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Title: Clinical Clearance and Imaging for Possible Cervical Spine Injury in Children in the Emergency Department: A Retrospective Cohort Study

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What is already known on this topic

- Possible cervical spine injury needs to be considered in all children with trauma. These children are often placed in uncomfortable initial spinal immobilisation and many undergo radiological evaluation.
- In adults clinical decision rules can assist in determining who should undergo neck imaging. No such rules exist for children.
- There are no Australian baseline data on clinician practice in children presenting to emergency departments with possible cervical spine injuries.

What this paper adds

- Children at an Australian tertiary paediatric trauma centre were frequently evaluated for possible cervical spine injuries.
- Two thirds of children with possible neck injuries underwent radiological evaluation, but radiologically confirmed injuries were infrequent (<5%)
- Ideally, a child specific cervical spine injury decision rule should be developed to better target radiological evaluation of these injuries.

ABSTRACT (232)

Background and Objectives: While cervical spine injuries are rare in the paediatric population, presentations to emergency departments (ED) with possible neck injuries are common. Based on a lack of Australian data we set out to determine how many possible injuries are clinically cleared, what imaging is used on the remainder and the incidence and characteristics of confirmed paediatric cervical spine injuries.

Methods: We undertook a retrospective electronic medical record review of children <18 years with potential cervical spine injuries at a large tertiary paediatric trauma centre in Victoria, Australia over a 12 month period (annual census 87,000). For possible injuries we extracted key epidemiologic, imaging and short term outcome data.

Findings: During the study period, a total of 617 patients with potential neck injuries were seen in the ED (617/87,000 0.7%). The median age was 11 years. The most common mechanisms of injury were falls (41%), motor vehicle injuries (28%) and sports-related injuries (24%).

414/617 (67%) underwent neck imaging (345/414 83% plain radiograph, 100/414 24% computed tomography, 7/414 1.6% magnetic resonance imaging). 23/617 (4.1%) had radiologically documented cervical spine injuries. Two required operative interventions for their neck injuries.

Conclusion: While two-thirds of children with potential cervical spine injuries undergo radiological evaluation, actual injuries are rare (<4%). These data suggest that there is a potential for improved targeting of cervical spine imaging for trauma. The development of a clinical decision tool may help reduce neck radiography.

INTRODUCTION

Cervical spine injury (CSI) in children is a potentially devastating condition that may result in permanent spinal cord damage or death. However, CSI in children is infrequent in trauma patients.(1-5) Even so, every emergency department (ED) patient with potential CSI needs consideration of assessment and initial immobilisation until serious injury is excluded.(6) This process can be distressing and uncomfortable, cause pressure sores during immobilisation as well as prolong ED length of stay. In addition to the cost of the procedure, radiographic studies to investigate possible CSI expose the child to radiation which increases long term cancer risks.(7-9) Younger children may also need sedation or a general anaesthetic to facilitate trauma-related radiological tests.(10)

The developmental changes and anatomical differences across a wide age range complicate the clinical assessment of neck injuries and the interpretation of imaging in children. Spinal injuries, particularly young children, differ from adult patterns: injuries to the upper cervical spine are more common; neurological abnormalities without radiological changes or spinal cord injury without radiological abnormality (SCIWORA) can be seen.(1, 3, 11)

The difficulty for ED staff is to identify the rare patient who has a CSI without subjecting those who do not to unnecessary immobilisation and tests. Clinical decision rules (CDRs) can be defined as decision making tools derived from original research (as opposed to a consensus-based clinical practice guideline), which incorporate three or more variables from the history, physical examination, or simple tests. They guide physicians in diagnostic and therapeutic decisions, and can mitigate the uncertainty of medical decision making and improve their efficiency.(12) In adults, two high quality clinical decision rules from North America - the Canadian C-spine Rule (CCR)(13) and US National Emergency X-Radiography Low Risk Criteria (NEXUS)(14) - help doctors decide whether or not diagnostic imaging is needed in adults with blunt trauma in the ED. A recent Cochrane review of retro- and prospective studies to determine the paediatric accuracy of CCR and NEXUS in

children(15) found that there was either insufficient evidence (CCR) or conflicting evidence (NEXUS) to support the use of either rule in children and called for “additional well-designed studies with large sample sizes...to better evaluate the accuracy of the NEXUS criteria or the Canadian C-spine Rule, or both”.

While a number of papers have signposted the development of a paediatric CDR for CSI,(16-20) more recently, using a case control methodology, the Paediatric Emergency Care Applied Research Network (PECARN) proposed an 8 variable model for evaluation towards a decision rule.(21) A bi-national Australian and New Zealand Delphi process by the Paediatric Research in Emergency Departments International Collaborative (PREDICT)(22) identified the development of a paediatric CDR for CSI as a top research priority.(23)

Before undertaking a definitive paediatric validation of an adult focussed CDR or deriving a paediatric CDR de novo, it is vital to understand current Australasian practice surrounding the emergency management of possible CSI in children. Using data from a tertiary children’s hospital ED and trauma centre we therefore set out to assess what proportion of children are clinically cleared in an ED, i.e. without undergoing imaging; if children are imaged, what modality is used; and the proportion of children who have radiologically documented abnormalities.

METHODS

We conducted a review of all patients presenting to the ED of an urban tertiary paediatric hospital over a 12 month period from August 2017. The study hospital, Royal Children’s Hospital (RCH), has a large ED with an annual census of 87,000 children and is the only paediatric trauma centre in the state of Victoria, Australia. The study was approved by the Human Research and Ethics Committee (HREC) at RCH (HREC 38251).

Study procedure

Patients with possible CSI were identified through a search of the electronic medical record (EMR) system at RCH; search terms used included patients with the term “neck” or “collar” or “spinal immobilization” in complaints section or free text. In addition, we searched for all patients who had received cervical-spine (c-spine) imaging ordered from the ED (plain radiography, computed tomography (CT) or magnetic resonance imaging (MRI). Medical records were manually reviewed to assess inclusion and exclusion criteria and relevant data were then extracted, using a formal data dictionary.(24)

Inclusion Criteria:

All patients <18 years presenting to ED

- Via ambulance with a neck collar in situ, OR
- Presenting with a history of trauma related neck pain OR
- Receiving c-spine imaging.

Exclusion Criteria:

- No assessment of neck by history or examination.
- Neck pain in the absence of trauma.
- Anterior neck injury only.
- Arriving on transfer from another hospital with prior imaging.
- Incomplete EMR information.

Definitions

- ED triage urgency was assessed using the national Australian triage scale (ATS).(25) Patients with ATS category 1, 2, 3, 4 and 5 are to be seen immediately, within 10, 30, 60 and 120 minutes respectively.
- We used the Glasgow Coma Scale (GCS) assigned by the ED clinician or if not available, GCS at triage.
- We used senior radiologist reports to determine the results of radiology tests, and operative reports for patients who underwent orthopaedic or neurosurgical interventions.

- Abnormal radiology of the C-spine was defined as any traumatic change reported on plain radiography, CT or MRI. If there were differences in interpretation of the same radiograph, we used the senior radiologist reading over subsequent interpretations by consulted surgical services. If there were discrepancies when multiple imaging modalities had been employed, we used the interpretation of CT and MRI scans over plain radiographs.

Statistical analysis

Data were entered into a REDCap database(26) and analysed using Stata 15 (Statacorp, College Station, Texas, USA). Descriptive statistics were calculated with 95% confidence intervals (95%CI) for key proportions.

RESULTS

Of 2178 records screened, we excluded 1561 (72%), leaving 617 (28%) patients who met inclusion criteria and represent the study sample (**Figure 1**).

The baseline clinical characteristics are outlined in **Table 1**. Four-hundred sixty-four of the 617 (75%) patients included in the study arrived with the c-spine immobilised; 50 (8%) of patients who arrived without immobilisation were then placed in a neck collar on arrival to ED. Falls were the most common mechanism of injury followed by motor vehicle collision and sports-related injuries.

Of the 617 patients who had their neck assessed, 186 (30.1%, 95% CI 26.5-33.9) were cleared clinically on initial examination, leaving 431 (70%) who went on to undergo further assessment; 414 (414/617; 67.1%, 95% CI 63.2-70.8) of these underwent imaging (**Table 2**): 345 (83%, 95% CI 79.4-86.8) underwent plain x-ray films, 100 (24%, 95% CI 20.1-28.6) CT scans and 7 (1.6%, 95% CI 0.07-3.4) MRIs. Thirty-seven patients (8.9%) underwent multiple imaging modalities (**Table 2**).

In addition to radiology, 263 (61%) patients received analgesia, 133 (31%) had their neck collar changed, removed or applied, and 26 (6%) underwent observation.

Of the 431 patients who were not cleared clinically on initial examination, only 17 patients did not undergo radiological imaging. Three were managed in an Aspen collar alone (2 discharged, one admitted for a lumbar spine fracture) and 14 were subsequently cleared following a secondary assessment (11 after analgesia, one after orthopaedic assessment, one after observation only and one left against medical advice).

Two hundred and two (49%) of the 414 patients who underwent radiological investigation (or 32.7% of 617, 95% CI 29.0-36.6) were subsequently cleared clinically on repeat examination after imaging. This equates to a clearance of 388 of 617 (62.9%, 95% CI 58.9-66.7) after initial clinical assessment or initial imaging in ED. Twenty-two patients underwent further imaging in the emergency department. The further pathway for patients not cleared in ED is shown in **Figure 1**.

In the total cohort there were 23 radiologically confirmed neck injuries (or 3.7% -95% CI 2.4-5.5%) of 617 patients assessed in ED or 5.5% (95% CI 3.5-8.2) of 414 undergoing neck imaging) identified at any time (in ED or during hospitalisation). 13 were identified on initial imaging (9 on plain film and 4 on CT) and 10 were identified on further imaging (6 on CT, 4 on MRI). The age of these patients ranged from 1 to 17, 10 were male. Beyond the 5 patients who were intubated and unable to be assessed for GCS, 13/18 patients had a GCS of 15, 2/18 had GCS 13/14 and 3/18 had GCS < 12. In the 14/23 patients in which presence or absence of midline tenderness was documented, 13 /14 patients had midline tenderness. Injury mechanisms were motor vehicle crashes in 8, falls in 7, and a variety of other mechanisms in 8. The injuries were located at the cranio-cervical junction and C1-3 in

12, C4-7 in six and multiple levels in five and included fractures in six, ligamentous injuries in 13, subluxations in three and multiple types of injuries in one. Twenty-two (88%) of these patients were admitted to hospital for further management; two had orthopaedic surgery to fit a halo, two were treated in a Minerva brace and two had halter traction. One patient had multiple severe injuries with craniocervical dissociation and died.

DISCUSSION

The key findings of this study were that ED clinicians initially “clinically cleared” about 30% of presenting possible CSI without radiography. Two-thirds of patients then underwent c-spine imaging, mainly plain radiography but also an unexpectedly high rate of CT scans (24%) for a low overall yield of radiographically documented CSI. After initial radiography and a second clinical evaluation, another 33% were able to be cleared. Overall children with possible CSI frequently present to ED (71/10,000) but the rate of patients with radiographically documented CSI was low at <5% (or 2.6/10,000 ED presentations). As expected in children the majority of radiographically documented CSI involved the upper c-spine, mainly with ligamentous injuries.(4, 5)

The data in this Australian study are broadly consistent with international reports, which find that paediatric CSI is relatively rare. Most case series use trauma registry data as the denominator and find an incidence between 0.74% and 2%.(4, 5, 17, 27) The incidence in our study is higher, as the cohort here was narrowed to those where evidence of CSI risk management exists (that is the presence of cervical immobilisation, neck pain or neck imaging), rather than a large cohort of all injury patients (which would have been impractical). Therefore incidence rates are not comparable. Additionally, it is possible that some cases of neck assessment or, less likely, injury may have been missed and this remains a limitation of this study.

The inclusion criteria for this study attempted to define a population with a non-negligible risk of CSI- that is those who arrived in a collar, received imaging or had a presentation of trauma with neck pain. Thus we investigated a cohort where

assessment for cervical spine injury was undertaken in depth: clearly any prospective study will need to define negligible risk cases where preliminary assessment rules out neck injury and can therefore be excluded- i.e. a fall with isolated limb trauma, a minor facial injury etc. Incidence rates also need to take into consideration the case mix of the venue: a paediatric trauma centre such as RCH would likely have a higher baseline rate of CSI than a general or metropolitan ED.

In agreement with the recent Cochrane review,(15) the development of a CDR for c-spine imaging has been identified as a high priority in a recent PREDICT network Delphi study.(23) PREDICT has previously conducted a large multicentre study to determine the best head injury imaging CDR,(28) and data in the current study will underpin the planning for a similar study around neck injuries. There are several findings in this study which will assist in developing a study to derive such a decision rule: 1. The c-spine imaging rate is very high at 67%, which indicates a large scope for change. Even a moderate change in the imaging rate by developing and implementing an appropriate CDR would have a large impact at national level. 2. We identified the number of radiologically documented c-spine injuries per 10,000 ED presentations. This will allow us to conduct a sample size calculation in the Australian setting and to determine the number of sites included. 3. We did collect and describe clinical and historical features featured in the adult focussed NEXUS(14) and Canadian C-spine rules(13) as well as the paediatric PECARN study.(21) While hampered by the retrospective nature of our study, our data indicate historical and clinical findings similar to the PECARN data. 4. In our study it became apparent that there were occasionally different interpretations of radiological studies by radiologists and surgical services involved. In addition, findings at times varied between different imaging modalities. It will be critical to define study outcomes precisely. For this study, as set out in methods, we used the senior radiologist reports to determine radiological abnormalities and CT and MRI findings over plain radiographs.

Limitations:

The main limitation is the retrospective nature of the case identification and data extraction. It is likely that a prospective case identification would have identified more patients with possible CSI which would have reduced the rate of imaging and abnormal cases identified. Retrospectively, we also could not easily correlate signs and symptoms with the radiological abnormalities. This will require a large, multicentre prospective study. A further limitation is the lack of clinical follow up of the patients concerned, although it is likely that the majority of significant neck injuries would eventually have been referred back to the study hospital as the main regional paediatric trauma centre. The imaging practice described reflects practice in Melbourne; comparable data from elsewhere in Australasia are not available.

Conclusions:

Children at an Australian tertiary paediatric trauma centre are frequently evaluated for potential CSI. While two-thirds of children with potential neck injuries undergo radiological evaluation, any radiologically detected injuries are rare (<4%). Ideally, a child specific CSI imaging rule should be developed to better target the radiological evaluation of these injuries.

Declaration of conflicts of interests

None of the authors have conflicts of interests.

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Table 1: Children assessed for possible cervical spine injury: Demographics, mechanism of injury and clinical features

		n	%
Sex	Male	369	59.8
Age (years)	Median	11	
	Mean	10.3	
	25th centile	8	
	75th centile	14	
	Range	0-18	
	Under 5 years	70	11.4
Mode of arrival			
	Ambulance/Retrieval	525	85.1
	Self-referred/Walk in	92	14.9
Australasian Triage Scale (ATS)			
	1	63	10.3
	2	154	25.5
	3	348	56.4
	4	48	7.8
	5	1	0.2
Mechanism			
	Motor vehicle related	170	27.8
	Fall	253	41.0
	Specific Sport/ activity related	146	23.6
	Other	48	7.6
<i>Examination in Emergency Department</i>			
Glasgow Coma Score	15	528	85.6
	14	32	5.1
	9 -13	17	2.8
	4 -8	10	1.6
	3	9	1.5
	intubated and sedated	15	2.5
	not documented	6	1.0
Altered mental state	yes	63	10.3
Distracting injury	yes	159	26.0
Midline tenderness	yes	239	39.1
Any neck pain on movement	Yes	52	8.5

	Not tested due to clinical concern	164	26.8
	Not documented	183	29.9
Focal neurology:			
Any	Yes	17	2.8
	Unknown	104	17.0

Table 2: Imaging performed in the Emergency Department

	n	%
Total patient group who had neck assessed	617	100
Patient not clinically cleared following initial examination	431	69.8
<i>Imaging (any modality)</i>	414	67.1
XR	345	83.3
CT	100	24.2
MRI	7	1.6
<i>Modality Sequence</i>		
XR only	309	74.6
CT only	65	15.7
MRI only	3	0.6
XR + CT	33	8.0
XR + MRI	2	0.5
XR + CT + MRI	2	0.5
<i>Secondary assessment</i>		
Was the patient cleared after imaging and repeat examination	202	32.7
Did the patient receive further imaging in ED		
Yes	22	10.3
<i>Outcomes</i>		
Cervical spine injuries	23	3.7
Deaths	1	0.2
Intensive care admissions	27	4.4
Spinal surgery	2	0.3

XR Xray, CT computed tomography, MRI magnetic resonance imaging,
ED emergency department

Figure 1: Patient flow

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XR Xray, CT computed tomography, MRI magnetic resonance imaging,
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