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Research article

Spinal clearance practices at a regional Australian hospital: A window to major trauma management performance outside metropolitan trauma centres

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ABSTRACT

Background: Prevention of secondary spinal injury via spinal protection measures is a standard component of trauma management, and a high-quality spinal clearance process is imperative in achieving this aim. To evaluate the current practice with a view to achieving best practice, we sought to examine the spinal clearance process and outcomes at a regional Australian referral hospital, which services a large geographical catchment area.

Methods: A retrospective review of medical records of all patients with major trauma who presented to an Australian regional hospital during 2014 was conducted. The primary outcome measure was missed or delayed diagnosis of spinal injury. Secondary outcome measures included compliance with internationally accepted spinal clearance process measures, timing and choice of appropriate imaging modalities, rates of spinal injury and documentation of spinal clearance.

Results: Of the 112 patients with major trauma who met the study eligibility criteria and were discharged from hospital during the study period from 1 January to 31 December 2014, 11 spinal injuries were missed or delayed in diagnosis. The injuries occurred in 3.6% of patients and all were thoracolumbar spine (TLS) injuries. The predominant reasons for missed or delayed diagnosis were reduced sensitivity of plain X-ray compared with computed tomography for spinal injury screening and incomplete full spinal imaging to detect non-contiguous fractures.

Conclusion: Evidence-based clinical decision rules are imperative in ascertaining the need for imaging in the TLS and would be enhanced by an internationally recognised definition of clinical significance based on injury morphology rather than clinician management decision alone. In addition, regional hospitals may have limited capacity to achieve spinal clearance, and other trauma quality assurance standards commensurate with national and international benchmarks without the valuable performance feedback provided by state trauma registries, as is currently the case in Queensland.

Keywords: Major trauma, spinal clearance, spinal injury, thoracolumbar spine

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BACKGROUND

Injuries sustained from major trauma mechanisms have a significant impact on the individual and the community. Spinal immobilisation for the prevention of secondary injury in the case of suspected spinal injury has become a routine component of the management of major trauma. The stepwise process of spinal protection, investigation for potential spinal injury and ultimately cessation of spinal precautions is known as spinal clearance.[1]

Prolonged duration of spinal protection measures are associated with known complications, such as decubitus ulceration[2] and deep vein thrombosis.[3] Thus, the benefits of spinal protection must outweigh the risks of these complications. Similarly, the modality of medical imaging chosen must reflect the balance between the detection of clinically significant injury whilst avoiding unnecessary radiation exposure.

The majority of evidence for the efficiency and effectiveness of the spinal clearance process has originated from Level I trauma centres.[4,5] The concentration of clinical trauma and imaging expertise in major trauma centres has allowed timely, consistent screening procedures and definitive management to be optimised in suspected spinal trauma, resulting in significant reductions in mortality and morbidity. Regional hospitals, particularly those which service large geographic catchment areas without a major trauma centre, are required to perform at a similar level of trauma capability, often with fewer resources available.[6] Therefore, regional trauma practice performance should be informed by regular state trauma registry feedback. In the absence of registry feedback, as is the case since the closure of the Queensland State Trauma Registry, regional trauma experience needs to be examined and reported in order to identify issues in aligning with international best practice.

The aim of this study was to review the performance of spinal clearance practice with a view to improving standards of trauma patient care in a regional Australian referral hospital. We sought to analyse outcomes with reference to a large Australian trauma database and international experience.

METHODS

A retrospective review of patients with blunt trauma over 14 years of age presenting to a regional Australian trauma referral centre between 1 January and 31 December 2014 was conducted. The study institution has 571 beds, including 10 intensive care unit (ICU) beds. It is the regional trauma referral service for nine satellite health services managing 294 beds, which oversee a primary catchment area of 141,000 km^2 and support a population of 283,197 people. Almost 18,000 patients presented to the emergency department from 1 July 2014 to 30 April 2015.[7] The study hospital is located at a flight distance of 282 km from the nearest dedicated major trauma centre. Patients meeting major trauma criteria according to the Victorian State Trauma Registry (VSTR) patient inclusion criteria (Table 1)[8] were included. In addition to the VSTR exclusion criteria, patients were excluded if spinal clearance procedures were performed at a referring hospital, and/or injury occurred within a health service or during medical or surgical care. Institutional ethics approval was obtained.

Medical records of patients were reviewed by a multidisciplinary team of five medical officers, including an intensive care specialist; anaesthetic registrar and orthopaedic, surgical and emergency residents. Patient data were collected from the emergency department, intensive care and general ward databases.

The study aimed to assess the instigation of pre-hospital spinal precautions, patient selection criteria for imaging requirements, appropriate timing and choice of imaging modalities, timing of spinal clearance or definitive spinal management plans, and rate of missed or delayed diagnosis of spinal injuries. Study definitions were developed with reference to international standards[9,10] and a large Australian trauma database,[6] as presented in Table 2.

Seasonal data were also collected. The wet season in Queensland occurs from October to March, which receives the majority of the annual rainfall (~80 in.). This renders conditions much more hazardous than in the dry season, and increases the risk of road trauma and falls. In addition, this season presents difficulties in road and air ambulance response times due to the treacherous weather conditions.

Continuous variables are expressed as median and interquartile range (IQR) for non-normally distributed variables. Categorical variables are presented as frequency and percentage (n(%)). The findings are presented descriptively. Statistical analyses were performed using STATA version 12.0 (Stata Corporation, TX, USA).

Table 1. Victorian State Trauma Registry patient inclusion and exclusion criteria for major trauma.[6]

Inclusion criteria
1. All deaths after injury 2. All patients admitted to an ICU or high-dependency area for more than 24 h and mechanically ventilated after admission 3. Significant injury to two or more ISS body regions (an AIS of 2 or more in two or more body regions) or an ISS >12 4. Urgent surgery for intra-cranial, intra-thoracic or intra-abdominal injury, or fixation of pelvic or spinal fractures 5. Electrical injuries, drowning and asphyxia patients admitted to an ICU and having mechanical ventilation for longer than 24 h 6. All patients with injury as their principal diagnosis whose length of stay is three days or more – unless they meet exclusion criteria 7. All patients with injury as their principal diagnosis transferred to or received from another health service for further emergency care or admitted to a high dependency area – unless they meet exclusion criteria
Exclusion criteria
1. Isolated fractured neck of femur 2. Isolated upper limb joint dislocation, shoulder girdle dislocation (unless associated with vascular compromise) and toe/foot/knee joint dislocation – unless meets inclusion criteria 1, 2 or 4 3. Isolated closed limb fractures only (e.g. fractured femur, Colles' fracture) – unless meets inclusion criteria 1, 2 or 4 4. Isolated injuries distal to the wrist and ankle only (e.g. finger amputations) – unless meets inclusion criteria 1, 2 or 4 5. Soft-tissue injuries only (e.g. tendon and nerve injury and uncomplicated skin injuries) – unless meets inclusion criteria 1, 2 or 4 6. Burns to <10% of the body – unless meets inclusion criteria 1, 2 or 4 7. Isolated eyeball injury

ISS = Injury Severity Score; AIS = Abbreviated Injury Scale.

Table 2. Study definitions.

Definitions
• Spinal precautions on arrival to hospital included any form of spinal immobilisation measure from minimal (e.g. soft cervical collar only) to maximal (e.g. rigid cervical collar, head taping and long back-board) • Clinical examination of the whole spine included documentation of cervical, thoracic and lumbar spine assessment. • Basic neurological assessment included Glasgow Coma Scale (GCS), pupillary reflexes, sensation and gross limb movement. • The requirement for cervical spine imaging was determined using the National Emergency X-radiography Utilisation Study (NEXUS) criteria[23] and the Canadian C-spine rule[24] • Sufficient mechanism to injure the thoracolumbar spine (TLS) included falls >3 m, ejection from a motor vehicle, motorbike accidents, high-velocity mechanisms and pedestrians vs. motor vehicles.[11] A bicycle collision, as per the Canadian C-spine Rule definition of 'dangerous mechanism,' was also considered by the study investigators to be of sufficient force to injure the TLS.[24] • The time from radiological clearance to documented spinal clearance was collected for those patients who had documentation of spinal clearance. • Missed or delayed diagnosis was defined as a diagnosis of spinal injury *after* documentation of spinal clearance during the hospital admission or on first outpatient clinic review after discharge from hospital if the assessing clinician determined that the injury was directly related to the original trauma. The rate of missed or delayed spinal injury is reported as the number of patients with missed or delayed diagnosis as a proportion of total study population. • Clinical significance for cervical spine injuries was determined using the definition employed by Hoffman et al.[23] As there is no internationally recognised definition of clinically significant TLS injuries, we adopted the definition suggested by Inaba et al.,[11] as injuries requiring orthotic or operative management.

RESULTS

Of the 748 trauma patients who presented during the data collection period, 112 (15%) were major trauma patients and were included in the study sample. Of these, 77 (69%) were male, and the median age was 45.5 years (IQR: 26.8–61.8, range: 15–94). The occurrence of major trauma was greater during the wet season (60%), and 17% required admission to the intensive care unit. A significant proportion of patients presented after hours (43%) and during the weekend (34%) when staffing resources were limited compared to those available during business hours. The median lengths of stay in hospital and the intensive care unit were 6 (IQR: 4–9) and 3 (IQR: 2–5) days, respectively. The most prevalent mechanisms of injury included falls (37%), motor vehicle accidents (25%), motorbike accidents (17%) and assaults (11%). The high number of falls from less than one metre occurred mostly in the older population: 86% of these cases were ≥60 years of age.

An unexpectedly high proportion of patients with major trauma (34.8%) presented without spinal precautions in place. After presentation to the emergency department, there were 40% of patients who did not have documented examination of the entire spine (cervical, thoracic and lumbar); however 91.9% had a basic neurological examination documented. The median time from triage to first imaging of the spine was 60 minutes (IQR: 34–113). Of the patients who had any spinal fracture diagnosed, only 53.7% went on to have complete imaging of the spine to assess for non-contiguous fractures. The median time from radiological clearance to documented spinal clearance was 162.5 minutes (IQR: 63–834.5) (Table 3).

Table 3. Baseline demographic, clinical and length of stay characteristics (n(%) unless otherwise stated).

Factor	Findings (n = 112)
Male sex	77 (69%)
Age (years: median and IQR)	45.5 (26.8–61.8)
Age range (years)	15–94
Presentations outside business hours	48 (43%)
Weekend presentations	38 (34%)
Wet season admissions	67 (60%)
Transferred to another facility	9 (8%)
ICU admission	19 (17%)
Hospital LOS (days: median, IQR)	6.0 (1–74)
ICU LOS (days: median, IQR)	5 (1–16)
Mechanism of injury	
MVA	25 (22%)
Falls < 1 m (age > 60 years)	19 (17%)
< 1 m (age < 60 years)	3 (2.7%)
> 1 m	19 (17%)
MBA	19 (17%)
Assault	12 (11%)
Cyclist or pedestrian	7 (6%)
Other	8 (7%)

Business hours = 0800–1800 h; wet season = October to April; ICU = intensive care unit; LOS = length of stay; MVA = motor vehicle accident; MBA = motorbike accident; other = hanging, diving, impacted by object, horse-related, helicopter accident.

Cervical spine

Almost all patients (n = 107 (95.5%)) met the criteria for cervical spine imaging; however, 29.9% were clinically cleared without imaging (Table 4). A total of 17 patients (16%) underwent cervical plain radiographs as first-line imaging, whereas 65 patients underwent CT imaging. There were 10 patients with cervical spine injury, identified on CT imaging in four cases, and on MRI in six cases. In less than half of the cases (47.3%), cervical spine clearance or an injury management plan was documented by the treating medical staff; however, cervical spine clearance within 24 hours of presentation occurred in 96% of cases. There were no cervical spine injuries missed or delayed in diagnosis.

Thoracolumbar spine

The mechanism of injury was considered to be high risk for thoracolumbar spine (TLS) injury[11] in 91 patients (81.3%); however, documentation of spinal assessment was present in only 61 (67%) patients. One-fourth (25%) of these patients had an altered conscious state (GCS < 15), of whom 35% were cleared clinically without imaging. There were 31 patients with thoracolumbar injuries detected on CT imaging, and an additional four patients had missed thoracolumbar injuries. Thoracolumbar spinal clearance or a thoracolumbar injury management plan was documented by medical staff in only 31.3% of cases. However, the majority of patients (91.4%) had thoracolumbar clearance within 72 h of presentation.

There were 11 missed TLS injuries in four patients, none of which required orthotic or operative management. The reasons for missed or delayed diagnosis are presented in Table 5.

DISCUSSION

This study identified 11 spinal injuries (in four patients), which were missed or delayed in diagnosis within the sample of 112 major trauma patients presenting to our Australian regional hospital over the 12-month study period. This results in a missed or delayed injury rate of 3.6%. However, according to

Table 4. Spinal clearance process measures ($n = 112$).

Process	Findings
Spinal precautions in situ on arrival to ED	73 (65.2%)
Documented clinical examination of whole spine	65 (58.0%)
Documented basic neurological examination	103 (91.9%)
Cervical spine	
(a) Imaging indicated	107 (95.5%)
(b) Clinical clearance without imaging in patients who met criteria for imaging ($n = 107$)	32 (29.9%)
(c) X-ray cervical spine ($n = 107$)	17 (15.9%)
(d) Acute injury on cervical spine CT ($n = 65$)	4 (6.2%)
(e) MRI cervical spine	7
(f) MRI-detected injury not reported on CT	6
Thoracolumbar spine	
(a) Mechanism of injury consistent with TLS injury	91 (81.3%)
(b) Any documentation of TLS assessment ($n = 91$)	61 (67.0%)
(c) Altered conscious state (GCS < 15) ($n = 91$)	23 (25.3%)
(d) Clinical clearance without imaging in patients with altered conscious state ($n = 23$)	8 (34.8%)
(e) X-ray TLS in patients with altered conscious state ($n = 23$)	2 (8.7%)
(f) Acute injury on TLS CT ($n = 65$)	31 (47.7%)
(g) Acute TLS injury overall ($n = 112$)	31 (27.6%)
MRI	
(a) MRI	7
(b) Detection of new clinically significant injury	5
Time from ED triage to first imaging of spine (median minutes (IQR))	60.0 (34–113)
Time from radiology report to documented spinal clearance (median minutes (IQR))	162.5 (63–834.5)
Full spinal imaging if any spinal fracture found	22/41 (53.7%)
Documentation	
Cervical spine clearance or plan documented by medical staff	53/112 (47.3%)
TLS clearance or plan documented by medical staff	35/112 (31.3%)
Cervical spine clearance within 24 h of ED triage ($n = 51$)	51/53 (96.2%)
TLS clearance within 72 h of ED triage	32/35 (91.4%)

ED = Emergency Department; MRI = magnetic resonance imaging; TLS = thoracolumbar spine; GCS = Glasgow Coma Scale.

the very limited pre-determined criteria for clinical significance for TLS injuries (requiring TLS orthoses or surgical fixation), these injuries would be categorised as not clinically significant. As this definition is based on individual clinician decision, rather than injury morphology, the reliability of the definition is dependent on the experience and preferences of the treating clinician and therefore has limited reproducibility. Conversely, a definition based on radiographically demonstrated injury morphology is objective and highly reproducible. The development of a reliable definition is imperative to direct the appropriate categorisation and subsequent management of thoracolumbar injuries.

Table 5. Missed injuries.

Patient no.	Mechanism of injury	Missed injuries	Reason for missed/delayed diagnosis
4	High-speed MVA rollover	L1, L2 superior end plate #s	Plain X-ray lumbar spine reported as normal. CT diagnosed #s
36	MBA	L2-5 transverse process #s	Plain X-ray lumbar spine reported as normal. CT diagnosed #s
53	Quad bike accident	T6-7 transverse process #s and small paravertebral haematoma	Plain X-ray thoracolumbar reported as normal. Persistent thoracic spine pain reported in outpatient clinic 1 week post-hospital discharge – #s diagnosed on CT
57	Fall <1 m	T8 crush # and paravertebral haematoma	Difficult historian, thoracolumbar pain reported, CT lumbar spine only ordered in ED. Persistent back pain misdiagnosed as herpes zoster. CT thoracic spine 6 days later revealed#

MVA = motor vehicle accident; L = lumbar; # = fracture: MBA = motorbike accident; T = thoracic.

The thoracolumbar injuries that were missed or delayed in diagnosis in our study were due to issues of reduced sensitivity of X-ray compared with computed tomography (CT), and/or incomplete full spinal imaging for the detection of non-contiguous spinal fractures. We also identified areas where performance was suboptimal in comparison with accepted international benchmarks for major trauma,[9,12,13] including documentation of clinical examination findings, and spinal clearance or injury management plans. Documentation of spinal clearance or injury management plan was sporadic, with between only half (cervical spine) and one-third (TLS) of cases formally documented. Reasons for this may include a perception of low clinical importance for spinal clearance and a reliance on verbal communication between health professionals. However, for those patients for whom documentation was completed, nearly all had this conducted within acceptable time frames.

While definitive trauma imaging time-frame recommendations are generally lacking, shorter time to initial CT imaging in trauma patients is associated with improved outcomes.[14,15] Our findings indicated a median time to initial spinal imaging of 60 minutes compared with an Australian Level I trauma centre, which reported a corresponding figure of 76 minutes.[14]

The phenomenon of non-contiguous spinal fractures is well established[16,17] and reported to occur in 20% of patients with trauma.[5] However, this knowledge has not translated into practice at our institution, with only half of our patients with spinal fracture progressing to complete imaging of the entire spine.

The main outcome measure of our study, and arguably the most clinically relevant for spinal clearance practice, is the rate of missed or delayed diagnosis of injuries. Missed or delayed diagnosis of cervical spine injuries has been reported in the literature as occurring in 5–20% of blunt trauma patients;[4] however, these studies were conducted in an era when plain X-rays were the dominant form of imaging.

It has been suggested that the use of plain X-rays for spinal injury screening is inadequate in the trauma population. A 2005 meta-analysis comparing plain films to CT for the evaluation of the cervical spine in trauma showed that pooled sensitivity for plain radiography was 52%, whereas for CT it was 98%.[18] In addition, the most recent Eastern Association for the Surgery of Trauma (EAST) clinical practice guidelines for the screening of thoracolumbar injuries also now recommend the use of multi-detector CT imaging for screening and diagnosis of thoracolumbar injuries.[12]

CT imaging, however, delivers significant radiation doses and should be used only after risk–benefit analysis is undertaken for each individual patient. In particular, the younger population has an increased lifetime cancer risk with medical radiation exposure.[19] Trauma patients are a high-risk group for excessive and potentially unnecessary radiation exposure due to scanning spinal regions separately at different time points with overlap of regions previously examined, and repeating imaging when patients move between institutions or between medical teams.

Ideally, all clinically significant injuries are detected with a minimum radiation exposure; however, as aforementioned, there is some conjecture regarding the lack of a robust definition of clinical significance in the TLS. The definition proposed by Inaba et al.,[11] and adopted for our study, is one which requires a high degree of injury. Inaba's definition of clinical significance for the group's multicentre prospective observational study of 3065 patients with trauma who underwent CT imaging for suspected acute thoracolumbar trauma was "Fractures were deemed clinically significant if the injury required either a TL-spine orthosis or surgical stabilisation". This would suggest a high degree of injury, which has the potential to result in spinal cord compromise. However, the decision to apply an orthosis or to operatively manage an injury is subjective and not comparable between institutions, thereby lacking reliability. Whilst one spine surgeon may apply an orthotic device to treat an injury, another may 'clear' the spine of serious injury, for example. Also, labelling all other TLS injuries as *not* clinically significant, even if they result in significant patient morbidity; for example, acute pain and risk of chronic pain syndromes and restricted range of movement, implies that on a risk versus benefit basis, it is clinically acceptable not to detect them. Defining clinical significance for TLS injuries largely informs the debate on choice of imaging modality and justified radiation exposure, for example, plain X-ray may miss an isolated TLS transverse process fracture but will save the patient from unnecessary CT imaging.

Imaging decision-making for the TLS must start with a thorough clinical examination. This includes an assessment of the patient's conscious state and a decision as to whether he/she is evaluable or not, as is a fundamental component of accepted cervical spine decision rules. However, in a recent prospective observational study of 3065 patients undergoing TLS imaging in 13 participating centres,

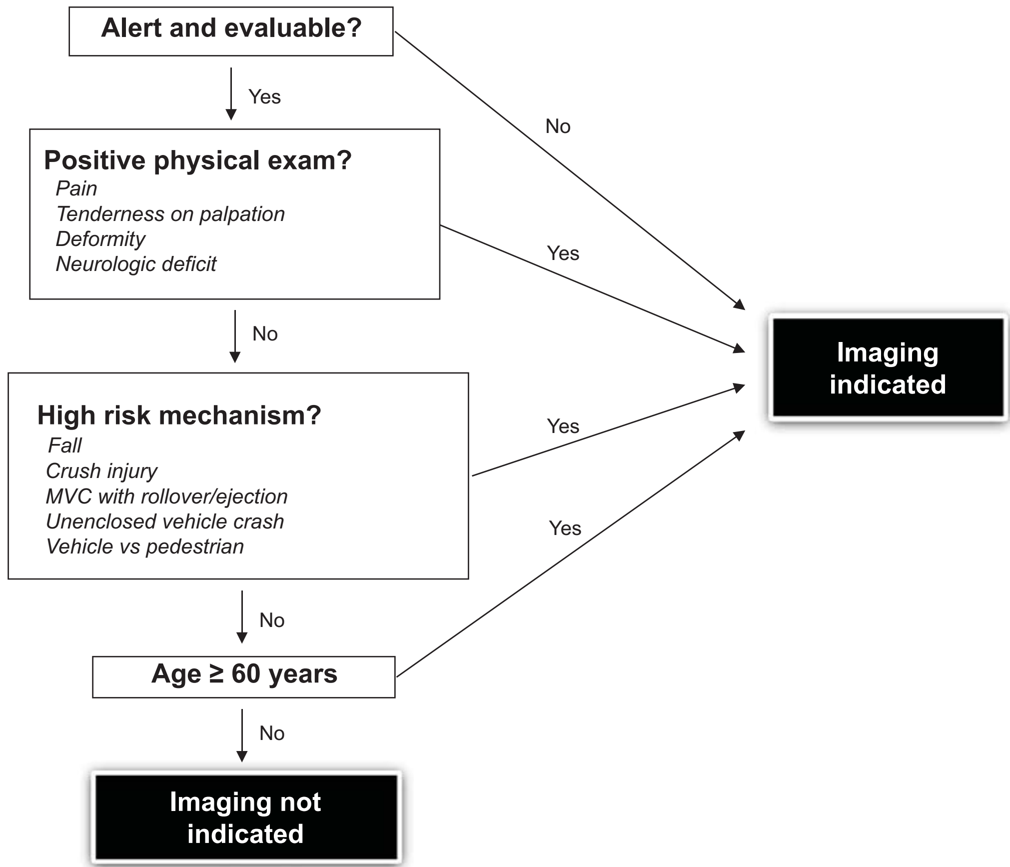

Figure 1. Clinical decision rule for determining the requirement for imaging in thoracolumbar trauma, as suggested by Inaba et al.[11]

Inaba et al.,[11] demonstrated that clinical examination alone is insufficient to determine the need for imaging of the TLS[11] and that the addition of a clinical decision rule incorporating age and high-risk mechanism of injury (Figure 1) improved the sensitivity for detecting clinically significant TLS injury from 78.4 to 98.9%. In Inaba's study, patients with neurological deficit due to cervical spine fractures were excluded; however, concomitant spinal fractures without neurological deficit were not mentioned as included in the regression analyses. This variable may need to be considered in order for Inaba's clinical decision rule to become widely accepted.

Cason et al.,[20] conducted a prospective study of 950 patients with blunt trauma, all of whom underwent clinical and radiographic assessment of the thoracolumbar spine to assess the relationship between distracting injury and clinical assessment. There were 601 patients (63%) with negative clinical examination findings, of whom 20 (3.3%) had missed injuries detected on CT imaging. Five of these missed injuries were managed in thoracolumbar spinal orthoses, and were therefore categorised as clinically significant. However, no formal definition of clinical significance was used in the study; hence, subjective clinician management decision, rather than objective injury morphology, dictated the definition. Additionally, as all patients underwent imaging in this study, there was no no clinical decision rule used to direct the need for radiographic imaging, and compliance with documentation of clearance or management plan was not measured. Interestingly, however, the CT images were reformatted from chest, abdominal and pelvic CT images, thereby minimising the radiation exposure which may have occurred if separate TLS imaging was obtained.

In our study, 35% of patients were in the category of high-risk mechanism for TLS injury and with an altered conscious state, who were cleared clinically without imaging. This may have contributed to the high rate of missed injuries. We also believe that the paucity of evidence-based TLS imaging decision rules contributes to clinicians having a lower index of suspicion for TLS injuries in major trauma.

We found no missed or delayed diagnoses of cervical spine injuries in our study. Optimal performance in the cervical spine clearance process is likely due to the presence of established internationally accepted imaging decision rules and cervical spine predominance in the trauma management literature.

In addition to best practice clinical standards, trauma management performance in regional centres, such as ours, is influenced by resource allocation. The majority of resources aimed at improvements in trauma management and outcomes are concentrated in metropolitan major trauma tertiary referral centres. This approach is underpinned by the philosophy of "the right patient to the right level of care in the shortest time."[21] Australia has a large geographical footprint and significant catchment areas for health services such that it is difficult to apply this philosophy to regional, non-trauma hospitals, which are located at considerable distances from designated trauma centres. These regional centres must therefore have the capability to manage major trauma at a high level, particularly in the early phase of patient stabilisation. The spinal clearance process, as an important component of trauma management, must be consistently robust in order to achieve this level of trauma capability.

Improving the management of trauma in regional centres hinges upon recognising areas of performance deficit, made possible only by data collection and feedback to treating clinicians. Established statewide major trauma registries provide support for individual hospitals through assessment of the quality assurance process along the treatment continuum from pre-hospital management to discharge. This feedback occurs by the review of all trauma cases in which care has varied from predefined standards of trauma management or where in-hospital mortality occurs.[22] Such is the case with the Victorian State Trauma Registry, which is jointly funded by the Victorian Department of Health and Human Services, the State Government of Victoria and the independent Transport Accident Commission. This comprehensive trauma registry regularly provides feedback on the clinical performance to trauma hospitals in the state of Victoria and publishes the findings of its trauma analyses on a frequent basis. Conversely, due to a change in government and a rationalisation of health funding, the Queensland Trauma Registry closed in 2012. Since the closure of the registry, the onus for quality assurance in trauma for the state of Queensland has been placed on individual hospitals. Regional hospitals, in particular, may have limited resources and capacity to achieve quality assurance standards commensurate with national and international benchmarks.

LIMITATIONS

There were several limitations in our study. First, the small, targeted sample size and subsequent small number of thoracolumbar injuries limited the analysis such that controlling for confounding variables in the cases of missed injury was not possible, and the results should be considered in this context. Second, the use of a strict and clinically relevant definition of 'missed or delayed' as an injury diagnosed *after* spinal clearance was documented is likely to have resulted in a significant underestimation of missed or delayed injuries due to the low rates of documentation found. Third, the potential for measurement bias is inherent in retrospective study designs; however, bias was minimised through the use of the three prospective institutional databases.

CONCLUSIONS

Patients with major trauma are at a significant risk of thoracolumbar injuries. The process of detecting these injuries whilst avoiding excessive radiation exposure presents a challenge to the clinician and would be enhanced through the use of evidence-based clinical decision rules. The detection of spinal injury should alert clinicians of the possibility of non-contiguous injury, and the need for subsequent investigation with CT imaging. Finally, prospective trauma registries play an integral part in providing feedback on trauma care to individual institutions; regional hospitals are at a significant disadvantage when such registries are unavailable.

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Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors contributed equally to this work.

REFERENCES

[1] Clancy MJ. Clearing the cervical spine of adult victims of trauma. *J Accid Emerg Med*. 1999;16(3):208–214.
[2] Ackland HMCD, Malham GM, Kossmann T. Factors predicting cervical collar-related decubitus ulceration in major trauma patients. *Spine*. 2007;32(4):423–428.
[3] Napolitano LM, Garlapati VS, Heard SO, Silva WE, Cutler BS, O'Neill AM, Anderson FA Jr, Wheeler HB. Asymptomatic deep venous thrombosis in the trauma patient: Is an aggressive screening protocol justified? *J Trauma*. 1995;39(4):651–657.
[4] Platzer PHN, Jaindl M, Chatwani S, Vecsei V, Gaebler C. Delayed or missed diagnosis of cervical spine injuries. *J Trauma*. 2006;61(1):150–155.
[5] Miller C, Brubacher J, Biswas D, Lawrence B, Whang P, Grauer J. The incidence of noncontiguous spinal fractures and other traumatic injuries associated with cervical spine fractures: A 10-year experience at an academic medical center. *Spine*. 2011;36(19):1532–1540.
[6] Victorian State Trauma Outcome Registry and Monitoring Group. Victorian State Trauma System and Registry 1 July 2013 to 30 June 2014 Summary Report. Melbourne, Australia: Monash University and State Government of Victoria, Department of Health and Human Services; 2015.
[7] Cairns and Hinterland Hospital and Health Service. The State of Queensland. Cairns and Hinterland Hospital and Health Service 2014–15 Annual Report. 2015.
[8] Department of Health and Human Services. Victorian State Trauma System and Registry: Summary Report. Melbourne, Australia: Monash University, 2013–2014.
[9] British Orthopaedic Association. Standards for Trauma: BOAST 2: Spinal Clearance in the Trauma Patient, volume 2, 2015. Available at: https://http://www.boa.ac.uk/wp-content/uploads/2015/03/BOAST-2-March-2015.pdf (accessed on May 2015).
[10] Patel MB, Humble SS, Cullinane DC, Day MA, Jawa RS, Devin CJ, Delozier MS, Smith LM, Smith MA, Capella JM, Long AM, Cheng JS, Leath TC, Falck-Ytter Y, Haut ER, Como JJ. Cervical spine collar clearance in the obtunded adult blunt trauma patient: A systematic review and practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg*. 2015;78(2):430–441.
[11] Inaba K, Nosanov L, Menaker J, Bosarge P, Williams L, Turay D, Cachecho R, de Moya M, Bukur M, Carl J, Kobayashi L, Kaminski S, Beekley A, Gomez M, Skiada D, the AAST TL-Spine Multicenter Study Group. Prospective derivation of a clinical decision rule for thoracolumbar spine evaluation after blunt trauma: An American Association for the Surgery of Trauma Multi-Institutional Trials Group Study. *J Trauma Acute Care Surg*. 2015;78(3):459–465.
[12] Sixta S, Moore FO, Ditillo MF, Fox AD, Garcia AJ, Holena D, Joseph B, Tyrie L, Cotton B. Screening for thoracolumbar spinal injuries in blunt trauma: An Eastern Association for the Surgery of Trauma practice management guideline. *J Trauma Acute Care Surg*. 2012;73(5 Suppl. 4):S326–S332.
[13] Como JJ, Diaz JJ, Dunham CM, Chiu WC, Duane TM, Capella JM, Holevar MR, Khwaja KA, Mayglothling JA, Shapiro MB, Winston ES. Practice management guidelines for identification of cervical spine injuries following trauma: Update from the Eastern association for the surgery of trauma practice management guidelines committee. *J Trauma*. 2009;67(3):651–659.
[14] Easton R, Sisak K, Balogh Z. Time to computed tomography scanning for major trauma patients: The Australian reality. *ANZ J Surg*. 2011;82:644–647.
[15] Bernhard M, Becker TK, Nowe T. Introduction of a treatment algorithm can improve the early management of emergency patients in the resuscitation room. *Resuscitation*. 2007;73(3):362–373.
[16] Winslow III JE, Hensberry R, Bozeman WP, Hill KD, Miller PR. Risk of thoracolumbar fractures doubled in victims of motor vehicle collisions with cervical spine fractures. *J Trauma*. 2006;61(3):686–687.
[17] Nelson DW, Martin MJ, Martin ND, Beekley A. Evaluation of the risk of noncontiguous fractures of the spine in blunt trauma. *J Trauma Acute Care Surg*. 2013;75(1):135–139.
[18] Holmes J, Akkinepalli R. Computed tomography versus plain radiography to screen for cervical spine injury: A meta-analysis. *J Trauma*. 2005;58(5):902–905.
[19] Smith-Bindman R, Lipson J, Marcus R, Kim KP, Mahesh M, Gould R, Berrington de González A, Miglioretti DL. Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. *Arch Intern Med*. 2009;169(22):2078–2086.
[20] Cason B, Rostas J, Simmons J, Frotan MA, Brevard SB, Gonzalez RP. Thoracolumbar spine clearance: Clinical examination for patients with distracting injuries. *J Trauma Acute Care Surg*. 2016;80(1):125–130.
[21] The Victorian State Trauma System. Major Trauma Guidelines and Education. Available at: http://trauma.reach.vic.gov.au/. 2016.
[22] Harvey K, Pollard C, Lang J, Dallow N, Spanagel C, Carroll J. Established trauma systems – Queensland Trauma Registry. *Injury*. 2010;41(Suppl 1:S31).
[23] Hoffman JR, Mower WR, Wolfson AB, Todd KH, Zucker MI. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. *N Engl J Med*. 2000;343:94–99.
[24] Stiell IG, Wells GA, Vandemheen KL, Clement CM, Lesiuk H, De Maio VJ, Laupacis A, Schull M, McKnight RD, Verbeek R, Brison R, Cass D, Dreyer J, Eisenhauer MA, Greenberg GH, MacPhail I, Morrison L, Reardon M, Worthington J. The Canadian C-spine rule for radiography in alert and stable trauma patients. *JAMA*. 2001;286:1841–1848.