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 - NSW Ambulance (NSWA). 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. NSWA 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.

NSW Ambulance linked dataset and data sources

This study utilised a dataset containing approximately 2.04 million NSWA 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 NSWA 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.

NSWA 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 NSWA 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 NSWA 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 NSWA 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				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)		
NSWA Protocol Usage[Υ]					
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[ΥΥ]	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				59.04	<0.001
None	65 (50)	0 (0)	82 (61.2)		
One	59 (45.4)	36 (76.6)	39 (29.1)		
Two or more	6 (4.6)	11 (23.4)	13 (9.7)		
Vital Status					
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, [Υ]In NSW Ambulance data – individual binary variables listed, [ΥΥ]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 NSWA, 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, x̄ (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.

	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, spinal surgery within 24 hrs, spinal injury level.				

Table 4: Predictors of admission to SCIU within 24 hours of injury for patients with TSCI (pseudo R^2=0.46).

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 NSWA 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.

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.

Limitation

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, NSWA 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 NSWA 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.

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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