to a trauma service for some patients with TSCI, where their injury occurs greater than one hour transport time from the nearest Trauma service, and for those not attended by medical retrieval services. However, subsequent decisions to transfer a patient to a higher level of care should be made on clinical grounds as opposed to available resources. This study has identified that a significant two thirds of patients transferred from non-trauma designated hospitals did not achieve admission to a SCIU, or where they did, this occurred more than 24 hours following injury in 40% of cases.

These data suggest that patients experienced unnecessary delays both in retrieval to higher level of care, and admission to a SCIU either at all or in a timely manner; however, it is not possible to understand the reasons for this here and further study is clearly needed. Although the patient with a final diagnosis of spinal cord concussion experiences much better outcomes than those with permanent neurological deficit, this injury can take up to 72 hours to resolve. As such, in the first 24 hours post injury, the exact diagnosis may be unknown, and these patients must be treated in the first instance, in the same manner as patients who ultimately remain permanently paralyzed.

Future studies will be able to evaluate the impact this policy change and any changes in patient outcomes that may have occurred as a result of these changes. They can also assist in the identification of barriers and facilitators to adherence to best practice guidelines among key stakeholders and state-wide trauma service providers.

Limitations

The risk of a Type I error is a limitations due to the multiple testing in the analyses we have used; we aimed to reduce this risk by reducing the error level to 0.025 [29], understanding that this may then reduce the power of the study. The final model was however, robust to this. Lack of a standard measure of injury severity in this study, such as the Injury Severity Score, which is not available in the administrative datasets, is a limitation. Patients who were admitted to a SCIU within 24 hours of injury had longer acute care admissions and were more likely to have a subsequent rehabilitation admission than those who were admitted after 24 hours. This may indicate that the former group had greater injury severity than the latter. The use of length of stay as a proxy for injury severity has previously been demonstrated as a reasonable and valid surrogate for serious injury when more detailed outcomes or measures are not available [22]. However, some caution is required as the discriminatory value of length of stay can differ according to other factors such as age and types of injury being studied. In addition, due to study design employing hospital administrative data to examine "health system-wide" behaviour no standardised clinical neurological examination (ISNCSCI) or imaging data were available for outcomes.

The recorded rates of less than 82% application of any prehospital spinal precautions/immobilisation and less than 48% for cervical collar use, suggest possible under-recognition of TSCI in some circumstances. However, ASNSW data from the time period of the study was extracted from an electronic database that was entered manually from the PHCR. As not all information is transcribed into the electronic format, including any 'free text', vital information about the care episode may not be available for analyses. For example, application of a cervical collar may be documented in the (non-transcribed) 'free text' and may account for the lower than expected rates of collar application. Since 2011, the Ambulance Service of NSW has transitioned to an electronic medical record and this may assist in more comprehensive data capture.

Noonan et al. [30] recently reported on the limitations of using ICD codes from administrative databases in an attempt to accurately capture clinical diagnoses and treatment [30]. To determine the validity of a patient who had been included using an algorithm of ICD codes, substantial checks were undertaken by hand, which brought to light many inconsistencies in the coding process. Similar findings have been reported in previous research, where coding errors and misclassifications led to skewed reporting of incidence and prevalence [30].

Patients with TSCI who did not receive care at a SCIU at any time were grouped with those who arrived at a SCIU after 24 hours. It may be that these 'no SCIU arrival' patients, who comprised the majority (74%) of the 'late arrival' group, differed substantially from those who received late SCIU care, which may influence differences noted between the two groups in these analyses. However, given the evidence of increased secondary complications experienced by patients not receiving timely admission to a SCIU [13-15], this study sought to identify potential barriers to adherence to current guidelines.

Conclusion

During 2006-09, patients with TSCI did not experience consistent, standardized treatment pathways across the state of NSW, according to the guidelines in place at that time. While the presence of multiple injury including TBI, and the need to stabilize patients before transfer are factors that may influence the time taken to reach a SCIU, transfer pathways and numbers of transfers between services seem to have also impacted the likelihood of TSCI patients receiving acute care in a SCIU within 24 hours. Although the retrospective nature of this study could not permit a quantification of the impact of these issues on time to arrival at a SCIU and ultimate patient outcomes, the findings indicated that many patients with TSCI were not admitted to a SCIU at any time following injury, or benefited from recommended early decompressive surgery. Delays to definitive care may have implications for long term outcomes. The findings from this study, however, have provided guidance on state-wide trauma system processes that may benefit from review, including rapid consultation with SCIU clinical experts to facilitate more timely definitive care and improved acute care pathways. These results will also inform prospective research [31,32] that will provide better context around clinical decision-making in view of injury severity, the location of the incident and referral pathways. This future prospective research will also facilitate an accurate mapping of care pathways for TSCI patients across the health system; review agency compliance with current guidelines, including care protocols and inter-hospital transfer policies and practice; determine policies with unintended consequences that lead to delays in the receipt of definitive care; and examine long term patient health outcomes. Importantly, these findings will be used to determine health service and policy reasons that may contribute to delay, and the influence of these factors on patient outcomes for this population.

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Competing Interests

No support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; and no other relationships or activities that could appear to have influenced the submitted work.

Contributions

LNS developed the statistical analysis plan and conducted the analysis, trained associated staff who reviewed the data and drafted and revised the paper, JM conducted the clinical review and interpretation of the data and revised the paper, SB contributed to the statistical analysis plan, conduct and interpretation of the analysis and revision of the paper, SM contributed to the interpretation of the findings and the revision of the paper.

Transparency Declaration

The lead author (LNS) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained. The lead author (LNS) also affirms that the manuscript, including related data, figures and tables has not been previously published and is not under consideration elsewhere.

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Identifying predictors of higher acute care costs for patients with traumatic spinal cord injury and modelling acute care pathway redesign: a record linkage study

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Abstract

Study Design: Record linkage study using healthcare utilisation and costs data.

Objective: To identify predictors of higher acute-care treatment costs and length of stay for patients with traumatic spinal cord injury (TSCI).

Summary of Background Data: There are few current or population-based estimates of acute hospitalisation costs, length of stay and other outcomes for people with TSCI, on which to base future planning for specialist SCI health care services.

Methods: Record linkage study using healthcare utilisation and costs data; all patients aged ≥ 16 years with incident TSCI in the Australian state of New South Wales (June 2013-June 2016). Generalised Linear Model regression to identify predictors of higher acute care treatment costs for patients with TSCI. Scenario analysis quantified the proportionate cost impacts of patient pathway modification.

Results: 534 incident cases of TSCI (74% male). Total cost of all acute index episodes approximately AUD$40.5 (95%CI ±4.5) million; median cost per patient was AUD$45,473 (IQR: $15,535–$94,612). Patient pathways varied; acute care was less costly for patients admitted directly to a specialist spinal cord injury unit (SCIU) compared with indirect transfer within 24 hours. Over half (53%) of all patients experienced at least one complication during acute admission; their care was less costly if they had been admitted directly to SCIU. Scenario analysis demonstrated that a reduction of indirect transfers to SCIU by 10% yielded overall cost savings of AUD$3.1 million; an average per patient saving of AUD$5,861.

Conclusions: Direct transfer to SCIU for patients with acute TSCI resulted in lower treatment costs, shorter length of stay and less costly complications. Modelling showed that optimising patient-care pathways can result in significant acute-care cost savings. Reducing potentially preventable complications would further reduce costs and improve longer-term patient outcomes.
Keywords: Traumatic spinal cord injury, Costs, Length of Stay, Complications, Record linkage

Level of Evidence: 3

Key Points

- The total cost of all acute index episodes during the study period was $40.5 million and the ‘per patient’ cost (as incurred by the health service provider) was estimated at a median (IQR) of $45,473 ($15,535–$94,612).
- Direct transfer to SCIU resulted in lower treatment costs, shorter length of stay and less costly complications.
- Optimising patient transfer pathways can result in significant cost savings at health system level.

Introduction

Traumatic spinal cord injury (TSCI) is a devastating, costly injury resulting predominantly from motor vehicle crashes and falls. Despite relatively low annual incidence in Australia (~21.0–32.3 cases/million population),[1] resulting treatment costs are exorbitant. The high economic burden on health care systems due to TSCI have been previously highlighted in several population-based studies in the United States of America (USA) and Canada;[2] delayed admission to specialist care for TSCI contributing to higher cost burden in Canada.[3,4] The estimated total national costs attributable to SCI-related hospitalizations in 2009 in the USA were approximately $1.69 billion, [5] however, this included both non-traumatic and traumatic SCI without acute-care costs itemised separately. Acute-care costs for TSCI have been increasing steadily despite decreasing lengths of stay (LOS),[6] predominantly due to medical advances and the resource intensive nature of specialist care. Examination of the true cost of acute-care for TSCI and its determinants is vital, in order to identify those factors potentially amenable to change.

Recent studies have examined complications and readmissions in TSCI,[8] [9] however, these studies did not provide robust cost estimates to evaluate the impact of these and other potential cost drivers in TSCI acute care. Early direct transfer to a specialist spinal cord injury (SCI) unit (SCIU) has proven efficacious in reducing risks of secondary neurological deterioration, leading to improved patient outcomes,[10-13] and implicit reduced health service expenditure. Expert consensus recommends transfer to SCIU within 24 hours post-injury. In Australia and the United Kingdom, studies have identified poor adherence to this recommendation;[14-16] proposing resultant impact on acute-care resource utilisation. Strategic use of population-based data has been called for; for example, to inform effective clinical pathway redesign.[7]

Undertaking prospective studies to quantify the impact and potential savings of clinical pathway redesign is time consuming and costly, even with demonstration of cost-effectiveness and improved outcomes.[17] Other methods, such as the strategic use of modelling techniques using accurate epidemiological health data, have provided validation of robust means to make substantial cost savings by redesigning care pathways.[18] Such evidence can be used to inform future funding decisions, by identifying cost-effective, and optimal acute-care pathways for patients, assisting in the pre-implementation phase.

Our study objectives were to a) determine true acute-care treatment costs for TSCI across New South Wales (NSW) using record-linked healthcare data, b) determine predictors of higher costs and LOS, c) apply scenario analysis modelling to measure proportionate cost impacts of potential health service pathway modifications.

Materials and Methods

Study population

Study setting: NSW, Australia's most populous state,[19] with the highest number of public and private hospitals and consequent hospital expenditure nationally.[20]

Inclusion criteria: Acute-care for patients aged≥16years with incident TSCI from June 2013-June 2016, identified using specific TSCI-related International Classification of Diseases (ICD-10AM)[21] diagnostic codes **(Appendix – 1,** http://links.lww.com/BRS/B419**)** within hospital separations data.

Exclusion criteria: Any rehabilitation admissions (diagnosis code prefix 'Z'), injury incident preceding study period, missing ICD-10AM codes for injury mechanism at time of injury (**Appendix - 1,** http://links.lww.com/BRS/B419), AR-DRG code for chronic para/quadriplegia (B82A/B/C) in index episode (indicating previous – not incident – injury) (Figure 1).

Data sources and linkage

Figure 1 illustrates the data linkage process. The Centre for Health Record Linkage linked patients with Appendix codes in any diagnosis field within the Admitted Patient Data Collection (APDC), with all corresponding records in administrative datasets (**Appendix,** http://links.lww.com/BRS/B419**)**, using probabilistic linkage methods and ChoiceMaker software **(Figure 1)**Error! Reference source not found..[22] The first hospital episode for the patient satisfying these conditions and constituent of all contiguous episodes of care, including nested/non-nested transfers, was recognised as the 'index event'. Acute-care completeness was ascertained when separation modes indicated either hospital discharge or transfer to a rehabilitation or private hospital. Socio-Economic Indexes for Areas quantiles derived from patient residence postcodes were used as a socio-economic measure for the study population.[23]

Injury severity

The International Classification of Diseases Injury Severity Score (ICISS) provided an injury severity measure for participants;[24] a well validated metric offering diagnosis-specific survival probabilities.[25] An injury's severity is inverse to its ICISS; a lower ICISS represents higher injury severity; higher ICISS less severe injury. Charlson Co-morbidity Indices (CCI) were derived from ICD-10AM diagnostic codes;[26] applying the highest CCI across episodes. Higher CCI represents higher mortality probability; absent comorbidities a CCI of zero. Multiple-trauma (defined **Appendix -1,** http://links.lww.com/BRS/B419**)** identified injuries to other body regions, including arm or shoulder, hip or leg, chest, abdomen, skull/face and brain. Secondary complications associated with TSCI in the acute episode were categorised into three 'major complication' classes; pressure injuries, respiratory related and urinary related (**Error! Reference source not found.** -1).

Costing method

All costs represent 2016 Australian dollars. Analyses stratified direct patient level costs by demographic and clinical characteristics. Total 'per patient' treatment costs were estimated with a bottom-up costing approach using the NSW activity-based funding District Network Return (DNR) data. DNR data captures the 'true costs' incurred by health service providers, most, but not of which comprises staff salaries and operating costs, for all admitted hospital and emergency department separations included in index admissions (**Appendix - 1,** http://links.lww.com/BRS/B419). Costs are presented as both median (IQR), accounting for non-normal distribution, and mean (SD), for cross-disciplinary interpretability.

Analysis

Acute-care treatment costs associated with TSCIs were estimated from the healthcare provider perspective. LOS included all days between first separation admission dates-last separation discharge dates. Eligible separations with intermediary time-gaps$\leq$ 24 hours were included as same episode.

Generalised Linear Model (GLM) regression analysis (log link and gamma error term) used to identify significant determinants of acute-care costs and LOS; variables initially included were those known at time of admission having univariate significance ($p \leq 0.2$). Derived variables added included ICISS, multiple-trauma, secondary complications and patient pathways. Patients with surgical procedures within the index episode were identified based on the relevant surgical procedure codes from APDC data (Appendix -1, http://links.lww.com/BRS/B419).

Sensitivity analysis and scenario analysis

Comorbid injuries were considered more severe than the TSCI where principal diagnoses were non-SCI related. Sensitivity analysis progressively reduced acute-care costs by 20%, 30% and 40% to account for the additional costs attributable to such co-morbidities.[27]

Scenario analyses examined cost impacts of proportionate variations in patient care pathway; acute-care specifically comparing patient costs and bed days between direct transfers to SCIU and varying levels of indirect transfers from non-spinal hospitals. Bootstrapped mean costs and LOS estimates for patient pathways were derived from GLM regression analyses for the scenario analysis. Indirect transfers to SCIUs were progressively reduced by 10%, 20% then 30%, assessing cost impacts of each pathway variation.

Statistical analyses were performed using STATA version 15.1; sensitivity and scenario analyses using Microsoft Excel.

Results

Patient characteristics

There were 534 patients identified with an acute incident TSCI, with a total of 811 separations in the study period; 32 patients (6.0%) died during acute-care admission. Mean (SD) age 53.6 (21.5) years; 396 (74.1%) males. Over half of all patients (n=284, 53%) had sustained cervical level injury. TSCI was the primary diagnosis for 377 (70.6%); falls the most common injury mechanism (n=285, 53.4%) overall. Almost one-third (n=144, 27.0%) were admitted directly to SCIU; 177 (33.1%) transferred there from another acute care service. Patients treated in a SCIU were deemed higher complexity, with 53.6% having cervical injury, the majority (79.4%) with complete SCI lesions and more severe mean ICISS (0.82 vs 0.86, $p<0.001$).

Hospitalisation costs and length of stay

The total cost for all acute TSCI episodes was estimated at $40.5 million; median (IQR) and mean (SD) per patient costs were $45,473 ($15,535–$94,612) and $75,801 ($99,096), respectively. Median (IQR) LOS was 15.4 (6.8-26.2) days; mean (SD) LOS, including hospital and ED episodes, was 22.2 (24.5) days. **Table 1** shows acute treatment costs by patient characteristics.

More than half of patients (n=299, 56%) had surgical procedures within the index acute care episode. Of operated patients, 197 (66%) had their surgical procedure at a SCIU, 86 (29%) were at Major Trauma Service Hospitals (MTS), the remainder at other hospitals. A higher proportion of patients transferred to a SCIU indirectly from a non-SCIU hospital within 24 hours (99%) had the surgical procedure within the SCIU compared to patients transferred after 24 hours (65%). The mean LOS was significantly higher in patients with surgical procedures compared to those with non-surgical procedures (27.2 vs 15.8 days; $p < 0.001$).

Over half (n=283, 53%) of all patients with TSCI had at least one major complication within their acute-care episode; 126 patients (24.0%) had two or more major complications. The most common complications were pressure injuries, reported in nearly 20% of patients. **Table 2** presents all complications recorded during acute-care. Mean LOS for patients with complications within their acute episode was 31.9 days, compared to 11.3 days for those without complications. Over half of all patients (n= 300, 56.2%) received in-patient rehabilitation within their index admission; the majority of them were treated in SCIU (n=243, 81%) and were relatively younger (mean age 49.7 years) compared to those admitted to non-spinal hospitals (mean age 64.1 years).

Predictors of acute-care costs and LOS

Table 3 presents the costs regression analysis**.** Statistically significant predictors of higher treatment costs were care pathways, complications within acute episodes, multiple-trauma, extent of injury, higher injury severity (lower ICISS) and co-morbidities (higher CCI). Patients with complications were comparatively less expensive if transferred to SCIU within the first 24 hours from injury. A patient admitted directly to SCIU, without intervening hospital transfer cost $63,626 (adjusted mean), compared with the significantly higher mean costs for patients transferred to SCIU from either a trauma centre (MTS/RTS) ($101,656) or from Metropolitan/Regional hospitals ($86,426). Patients treated entirely either at MTS/RTS ($46,210) or metropolitan/regional hospital ($42,403) incurred lower mean costs. Regression analysis showed complications to be less expensive if patients were admitted to SCIU within 24 hours post-injury (**Table 3**); except where patients had all three categories of complications.

The regression results for LOS (**Table 4**) show LOS being incrementally influenced by complications, multiple-trauma, injury severity, co-morbidities and indirect SCIU transfer. LOS was higher if transferred to a SCIU from either MTS/RTS (26 days) or metropolitan/regional hospital (35 days).

Summarising, both acute-care costs and LOS were higher if the patients were secondarily transferred to SCIU from any non-SCIU hospital type.

Sensitivity analysis

Applying 40%, 30% and 20% decreases respectively to acute-care costs of patients without TSCI-related principal diagnosis, median acute-care costs per patient were $38,642 ($12,964-$84,826), $39,655 ($13,373-$86,811) and $41,248 ($14,414-$89,387).

Scenario analysis

Overall incremental cost savings of $3.1 million, $6.3 million and $9 million were demonstrated from reductions in indirect transfers to SCIU by 10%, 20% and 30%, respectively (**Table 5)**. A proportion of these savings (between 44%-50%) were bed days saved; the remainder as direct savings from patient transfer pathway modifications.

Discussion

This record-linkage study identified 534 patients to have sustained acute incident TSCI over a three-year period. The findings provide unique and improved acute-care cost estimates for this group with severe injury from the healthcare provider's perspective. The total cost of all acute index episodes during the study period was around $40.5 million AUD; the 'per patient' cost estimated at a mean (SD) of $75,801 ($99,096), inflation-adjusted.

Key findings from this study were that multiple hospital transfers and indirect or delayed transfer (>24 hours) to SCIU were key drivers of higher acute-care costs. Importantly, the cost of secondary complications was significantly less expensive for patients who experienced direct transfer to SCIU. The development of complications in addition to the TSCI is detrimental to the patient health and overall patient outcomes. Early recognition with appropriate prehospital management and timely transfers to SCIU can facilitate access to specialist care and reduce preventable complications.[15] Importantly, secondary complications are potentially preventable,[28] and attending to their risk and development offers not only cost savings, but improved longer term quality of life for patients with TSCI.[28 29]

Considering these findings, clinical pathway reform was modelled using scenario analyses to quantify potential cost effects of system manipulation. This model demonstrated significant cost savings by optimising acute-care pathways. These findings are in line with previous international studies which have shown the direct transfer to the SCIU to be cost-effective and beneficial.[3 10] While the simultaneous impact on the remainder of the health service was not assessed in this model, the argument for such reform is strong, with clear benefits to both the health service budget and the patient's quality of life. Other studies have also advocated transfer to the SCIU from non-SCIU hospitals within a specific time frame to minimise the complications and resource utilisation.[4 12] Such findings further encourage the vital need to consider more cost-effective care pathways for patients with serious injury that address not only their needs for evidence based specialised care for their injuries, but rising healthcare costs.

This study has distinct strengths, which include the comprehensive estimation of acute-care costs using the DNR data; a novel method capturing the true treatment costs from the health care provider's perspective, adjusting for patient heterogeneity. Scenario analysis provides evidence of cost savings and reduction in bed days through variation in patient referral pathways to specialist centres.

This study also has several limitations. Firstly, in assessing costs from the healthcare provider perspective over a relatively short time-frame, the long-term care or societal costs such as productivity and earnings losses, or medico-legal costs are not considered. This may result in an underestimation of the true costs, as long term care costs are a key cost driver for patients with TSCI.[27 30] However, the intentional primary objective was to focus on the acute phase of care. Patients with major trauma will have other immediate healthcare needs in addition to TSCI management and may follow a pathway best suited to these. In order to account for some of this variation, we included measures for patient injury severity, co-morbidity and multiple-trauma in the analyses. Patients with surgical procedures within the index acute care episode had statistically significant higher mean costs and mean LOS than patients without any surgical procedures. Surgical intervention at a SCIU may synergize with the effects of direct admission to SCIU resulting in cost savings. Nevertheless, surgical procedures variable was deliberately not included in the regression models as only those variables already known at the time of admission were included in the prediction models to avoid dilution of the causal effects. Additionally, sensitivity analyses attempted to account for the added costs associated with multiple-trauma, showing median per patient cost decreases of 15%, 13% and 9% for a corresponding reduction of acute-care costs in patients with non-TSCI-related principal diagnosis by 40%, 30% and 20%, respectively.

Hospital administrative data is limited by the absence of injury severity scoring. However, ICD-10AM codes-based measures, such as the validated ICISS, are widely used to address this gap. Recent studies show ICISS to better predict in-hospital mortality, with better discriminative ability than AIS-mapping. It is recommended for describing injury severity when using ICD-10 codes.[31]

Previous studies of predictors of higher treatment costs for major trauma patients in Australia are consistent with the current study findings,[8 32] although this study has identified some important additional and potentially modifiable factors. Amongst the predictors of higher costs, optimising the patient care pathways by promoting transfer to SCIU within 24 hours, reducing the number of transfers and reducing potentially preventable complications within acute episodes are all feasible through reform to achieve more efficient care pathways that reduce costs and improve short term patient outcomes.

The findings from this study provide strong and further evidence to support following consensus recommendations to admit patients with TSCI directly to the SCIU or to transfer them there expeditiously within 24 hours post-injury,[4, 10, 12] leading to optimisation of both costs and patient outcomes. Piloting implementation of these reforms locally, would facilitate better understanding of their impact at a health system level, and assist healthcare providers, insurers and other policy stakeholders in planning for future acute-care services. Further investigation is required to estimate the true financial impact of these variations on the entire Australian healthcare system, mapping patient pathways in detail to inform future healthcare planning for patients with TSCI.

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Table 1: Summary study patient characteristics and related costs

Variable	Total (n=534)	%	Median cost ($)	Mean cost ($)
Sex				
Female	138	26%	36799 (13382, 72675)	59331 (72757)
Male	396	74%	48216 (17932, 98975)	81540 (100000)
Age				
16-30	101	19%	51392 (14695, 98541)	91083 (120000)
31-45	108	20%	43259 (12679, 93474)	79573 (110000)
46-60	113	21%	47029.5 (20687, 97965)	70644 (84293)
61-75	119	22%	52261 (21886, 100000)	75484 (86406)
76+	93	17%	29332 (14798, 80680)	61495 (84915)
SEIFA* Quantiles				
1 (Lowest)	76	14%	57086 (24638,110000)	88751 (95249)
2	115	22%	43035.3 (19104, 100000)	81122 (120000)
3	121	23%	34889 (15535, 69475)	54701 (61800)
4	60	11%	50045 (14708, 86033)	83582 (120000)
5 (Highest)	146	27%	52210 (13382, 110000)	84116 (100000)
Unknown	16	3%	12212 (5745, 43206)	31403 (38089)
Charlson Co-morbidity Index				
0	407	76%	46514 (14018, 89092)	73833 (97770)
1	71	13%	38141 (20855, 130000)	84657 (110000)
≥2	56	11%	48456 (18250, 110000)	78875 (99107)
Multiple-trauma				
Isolated TSCI	266	50%	25156 (8959, 56906)	47960 (70096)
1 additional injury	118	22%	53117 (22589, 89092)	74597 (81515)
2 or more injuries	150	28%	87302 (40454, 140000)	130000 (130000)
ICISS[#] Score				
< 0.7 (More severe)	47	9%	130000 (47719, 230000)	160000 (160000)
0.7 to <0.83	176	33%	69140 (26547, 120000)	94102 (110000)
0.83 to <0.89	107	20%	35026 (11312, 82333)	61865 (85070)
0.89 to <0.95	102	19%	38133 (17402, 74917)	56921 (73148)

0.95 to 1.00	102	19%	29069 (7665, 51370)	37470 (41806)
Highest Level of Injury				
Cervical	284	53%	45473 (17833, 98935)	78212 (99859)
Thoracic	144	27%	63475 (24579, 110000)	87994 (100000)
Lumbar	106	20%	30424 (9082, 65134)	52776 (86791)
Extent of Injury				
Unspecified	131	25%	22092 (7349, 50069)	43777 (67500)
Incomplete	223	42%	48720 (20929, 86811)	70759 (75071)
Complete	82	15%	110000 (75459, 200000)	170000 (150000)
Conus medullaris/Cauda equina	98	18%	30424 (9847, 68223)	54446 (89486)
Died in Hospital				
No	502	94%	42232 (13753, 87071)	74980 (100000)
Yes	32	6%	70544 (29635, 120000)	88684 (72100)
TSCI-related Principal Diagnosis Code				
No	157	29%	29080 (8959, 65134)	52540 (68195)
Yes	377	71%	49766 (20687, 10000)	85488 (110000)
No. of Hospital transfers				
No Transfers	311	58%	36742 (11861, 83133)	66803 (92723)
1 or more transfers	223	42%	54910 (28278, 100000)	88349 (110000)
Inpatient Rehabilitation				
No	234	44%	19083 (7397, 49766)	42503 (63298)
Yes	300	56%	68880 (38085, 120000)	100000 (110000)
Transfer to Spinal Unit within 24 hours				
No	275	52%	25793 (10546, 55571)	50125 (78001)
Yes	259	48%	73531 (38029, 120000)	100000 (110000)
Surgical procedures				
No	235	44%	15911 (6855, 38775)	40092 (72377)
Yes	299	56%	74917 (41149, 120000)	100000 (110000)
Surgical procedures at SCIU				
No	102	34%	40380 (21743, 97665)	71327 (88898)
Yes	197	66%	83798 (56831, 130000)	120000 (110000)

Patient Pathway				
SCIU┐ only	144	27%	66041 (24772, 120000)	95899 (110000)
TS^ only	152	28%	19272 (102512, 44471)	37872 (51763)
TS to SCIU≥24 hrs	37	7%	100000 (437734, 140000)	140000 (150000)
TS to SCIU≤24 hrs	86	16%	83942 (55966, 120000)	120000 (110000)
Other to SCIU≥24 hrs	22	4%	43678 (272845, 67334)	59210 (59441)
Other to SCIU≤24 hrs	32	6%	54489 (32172, 100000)	92682 (110000)
Others	61	11%	13099 (6096, 31768)	24662 (34913)
Hours in ICU	275	51%	87 (36, 288)	248 (371)

*Socio-Economic Indexes for Areas

International Classification of diseases-based Injury Severity Score

┐Specialist Spinal Cord Injury Unit

^Trauma Service hospital

Table 2: Complications within acute-care treatment

Complication category	N	%	Mean LOS (days)*	Median LOS (days)**	Median cost ($)**
No Complications	258	48%	11 (10, 13)	8 (4, 16)	19,869 (7570, 49006)
Urinary related	84	16%	23 (21, 27)	19 (11, 29)	49,807 (25838, 93528)
Respiratory related	86	14%	25 (28, 43)	21 (13,33)	80,020 (43047, 140000)
Pressure injuries	106	22%	45 (44, 69)	33 (21, 68)	110000 (58145, 210000)
Number of Complications	**N**	**%**	**Mean LOS (days)***	**Median LOS (days)****	**Median cost ($)****
No Complications	258	48%	11 (10, 13)	8 (4, 16)	19,868.80 (7570, 49006)
Any 1 complication	84	28%	24 (21, 27)	20 (13,29)	72,358.50 (31873, 110000)
Any 2 types of complications	89	17%	36 (29, 43)	24 (18, 46)	87,311 (48239, 150000)
ALL 3 types of complications	37	7%	57 (44, 69)	53 (23, 92)	180,000 (66321, 350000)

*Mean (95% Confidence Intervals), ** Median (Inter Quartile Range)

Table 3: GLM Regression Results for Predictors of Total Acute-care Cost per patient

Total Cost per Patient	Coefficient	P>|z|	[95% Conf. Interval]	
Age				
16-30	1			
31-45	0.97	0.802	0.77	1.22
46-60	1.01	0.915	0.80	1.28
61-75	0.94	0.585	0.74	1.19
76-116	0.92	0.535	0.71	1.19
Sex				
Female	1			
Male	1.04	0.628	0.88	1.24
Highest level of Injury				
Cervical	1			
Thoracic	1.11	0.331	0.90	1.39
Lumbar	1.32	0.387	0.70	2.49
Multiple-trauma				
Isolated TSCI	1			
1 additional injury	1.22	0.042	1.01	1.48
2 or more injuries	1.73	<0.01	1.40	2.13
ICISS[#] Score				
< 0.7 (More severe)	1			
0.7 to <0.83	0.71	0.028	0.53	0.96
0.83 to <0.89	0.55	<0.01	0.39	0.77
0.89 to <0.95	0.62	0.01	0.43	0.89
0.95 to 1.00	0.49	<0.01	0.32	0.74
TSCI-related Principal Diagnosis Code				
No	1			
Yes	1.02	0.877	0.83	1.24
Transfer to Spinal Unit within 24 hours				
No	1			

Yes	1.80	0.255	0.66	4.92
No. of Complications#Transfer to Spinal Unit within 24 hours				
Any 1 complication#No	2.20	<0.01	1.71	2.84
Any 1 complication#Yes	1.54	<0.01	1.20	1.98
Any 2 complications#No	2.52	<0.01	1.83	3.47
Any 2 complications#Yes	2.21	<0.01	1.64	2.98
All 3 complications#No	2.80	<0.01	1.66	4.71
All 3 complications#Yes	4.01	<0.01	2.70	5.96
Patient care Pathway				
SCIU only	1			
MTS/RTS^ only	1.07	0.891	0.40	2.89
MTS/RTS to SCIU>=24 hrs	2.42	0.089	0.88	6.69
MTS/RTS to SCIU<=24 hrs	1.50	<0.01	1.19	1.90
Other to SCIU>=24 hrs	1.76	0.289	0.62	5.04
Other to SCIU<=24 hrs	1.43	0.042	1.01	2.02
Others	0.91	0.85	0.33	2.49
Extent of Injury				
Complete	1			
Unspecified	0.65	<0.01	0.48	0.87
Incomplete	0.83	0.148	0.64	1.07
Conus medullaris/Cauda equina	0.70	0.285	0.36	1.35
Charlson Index	1.11	<0.01	1.03	1.19
_cons	31744.71	<0.01	10903.71	92420.54

[#] International Classification of diseases-based Injury Severity Score

^Major Trauma Service/ Regional Trauma Service

Table 4: GLM Regression Results for Acute-care Length of Stay

Length of Stay	Coefficient	P>|z|	[95% Conf. Interval]	
Age				
16-30	1			
31-45	0.84	0.159	0.66	1.07
46-60	1.01	0.952	0.79	1.28
61-75	0.98	0.85	0.76	1.25
76-116	0.95	0.698	0.72	1.24
Sex				
Female	1			
Male	0.88	0.166	0.73	1.06
Highest level of Injury				
Cervical	1			
Thoracic	1.10	0.418	0.88	1.38
Lumbar	0.88	0.714	0.45	1.72
Multiple-trauma				
Isolated TSCI	1			
1 additional injury	1.20	0.07	0.99	1.47
2 or more injuries	1.63	<0.01	1.30	2.03
ICISS[#] Score				
< 0.7 (More severe)	1			
0.7 to <0.83	0.85	0.303	0.62	1.16
0.83 to <0.89	0.70	0.043	0.49	0.99
0.89 to <0.95	0.78	0.197	0.53	1.14
0.95 to 1.00	0.70	0.11	0.46	1.08
TSCI-related Principal Diagnosis Code				
No	1			
Yes	0.98	0.852	0.79	1.22
Number of Complications				
No complications	1			
One complication	1.62	<0.01	1.34	1.96
Two or more complications	2.58	<0.01	2.07	3.22

Charlson Co-morbidity Index				
	1.12	<0.01	1.04	1.21
Patient care Pathway				
SCIU only	1			
TS only	0.81	0.07	0.65	1.02
TS to SCIU>=24 hrs	1.57	<0.01	1.12	2.18
TS to SCIU<=24 hrs	1.27	0.054	1.00	1.62
Other to SCIU>=24 hrs	1.07	0.763	0.69	1.64
Other to SCIU<=24 hrs	1.45	0.041	1.01	2.06
Others	0.82	0.179	0.61	1.10
Extent of Injury				
Complete	1			
Unspecified	0.86	0.351	0.63	1.18
Incomplete	0.86	0.276	0.66	1.13
Conus medullaris/Cauda equina	1.10	0.784	0.55	2.19
_cons	15.67	<0.01	9.72	25.28

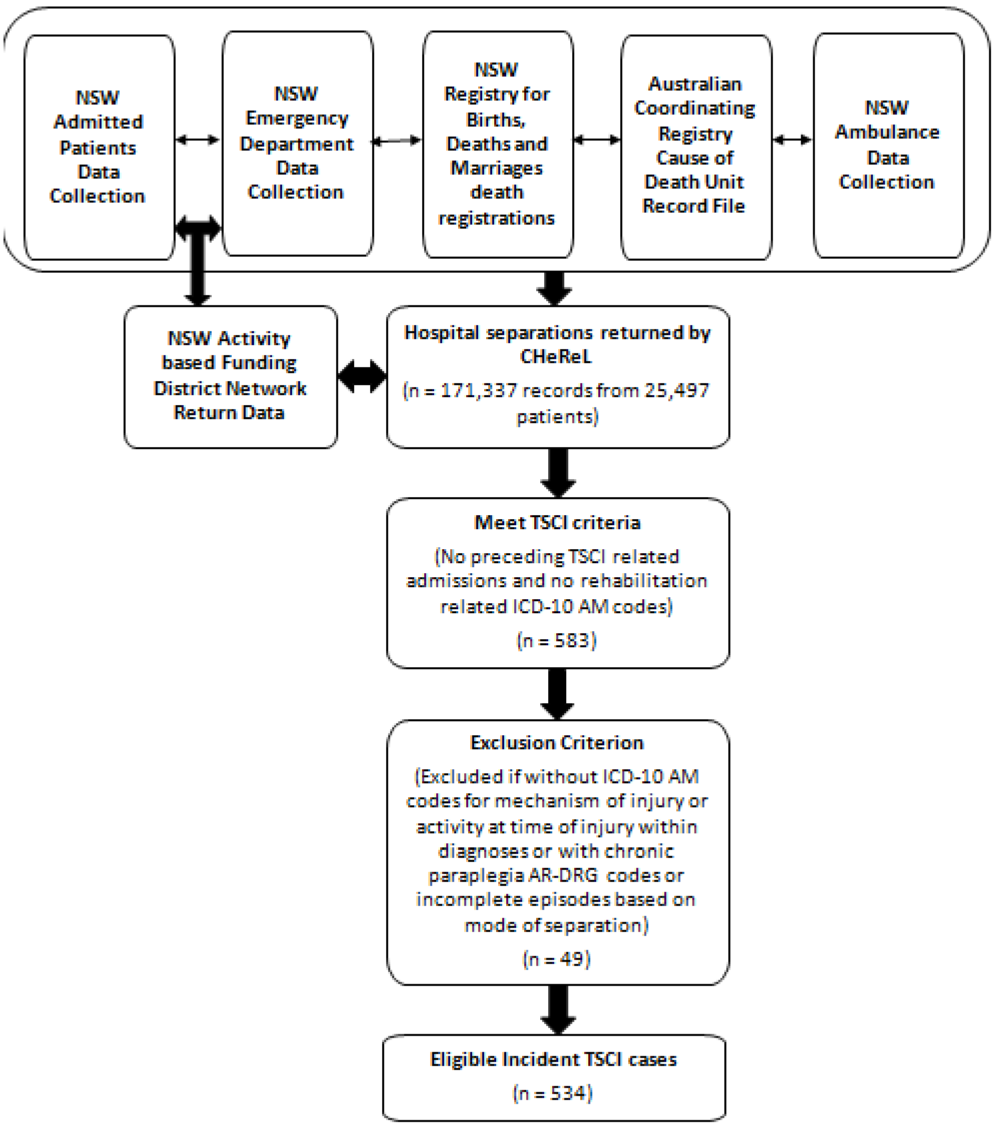
International Classification of diseases-based Injury Severity Score

Table 5 Scenario Analysis results

			Reduction in indirect transfers to SCIU					
Pathway	**n**	**%**	**10% reduction**		**20% reduction**		**30% reduction**	
Base case (n)			**Direct Cost Savings ($)**	**Bed days Saved**	**Direct Cost Savings ($)**	**Bed days Saved**	**Direct Cost Savings ($)**	**Bed days Saved**
SCIU	144	27	-3,245,768	-1155	-6,491,535	-2311	-9,737,303	-3466
TS only	152	28	0	0	0	0	0	0
TS to SCIU	123	23	2,592,928	700	5,185,856	1401	10,371,712	2802
Others to SCIU	54	10	2,204,451	939	4,408,901	1877	4,408,901	1877
Others only	61	11	0	0	0	0	0	0
Direct cost savings ($)			1,551,611	484	3,103,222	967	5,043,310	1213
Bed day savings ($)			1,578,141		3,156,281		3,957,290	
Total Savings ($)			3,129,752		6,259,503		9,000,600	
Savings Per patient ($)			5,861		11,722		16,855	

Figure Legend

Figure 1: Record Linkage and Incident TSCI Patient Identification from Record Linked Data



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External benchmarking of trauma services in New South Wales: Risk-adjusted mortality after moderate to severe injury from 2012 to 2016

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ABSTRACT

Background: Trauma centres and systems have been associated with improved morbidity and mortality after injury. However, variability in outcomes across centres within a given system have been demonstrated. Performance improvement initiatives, that utilize external benchmarking as the backbone, have demonstrated system-wide improvements in outcomes. This data driven approach has been lacking in Australia to date. Recent improvement in local data quality may provide the opportunity to engage in data driven performance improvement. Our objective was to generate risk-adjusted outcomes for the purpose of external benchmarking of trauma services in New South Wales (NSW) based on existing data standards.
Methods: Retrospective cohort study of the NSW Trauma Registry. We included adults (≥16 years), with an Injury Severity Score ≥12, that received definitive care at either Major Trauma Services (MTS) or Regional Trauma Services (RTS) between 2012-2016. Hierarchical logistic regression models were then used to generate risk-adjusted outcomes. Our outcome measure was in-hospital death. Demographics, vital signs, transfer status, survival risk ratios, and injury characteristics were included as fixed-effects. Median odds ratios (MOR) and centre-specific odds ratios with 95% confidence intervals were generated. Centre-level variables were explored as sources of variability in outcomes.
Results: 14,452 patients received definitive care at one of seven MTS (n = 12,547) or ten RTS (n = 1905). Unadjusted mortality was lower at MTS (9.4%) compared to RTS (11.2%). After adjusting for case-mix, the MOR was 1.33, suggesting that the odds of death was 1.33-fold greater if a patient was admitted to a randomly selected centre with worse as opposed to better risk-adjusted mortality. Definitive care at an MTS was associated with a 41% lower likelihood of death compared to definitive care at an RTS (OR 0.59 95%CI 0.35-0.97). Similar findings were present in the elderly and isolated severe brain injury subgroups.
Conclusions: The NSW trauma system exhibited variability in risk-adjusted outcomes that did not appear to be explained by case-mix. A better understanding of the drivers of the described variation in outcomes is crucial to design targeted locally-relevant quality improvement interventions.

Introduction

Trauma systems were established to ensure injured patients receive timely access to life saving interventions as well as ongoing care and rehabilitation. Integral parts of trauma systems include ambulance and medical retrieval protocols as well as the designation of specific hospitals as trauma centres. Trauma centres and trauma systems have been associated with improved morbidity and mortality after injury [1,2]. However, improved patient outcomes do not appear to be related entirely to better resources at trauma centres. The designation of specific hospital as

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trauma centres leads to increased experience, improved interdisciplinary communication, development of standardized processes of care, and improved critical care delivery. Nonetheless, variability in outcomes across centres within a given trauma system have been repeatedly demonstrated [3–5].

Even within the same system, not all trauma centres are created equal. Based on a centre's geographic location, patient-mix across centres can vary to a great extent. A centre's proportion of patients with penetrating injuries, elderly patients with falls, or blunt multisystem injuries can lead to differing expertise, protocols of care, and culture. Understanding the strengths and weaknesses of different centres is instrumental in order to properly evaluate the variability in outcomes within a system.

Performance improvement initiatives are at the forefront of trauma system evaluation. These initiatives have evolved from comparing outcomes at the same institution over time (i.e. internal benchmarking) to comparing risk-adjusted outcomes across trauma centres (i.e. external benchmarking). Initiatives that utilize external benchmarking, as the backbone of system-wide performance improvement, have demonstrated system-wide reductions in morbidity and mortality [6,7]. External benchmarking allows for the identification of centres in which patients experience outcomes that are either above or below what would be expected after risk-adjustment. This allows for the identification and dissemination of resources and best practices that have been proven to be effective within the system. However, external benchmarking is highly dependent on valid, reliable, and standardized data.

Over the past 10 years, the evaluation of trauma system performance in Australia has undergoing a rapid evolution. The Australian Trauma Quality Improvement Program (AusTQIP) has produced two reports to date with 25 trauma centres participating nation-wide [8]. It is a treasure trove of injury epidemiology data. However, no attempts at external benchmarking were carried out on the most recent report. At the state level, the New South Wales (NSW) Institute of Trauma and Injury Management (ITIM) produces yearly reports that provide extensive injury epidemiology data as well as unadjusted trauma centre outcomes. Only standardized mortality ratios based on injury severity score and age are currently provided [9]. External benchmarking efforts have been limited to date by issues with data quality, primarily missing vital sign data.

The NSW trauma registry was established by ITIM in 2002. However, it was not until 2006 when initial attempts at the creation of a single standardized data set were launched. By 2009 a comprehensive state-wide trauma registry had been developed. Standardized data dictionaries, minimum data sets, and the use of a single software platform to collect data has significantly improved data quality [10]. However, missingness of vital sign data remained a significant issue. These recent improvements in data quality provide the opportunity to generate sophisticated risk-adjusted outcomes.

Our objective was to generate risk-adjusted outcomes for the purpose of external benchmarking of trauma services based on locally existing data collection standards. Secondary objectives included the evaluation of data quality, as well as evaluation of overall and subgroup risk-adjusted mortality with the purpose of guiding future performance improvement initiatives.

Methods

Setting

The NSW trauma system is based on an inclusive system of hospitals designated to provide care based on injury severity, resources, and expertise. The system consists of seven Major Trauma Services (MTS), three Paediatric MTS (PTS), and ten Regional Trauma Services (RTS). MTS are equivalent to level I trauma centres as defined by the American College of Surgeons (ACS), and possess the depth of resources and personnel required to provide definitive care to severely injured patients [11]. MTS are regional resources and act as the cornerstone of the system. An RTS provides initial assessment, stabilization, and initiates transfer to MTS if required. Each RTS has a designated MTS for referral and support. RTS can provide definitive care to patients with minor to moderate injuries as well as definitive care to a limited number of severely injured patients in collaboration with the MTS. For the most part, an RTS is equivalent to a level III trauma centre as defined by the ACS.

State-wide prehospital triage criteria state that patients meeting major trauma criteria should be transported to the highest level Trauma Service located within a 60 min travel time from the scene, even if this means bypassing closer hospitals and/or an RTS [12].

Data sources

Data were derived from the NSW trauma registry which contains demographic, injury, and outcome data on patients admitted to a trauma service after major trauma. In the registry, major trauma is defined by an Injury Severity Score (ISS) $\geq$12, admission to an intensive care unit or death in hospital following injury [10]. The registry is compiled by the Institute of Trauma and Injury Management. Data was provided in a fully de-identified manner. This project was approved by the Hunter New England ethics and governance office. No external funding was required. All authors had full access to data, statistical reports, and tables, prior to drafting the manuscript.

Patient selection

We focused on adult patients ($\geq$16 years), with moderate to severe injuries (ISS$\geq$12), who received definitive care at either an MTS or RTS after mechanical injuries. Patients admitted after poisoning, suffocation, drowning, overexertion, environmental causes, and burns were excluded. Patients without signs of life on arrival (heart rate = 0, systolic blood pressure = 0 and Glasgow Coma Scale = 3) were also excluded [13]. Patients with isolated hip fractures are not included in our study population. Patients transferred from RTS to MTS were only analysed as MTS patients.

Data quality

The overall dataset as well as the study population derived after applying the inclusion and exclusion criteria was evaluated. Only the variables deemed relevant to mortality risk-adjustment were evaluated (i.e. demographic, vital signs, injury characteristics, outcome status) for completeness and out of range values. Changes in data quality over time were also assessed and were used to guide the study period for which risk-adjusted outcomes would be evaluated.

Risk-adjusted outcomes

The main outcome measure was in-hospital death. Given the nested structure of the data, hierarchical logistic regression models were used [14]. Patients were treated as the lower level units which were nested within each centre (higher level units). To adjust for possible differences in case-mix across centres, age, gender, mechanism, systolic blood pressure, heart rate, Glasgow Coma Scale, and transfer status were included in the model as fixed effects. Centres were included in the model as random effects. Survival risk ratios (SRR) based on Abbreviated Injury Scale (AIS) scores were calculated for each patient and included as a fixed effect. A SRR is defined as the number of patients who survived the AIS-coded injury divided by the total number of patients who sustained the same injury. It is a database-specific point estimate of survival which has been shown to further explain variance and offer better discrimination compared with other injury scoring systems [15]. A traditional worst-injury approach to calculating SRRs was used.

Risk-adjusted outcomes were expressed as a centre-specific risk-adjusted odds ratio (OR) of death with 95% confidence intervals. Trauma centre odds ratios were derived from shrinkage estimates of random effects. A patient that receives care at a centre has a significantly lower than expected mortality if the upper limit of its 95% CI is <1. If the lower limit of the 95% CI is >1, the centre has a significantly higher odds of death compared to the overall average.

In order to quantify the variability in risk-adjusted mortality across centres, independent of patient factors, we calculated the median odds ratio (MOR). It is defined as the median value of the OR between the centre with the highest compared to the centre with the lowest likelihood of death [16]. It can be interpreted as the excess likelihood of in-patient mortality associated with the same patient receiving care at any centre with worse risk-adjusted mortality. The MOR always has a value of 1 or more because it compares a higher- with a lower-ranked centre.

An additional hierarchical model was generated in order to explore the centre characteristics that might contribute to risk-adjusted differences in outcomes. Centre-type (e.g. MTS vs. RTS) and patient volume (i.e. quartiles) were explored and included in the model as additional fixed effects.

Subgroup risk adjusted outcomes

Patients with moderate to severe injuries are quite heterogeneous and may pose distinct challenges which require different resources and expertise. For this reason, the overall cohort was divided into sub-groups for which specific risk-adjusted outcomes were generated: i) *polytrauma (i.e. severe multisystem blunt injuries)*: blunt mechanism of injury and AIS ≥ 3 in =>2 body regions; ii) *elderly patients*: ≥65 years with any mechanism; and iii) *isolated severe traumatic brain injury*: head AIS ≥ 3, Glasgow Coma Scale≤9, and AIS ≤ 2 in all other body regions. Patient sub-groups were not mutually exclusive. The methodology mirrored that of the overall cohort. Patient subgroups were chosen based on clinical differences and not results of significance testing.

Statistical analysis

Medians and interquartile ranges were calculated for continuous variables, and absolute and relative frequencies were used to summarize discrete variables. Proportions were compared using the chi [2] test, medians were compared using non-parametric tests. We elected to use multiple imputation to address missing values for heart rate (7%), systolic blood pressure (7%) and GCS (8%) (Appendix A – statistical analysis). We believe this is a better approach than discarding patients with missing data or using a missing indicator given the low proportion of missing data as well as the relatively large sample size. In addition, this allows for the appropriate use of vital signs as continuous variables in the model [17,18].

Model performance and calibration was evaluated across all models using the C-statistic, the Hosmer Lemeshow test, and observed-versus-predicted outcome plots (Appendix A – statistical analysis). In all analyses, a 2-sided p <0.05 was considered significant. All data were analysed using SAS software (v. 9.4, SAS Institute, Cary, NC).

Results

Data quality

Prior to applying inclusion and exclusion criteria we identified 23,407 injured patients that received care at either an MTS (n = 17,895), RTS (n = 4456), or PTS (n = 1056). Non-vital sign variables were missing in <0.2% of patients. There were no out of range values. However, vital sign data was missing at much higher rates with differences in the proportion of missing data identified across centre-types (Table 1). The proportion of missing data significantly decreased over time, with vital sign data missing in 5% of patients in 2016. Given the high rate of missing vital sign data in 2011, we limited our subsequent analysis to patients that received care between January of 2012 and December of 2016. Furthermore, given that the motor component of the Glasgow Coma Scale was missing in over 10% of patients for the duration of the study period we elected to use the Glasgow Coma Scale instead.

Study population

After applying inclusion and exclusion criteria we identified 14,452 moderately to severely injured adult patients whom received definitive care at one of seven MTS (n = 12,547) or one of ten RTS (n = 1905) (Fig. 1). MTS volume ranged from 874 to 2689 while RTS volume ranged from 101 to 347 patients. On average, there was a 5% increase in the yearly number of patients. The proportion of patients that received definitive care at RTS did not change over time (p = 0.07).

Most patients were male (72%), mean age was 55 (SD 22.5), most were injured either after a fall (46%) or motor vehicle collision (43%), and the median ISS was 17 (IQR 14–25). Overall unadjusted in-hospital mortality was 10% (n = 1390). There were major differences in the volume and characteristics of patients that received definitive care at MTS compared to those at RTS.

There were differences in patient as well as injury characteristics when comparing those that received definitive care at RTS and MTS. Patients at RTS were older and less likely to be transferred from another hospital. Patients at RTS were less severely injured as evidenced by lower median injury severity scores. Over one third of patients at RTS [37%, n = 7060] had isolated severe chest injuries

Table 1
Proportion of missing data.

	Missing data					
	Overall (n = 23,407)	MTS (n = 17,895)	RTS (n = 4456)	PTS (n = 1056)	2011 (n = 3518)	2016 (n = 4071)
GCS	2,979 (13)	2013 (11)	708 (16)	258 (24)	1052 (30)	222 (5)
mGCS	5,949 (25)	4314 (24)	1357 (30)	278 (26)	1669 (47)	504 (12)
Heart rate	2,569 (11)	1967 (11)	423 (9)	179 (17)	977 (28)	133 (5)
Systolic blood pressure	2,780 (12)	2003 (11)	470 (11)	307 (29)	1021 (29)	155 (4)

MTS: Major Trauma Service, RTS: Regional Trauma Service, PTS: Paediatric Trauma Service; GCS: Glasgow Coma Scale; mGCS: motor component of the Glasgow Coma Scale.

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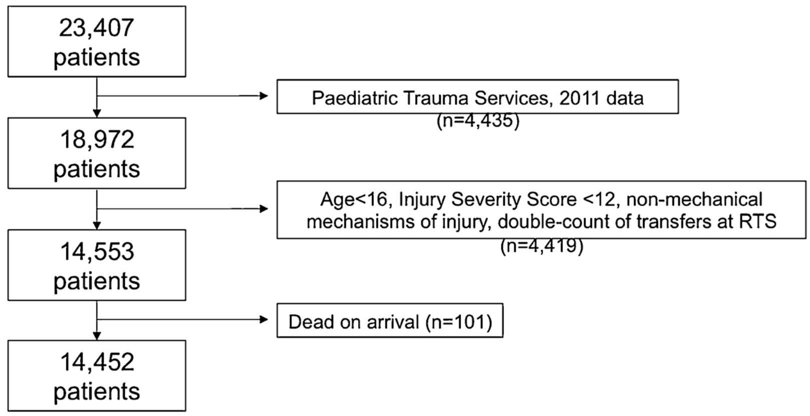

Fig. 1. Patient selection.

(AIS=>3 in the chest and AIS=<2 in all other body regions). However, 1 out of every 5 patients that received definitive care at RTS had an ISS $\geq$25 compared to 1 out of 3 at MTS. Finally, there was a lower proportion of patients who presented with a systolic blood pressure in the emergency department lower or equal to 90 mmHg at RTS compared to MTS (Table 2).

Overall risk-adjusted outcomes

Unadjusted in-hospital death was lower at MTS compared to RTS (Table 3). In addition, a greater degree of unadjusted variability in the range of in-hospital death was observed across RTS (6–20%) compared to MTS (7–12%). Given the observed univariate

Table 2
Patient characteristics across centre type.

	MTS (n = 12,547)	RTS (n = 1905)	*p* value
Age, mean (SD)	54.5 (22.6)	57.8 (21.9)	<0.001
Elderly ($\geq$ 65 years)	4691 (37)	793 (42)	<0.001
Male gender	9,009 (72)	1387 (73)	0.36
Mechanism			<0.001
Fall	5,875 (47)	787 (41)	
Motor vehicle collision	5,270 (42)	914 (48)	
Other blunt	666 (5)	102 (5)	
Gunshot wound	82 (1)	7 (1)	
Stab wound	353 (3)	65 (3)	
Other	301 (2)	30 (2)	
Transfer from another hospital	3,134 (25)	384 (20)	<0.001
Injury Severity Score, median (IQR)	17 (16–25)	17 (14–22)	<0.001
Injury Severity Score 12–15	2967 (24)	651 (34)	
Injury Severity Score 16–24	5730 (46)	866 (45)	
Injury Severity Score 25–47	3601 (29)	372 (20)	
Injury Severity Score 48–75	249 (2)	16 (1)	
Severe injury by body region (AIS=>3)			
Head	6027 (48)	662 (35)	<0.001
Face	285 (2)	21 (1)	0.001
Neck	139 (1)	8 (1)	0.005
Chest	4654 (37)	919 (48)	<0.001
Abdomen	1024 (8)	205 (11)	<0.001
Spine	1867 (15)	174 (9)	<0.001
Upper extremity	216 (2)	24 (1)	0.14
Lower extremity	1,998 (16)	201 (11)	<0.001
Heart rate in emergency department			<0.001
0–60 bpm	1124 (9)	150 (8)	
61–90 bpm	6929 (55)	1129 (59)	
91–109 bpm	2809 (22)	401 (21)	
$\geq$110 bpm	1,685 (13)	225 (12)	
Systolic blood pressure in emergency department			0.04
0–60 mmHg	120 (1)	17 (1)	
61–90 mmHg	573 (5)	65 (3)	
91–110 mmHg	1310 (10)	176 (9)	
$\geq$110 mmHg	10,544 (84)	1647 (86)	
Glasgow Coma Scale in emergency department			<0.001
13–15	9455 (75)	1571 (82)	
10–12	829 (7)	146 (8)	
3–9	2253 (18)	188 (10)	

All data presented as n (%). MTS: Major Trauma Service; RTS: Regional Trauma Service; AIS: Abbreviated Injury Scale score.

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differences in case-mix and variability in outcomes, risk-adjusted outcomes were evaluated.

After adjusting for patient-level variables, the overall MOR was 1.33, suggesting that the odds of in-hospital death was 1.33-fold greater if the same patient was admitted to a randomly selected centre with worse risk-adjusted mortality as opposed to a centre with better risk-adjusted mortality. In addition, three centres were identified as having significantly lower risk-adjusted mortality compared to the overall average, all were MTS (Fig. 2).

Centre characteristics were then used to explore the variability in centre outcomes. After adjustment, definitive care at an MTS was associated with a 41% lower likelihood of in-hospital death compared to definitive care at an RTS (OR 0.59 95%CI 0.35-0.97). There was no association between centre volume quartile and risk adjusted outcomes.

Subgroup risk-adjusted outcomes

Similarly to the overall cohort, unadjusted in-hospital mortality was lower and time to death was longer across most patient subgroups when comparing MTS to RTS (Table 3). After adjusting for case-mix, definitive care at MTS was consistently associated with a lower likelihood of in-hospital death compared to RTS across the isolated severe brain injury and elderly subgroups (Fig. 3).

Discussion

The NSW Trauma system represents a complex system of designated trauma centres acting as hubs for rural and regional referral networks covering large areas. The generation of risk-adjusted outcomes for the purpose of external benchmarking of trauma services was considered an important step towards data-driven trauma system improvement.

This study has three main findings. First, current data collection standards across trauma services in NSW are of sufficient quality to produce risk-adjusted outcomes. Similar rates of missing data (<0.5%) were reported by the National Trauma Data Bank of the ACS, the largest repository of injured patient data [19]. In addition, data quality has improved over time with most vital sign variables reported in 2016 missing in <5% of patients. Improved data quality and the use of multiple imputation allowed the incorporation of heart rate, systolic blood pressure, and Glasgow Coma Scale as covariates in the risk-adjustment model which are considered essential in other trauma risk-adjustment strategies [20]. Previous attempts at evaluating the NSW trauma system have been limited by the lack of inclusion of vital sign variables in risk adjustment [21]. In addition, acknowledging the nested structure of the data as well as the local context of low volume centres through the use of hierarchical models, provides a more stable estimates that will not penalize low volume centres. Complete data coupled with valid risk-adjustment strategies are the foundations of a successful performance improvement initiative.

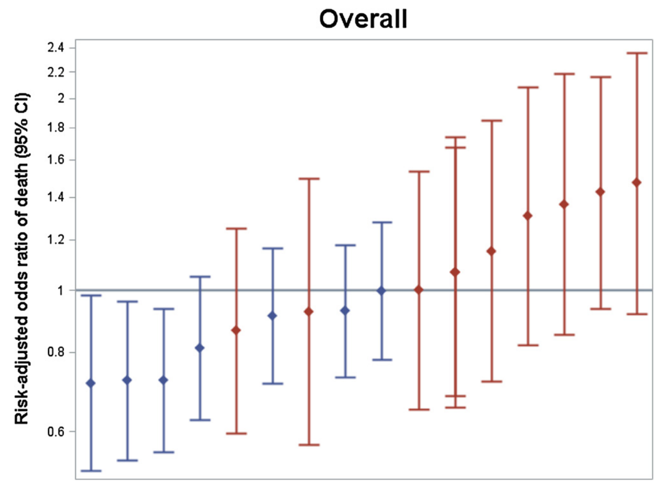

Fig. 2. Overall risk-adjusted outcomes across centre type.
Each diamond represents an individual centre's risk-adjusted odds ratio of in-hospital death with bars representing the 95% confidence interval. Centres in blue are Major Trauma Services while centres in red are Regional Trauma Services.

Table 3
Overall and subcohort unadjusted outcomes across centre type.

	MTS	RTS	*p* value
Overall			
Sample size	12,547	1905	
Unadjusted in-hospital mortality	1171 (9)	217 (11)	0.005
Time to death in days, median (IQR)	3 (1–8)	2 (1–4)	<0.001
Unadjusted centre in-hospital mortality, range in %	7–12%	6–20%	<0.001
Injury Severity Score > 15			
Sample size	9580	1254	
Unadjusted in-hospital mortality	1112 (12)	211 (17)	<0.001
Time to death in days, median (IQR)	2 (1–7)	2 (1–4)	<0.001
Unadjusted centre in-hospital mortality, range in %	7–14%	10–28%	<0.001
Polytrauma (blunt mechanism and AIS=>3 in at least two body regions)			
Sample size	2876	274	
Unadjusted in-hospital mortality	375 (13)	35 (13)	0.9
Time to death in days, median (IQR)	2 (1–7)	1 (1–3)	0.06
Unadjusted centre in-hospital mortality, range in %	9–15%	5–25%	0.26
Isolated severe head injury (head AIS=>3, AIS=<2 in all other body regions, and GCS =<9)			
Sample size	971	109	
Unadjusted in-hospital mortality	343 (35)	79 (72)	<0.001
Time to death in days, median (IQR)	1 (1–4)	1 (1–2)	0.11
Unadjusted centre in-hospital mortality, range in %	28–53%	33–100%	<0.001
Elderly injured (=>65 years)			
Sample size	4691	763	
Unadjusted in-hospital mortality	789 (17)	169 (21)	0.002
Time to death in days, median (IQR)	3 (1–8)	2 (1–5)	0.008
Unadjusted centre in-hospital mortality, range in %	13–21%	28–53%	<0.001

All data presented as n (%) unless otherwise specified. MTS: Major Trauma Service; RTS: Regional Trauma Service; IQR: interquartile range.

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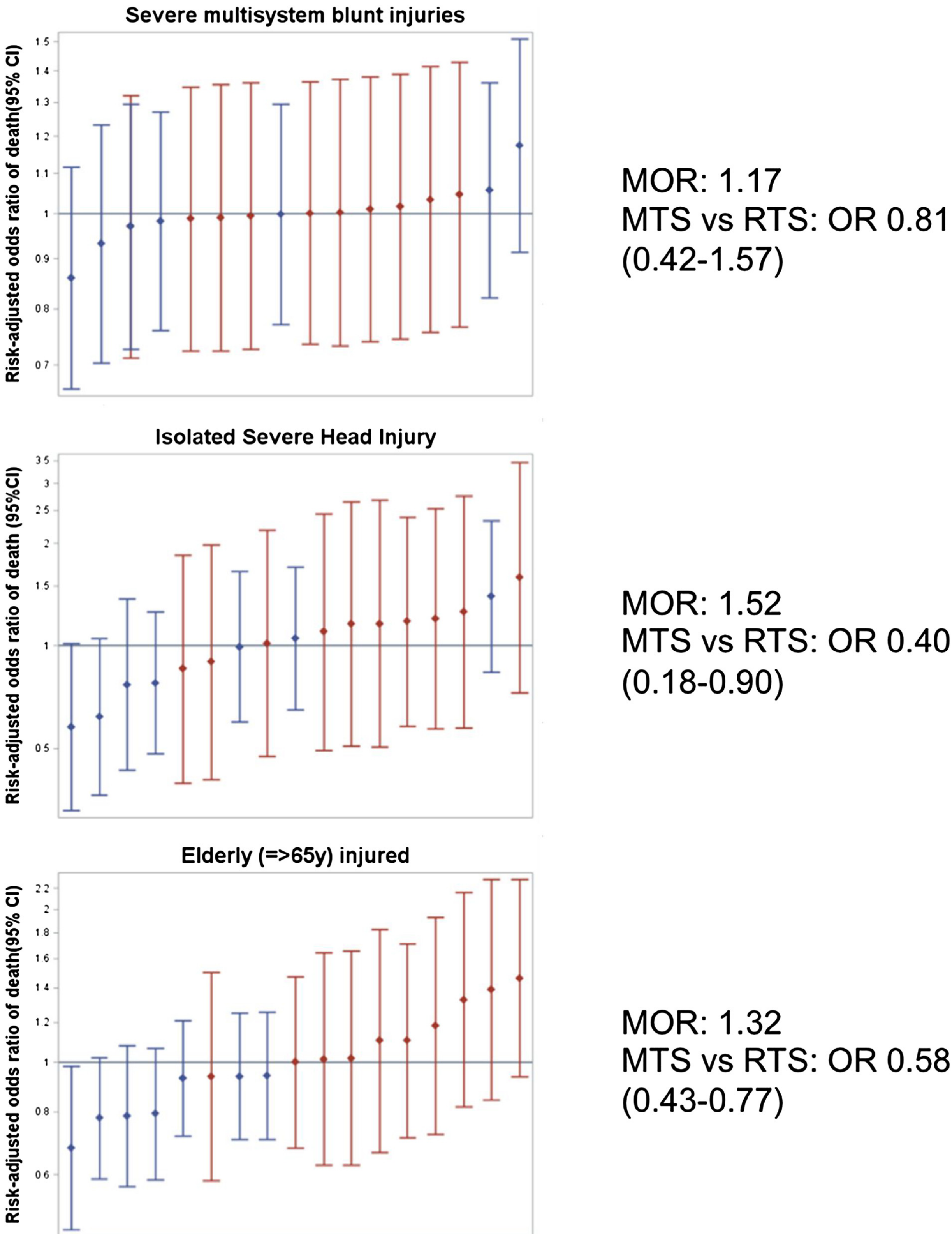

Fig. 3. Subcohort risk-adjusted outcomes across centre type.
Each diamond represents an individual centre's risk-adjusted odds ratio of in-hospital death with bars representing the 95% confidence interval. Centres in blue are Major Trauma Services (MTS) while centres in red are Regional Trauma Services (RTS). MOR: Median Odds Ratio.

Second, unadjusted mortality after moderate to severe injury in NSW is in-line with other mature trauma systems [22–25]. However, after risk-adjustment, we identified a median 33% increased odds of death if the same patient received care at a centre with worse risk-adjusted outcomes (MOR 1.33). In other words, to a moderate extent, a patient's likelihood of death was associated with the centre at which definitive care was received. It suggests a moderate degree of heterogeneity between centres that was unexplained by patient factors. However, the type of centre at which patients received definitive care was associated with their outcomes. Definitive care at MTS was associated with a 41% lower likelihood of death compared to RTS, even after taking into account case-mix and centre-volume. This finding implies that even though there is variability in outcomes within the MTS group as well as within the RTS group as evident in the caterpillar plot, definitive care at an MTS overall is associated with a lower likelihood of death compared to an RTS.

Third, care at an MTS, as in the overall cohort, was consistently associated with a lower likelihood of death across the isolated severe brain injury and elderly subgroups. Although a degree of variation would be expected given the range in facilities involved, the degree of variability in risk-adjusted outcomes identified may also be an indication of unwarranted variation due to resourcing, clinical practice, and models of care.

These findings assist with ongoing Australia-wide efforts to benchmark trauma system performance and improve the care of severely injured patients [8]. It is important to note that external benchmarking is only the backbone of what should be a multipronged approach at performance improvement. Risk-adjusted outcomes must be analysed within the larger context of associated variations in structures and processes of care across centres. A better understanding of the drivers of the described variation in outcomes is crucial to design targeted locally-relevant quality improvement interventions. The obvious next step would be an attempt towards delineating the underlying causes of this variation. Efforts towards the collection of consensus derived process indicators as well as the establishment of a clinical quality registry comprising patient reported outcomes and experience measures are currently underway at the state level. This data driven approach has improved system-wide outcomes in the National Surgical Quality Improvement Program of the ACS [6] and in the Michigan trauma collaborative [7].

Some limitations must be taken into account when interpreting our results. Patient factors that may influence outcomes and were not captured in our risk-adjustment, include but are not limited to prolonged discovery and transport times that are common in rural and remote locations. The incorporation of vital signs and a transfer flag into our risk-adjustment model should limit the impact in our results. Pre-existing conditions that may influence the likelihood of death after injury, as well as pre-existing medical directives to withhold care, are not captured. The absence of these variables may negatively impact centres with a higher proportion of elderly patients. In addition, patients may have been deemed non-salvageable and thus remained at RTS instead of undergoing transfer to MTS. The trauma registry does not capture this information. As a sensitivity analysis, we repeated the analysis in the overall cohort after excluding patients with severe isolated brain injury in order to limit the impact of non-salvageable brain injured patients deemed not fit for transfer from RTS to MTS. The MOR of the overall cohort decreased from 1.33 to 1.16 suggesting that not all variability across centres is secondary to patients with isolated severe brain injury. No centre was identified as having lower or higher than expected risk-adjusted mortality, a finding that must be interpreted with caution as sample size decreased by over 1000 patients. However, definitive care at a MTS was still associated with a 33% lower adjusted likelihood of death compared to care at a RTS [OR 0.67 (95%CI 0.50-0.91)] after excluding patients with severe isolated brain injury.

Conclusion

There was variability in risk-adjusted outcomes across the NSW trauma system exhibited. Possible target for future study and targeted interventions are the subgroups of patients with isolated severe brain injuries and the elderly injured where significant variability in outcomes was identified. The ongoing evaluation of trauma system performance, as well as targeted interventions derived from such analyses, are instrumental in the delivery of high-quality care for injured patients.

Conflicts of interest

The authors have no financial or personal conflicts of interest to disclose.

MTS vs. RTS: Risk-adjusted odds ratio of death with 95% confidence intervals.

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.2018.09.037.

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