Title

HETEROGENEITY IN CERVICAL SPINE ASSESSMENT IN PAEDIATRIC TRAUMA: A SURVEY OF PHYSICIANS' KNOWLEDGE AND APPLICATION AT A PAEDIATRIC MAJOR TRAUMA CENTRE

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Abstract

Objective

Evidence-based decision making tools are widely used to guide cervical spine assessment in adult trauma patients. Similar tools validated for use in injured children are lacking. A paediatric-specific approach is appropriate given important differences in cervical spine anatomy, mechanism of spinal injury and concerns over ionizing radiation in children. This study aims to survey physicians' knowledge and application of cervical spine assessment in injured children.

Methods

A cross-sectional survey of physicians actively engaged in trauma care within a paediatric trauma centre was undertaken. Participation was voluntary and responses de-identified. The survey comprised 20 questions regarding initial assessment, imaging, immobilisation and peri-operative management. Physicians' responses were compared with available current evidence.

Results

67 physicians participated (28% registrars, 17% fellows, 55.2% consultants). Physicians rated altered mental state, intoxication and distracting injury as the most important contraindications to cervical spine clearance in children. 54%

considered adequate plain imaging to be 3-view cervical spine radiographs (anterior-posterior, lateral, odontoid), whilst 30% considered CT the most sensitive modality for detecting unstable cervical spine injuries. Physicians' responses reflected marked heterogeneity regarding semi-rigid cervical collars and what constitutes cervical spine 'clearance'. Greater consensus existed for peri-operative precautions in this setting.

Conclusions

Physicians actively engaged in paediatric trauma care demonstrate marked heterogeneity in their knowledge and application of cervical spine assessment. This is compounded by a lack of paediatric-specific evidence and definitions, involvement of multiple specialties and staff turnover within busy departments. A validated decision-making tool for cervical spine assessment will represent an important advance in paediatric trauma.

Key Words

Spine injury; Cervical spinal clearance; Child; Decision making; Healthcare surveys

Introduction

Cervical spine clearance following trauma is common and important task. Many emergency departments utilise clearance protocols and guidelines evidence-based decision-making tools, e.g. the 'Canadian c-spine rules' ^{1, 2} and the NEXUS low-risk criteria (NLC) ³⁻⁵. However, these rules were designed to assist clinicians decide whether an adult patient warranted plain x-rays to investigate cervical spine injuries (Fig 1). This qualification is important for two reasons. First, the decision-making tools inform 'imaging' not 'clearance' of the cervical spine. Second, this evidence base is derived from 'adult' patients, and yet is widely applied to adult and paediatric trauma patients alike. Currently, there are no validated decision-making tools for cervical spine clearance in paediatric trauma patients.

It is often stated: 'Children are not little adults'. Certainly, cervical spine injuries (CSI) in children differ from those in adults due to differences in anatomy, mechanism of injury, age-dependent clinical and radiologic evaluation and immobilisation ^{6, 7}. Another distinction of paediatric CSI is the higher incidence of SCIWORA, i.e. spinal cord injury without radiologic abnormalities ⁸. For all these reasons, a paediatric-specific approach is likely appropriate.

This study was conducted at a paediatric major trauma centre, with the aim of assessing variability in the knowledge and application of cervical spine assessment and management by physicians engaged in paediatric trauma.

Methods

A survey investigating the knowledge and application of cervical spine assessment and management in paediatric trauma patients was designed and distributed to registrars, fellows and consultant (attending) staff at The Royal Children's Hospital (RCH). RCH is the sole state-designated paediatric major trauma service for Victoria, Australia. It services a population of approximately five million people, and admits approximately 90% of the region's paediatric major trauma patients. Within the Victorian State Trauma System, 'paediatric' is defined as being aged less than 16 years.

For the purposes of this study, physicians with varying number of years of post-graduate clinical practice were recruited for the survey between April and June 2013 if their current role involved consultation on the assessment or management of paediatric CSI. Each participant voluntarily completed the 20-question survey, the content of which addressed the initial assessment, immobilisation, imaging, and peri-operative management of paediatric CSI; see Appendix A. Thus, a cross-sectional survey of physicians primarily involved in the acute care of paediatric cervical spine trauma was compiled.

Ethical standards

According to the Australian Health Records Act, this study represents a quality activity and does not require organisational ethics review. This notwithstanding, the study was performed in accordance with ethical standards outlined in the Declaration of Helsinki, including de-identification of physicians' responses prior to analysis.

Results

Sixty-seven out of a total 136 eligible physicians (49%) participated in the survey: 28% registrars, 17% fellows and 55% consultants (attending staff). Ninety-three percent of physicians had at least 5 years of post-graduate clinical experience, and 57% more than 10 years experience. Thirty-seven percent were from Emergency Medicine, 33% from Anaesthesia or Intensive Care and the remaining 30% from General Surgery, Orthopaedic Surgery or Neurosurgery. With the exception of three questions applicable only to physicians from Anaesthesia or Intensive Care, all physicians provided responses for 100% of the survey questions.

Contraindications to Cervical Spine Clearance

Physicians were asked to indicate which factor(s) from a list of options were contraindications to cervical spine clearance in children following trauma.

Altered mental state was the most frequently indicated factor, closely followed by intoxication and distracting injury; each being indicated by more than 90% of physicians (Table 1). Midline tenderness, mechanism of injury, and fall from greater than 1.5 metres were rated of lesser importance than distracting injury. Despite the importance placed on distracting injury when assessing a child for CSI, opinions varied markedly as to what constituted a 'distracting injury' (Table 2).

Imaging of the Paediatric Cervical Spine

Participants were asked what constituted 'adequate imaging' on plain x-rays. The most commonly cited response was 3-view cervical spine radiographs (AP, lateral and odontoid views) in all age groups, with only 10% of physicians opting for an age-stratified approach that only includes the odontoid view in children more than 5 years of age (Table 3).

There were varied opinions as to the incidence of missed unstable CSI in children with normal plain radiographs (Table 4). When asked what they considered the most sensitive imaging modality to detect unstable CSI in children, 67% of physicians responded MRI, 30% CT, 1.5% immediate flexion-extension x-rays and delayed flexion-extension x-rays in 1.5% each. Twelve percent of the surveyed physicians were unaware of the concept of 'SCIWORA'.

Definition of 'Clearance' of the Cervical Spine

Variability in physicians' opinions existed in defining cervical spine 'clearance'.

Fifty-five percent of physicians indicated the statement best defining cervical spinal 'clearance' was: 'spinal precautions are not required'. Eleven percent cited 'removal of the cervical collar' as the defining feature of cervical spine 'clearance', and a further 10% indicated 'absence of bony or soft-tissue injury'.

Sixteen percent believed it was defined by 'absence of pain on active or passive movement'. Only 8% of responders chose the option 'the patient may safely move the neck & mobilise without a collar.'

Cervical Collar Management and Complications

The role of a cervical collar was most commonly cited for prevention of instability (67%), followed by fracture immobilisation (21%) and comfort (12%). Rigid (i.e. ambulance or emergency style) collar removal within 4 hours was suggested by 37%, within 6 hours by 31% and within 8 hours by 31%. With regard to semi-rigid (i.e. Philadelphia, Miami J or Aspen) collar immobilisation, 82% of respondents believed the incidence of collar related complications was ' $\leq 1\%$ when used for $< 48\text{hrs}$ ', and 64% believed the incidence of complications was ' $\geq 5\%$ when used for $> 48\text{hrs}$ '. Finally, 54% of physicians believed that wearing a cervical collar required full-spinal immobilisation.

Anaesthesia in the Setting of Suspected Spinal injury

Physicians from Anaesthesia and Intensive Care were asked to comment on implications of suspected CSI on airway management, intubation or extubation and patient positioning. More than 90% of this subgroup stated their management would not vary between unstable, indeterminate and low risk patients if a cervical collar (rigid or semi-rigid), remained in place. The most common cited additional interventions employed in this setting were in-line immobilisation, video laryngoscopy and fibre-optic intubation.

Discussion

The lack of a consensus definition for cervical spine 'clearance' is clearly reflected by our institutional survey. Far from esoteric, this ambiguity may lead to unnecessary immobilisation, specialist referrals and anxiety for injured children, families and even staff. To mitigate such uncertainty, the authors recommend clear and structured documentation regarding stability of the cervical spine, ability for the cervical collar to be removed, and any restrictions on patient movement, transfers and ambulation.

This study demonstrates marked heterogeneity of understanding and practice in assessment of the cervical spine at our paediatric major trauma centre.

This heterogeneity was distributed between speciality groups, and unrelated to years of experience in paediatric trauma care, indicating a multifactorial basis for diversity.

A 'distracting injury' is a barrier to safe clinical cervical spine clearance according to the NEXUS low-risk criteria and paediatric-specific algorithms^{3, 4, 9}, and yet consensus as to what constitutes a 'distracting injury' is lacking. Our physician cohort mirrors this: the vast majority agreed a 'distracting injury' precluded clinical cervical spine clearance, but there was no agreement as to the definition of a 'distracting injury'. Level 1 adult evidence provided by randomised controlled trials challenges the importance of 'distracting injuries': in alert trauma patients (GCS ≥ 14) with a distracting injury, 'midline tenderness' retains a sensitivity of 99% and negative predictive value $>99\%$ for CSI¹⁰. Furthermore, the majority of adults with distracting injuries were successfully cleared without any radiology¹⁰. Another prospective series of 406 adult trauma patients found lower torso injuries were not 'distracting' to prevent clinical cervical spine clearance¹¹. Children present a very different challenge, and to date there is no Level 1 or 2 evidence to show which injuries, in children of which age, should be considered 'distracting' during clinical assessment for CSI. Leonard et al. reported injuries to the head and torso, but not injuries to the extremities, as factors associated with CSI¹².

Physicians in this study varied with respect to the minimum radiology requirement for clearance of the cervical spine in children following trauma. Literature supports a safe role for 'clinical' clearance, i.e. without any imaging. A systematic review of level 3 evidence found children cervical spine clearance without imaging is safe in children under 9 years without any of intoxication, midline tenderness or 'painful distracting injury' ⁷. Further, Leonard et al. also reported that torticollis, altered mental status and complaints of neck pain were predictive factors associated with CSI in a retrospective case control study ¹². A prospective study of paediatric trauma patients found no radiological evidence for CSI in 603 children (<18 years) deemed 'low-risk' by NEXUS guidelines, suggesting imaging was not necessary in this 'low-risk' group ⁸. Importantly, the applicability of recommendations from this influential study may be limited in children under 8 years, given the small number of patients under 8 years in the NEXUS cohort (2.8% under age 2yrs, 26% age 2 to 8 years), and the absence of any cases of SCIWORA. When indicated, our physicians most commonly selected 3-view cervical spine radiographs as the primary imaging modality, with 'satisfactory' imaging demonstrating occiput to T1 on the lateral view. 10% of our respondents reflected the viewpoint of Buhs et al., who presented level 3 evidence showing no additional benefit of the 'odontoid' view in children younger than 9 years ¹³.

One third of physicians surveyed in this study considered the incidence of missed unstable CSIs in children with normal x-rays to exceed 5%. Nigrovic et al. reported a sensitivity of 90% of plain radiographs in a retrospective review of 206 children with blunt trauma and confirmed CSI in the Pediatric Emergency Care Applied Research Network (PECARN). However, none of these children sustained neurological injury or required surgical intervention¹⁴. Our data shows an adequate awareness amongst our colleagues, and likely explains the prevalent use of additional imaging modalities to augment (or even replace) plain x-rays, particularly if there is persistent tenderness of the cervical spine, or equivocal initial imaging. Three imaging modalities warrant comment here: CT, flexion-extension cervical spine radiology (FECSR) and MRI.

In adult trauma, CT is now recommended as the default modality for cervical spine imaging by the American College of Surgeons Committee on Trauma¹⁵. This trend has been observed in the use of cervical CT in children, with a six-fold reported increase in use in Korea and the United States^{16, 17}, especially those presenting to an adult trauma centre¹⁸. This being said, 30% of our experienced physician cohort incorrectly identified CT as the 'most sensitive test for an unstable C-spine injury'. This is despite MRI being the most sensitive modality for CSI¹⁹. Our findings, together with the escalating use of cervical CT in paediatric trauma, are of concern for three key reasons. First, it

is well documented that children exposed to ionizing radiation are at increased risk of thyroid and other cancers²⁰⁻²². Second, debate exists regarding the sensitivity of CT compared with plain radiography in the diagnosis of CSI in children younger than five years in whom more of the skeleton has not undergone secondary ossification²³. Third, there are ancillary costs of CT imaging to screen for paediatric CSI, with increases in cost, possible sedation requirements and emergency room time²⁴.

In children, acute FECSR does not increase the sensitivity of CSI diagnosis over plain radiographs, possibly due to the limitations imposed on the assessment due to patient discomfort, anxiety and refusal^{25, 26}. For all of these reasons, our physicians were appropriately dismissive of this modality.

Unlike CT and FECSR, MRI is attractive adjunct to plain radiographs, due to superior sensitivity and no exposure to ionising radiation. MRI has been shown to be applicable in the acute assessment of paediatric CSI, especially those with equivocal radiography, altered conscious state, or abnormal neurology^{19, 27}. While considered the 'gold standard' for detection of CSI, MRI does have drawbacks, including detection of non-clinically significant and incidental findings^{28, 29}, notable resource burden (e.g. limited access, duration of scans, expense) and the need for general anaesthesia in young children. The use of single-sequence STIR MRI has been reported to reduce scanner

time whilst maintaining a sensitivity of 100% for unstable CSI in children (specificity 97%, NPV 100%)³⁰.

The sensitivity of MRI also addresses concerns regarding spinal cord injury not evident on plain x-rays or CT, i.e. 'SCIWORA'. That even a minority of our physicians engaged in paediatric trauma were unaware of 'SCIWORA' is surprising. Described almost 25 years ago³¹, SCIWORA is considered a mainstream concept in spinal trauma scholarship and teaching. SCIWORA is more common in children than adults, with an incidence of 18-38%^{31, 32}. This is attributed to the relatively greater flexibility of the paediatric cervical spine compared to the spinal cord, and was described prior to the advent of MRI in spinal trauma. With current MRI imaging on patients with neurological deficits, previously undetectable radiological abnormalities of the cord are now easily detected. The authors believe this may have contributed to the lower than expected awareness of SCIWORA in our physician cohort.

Delayed cervical spine clearance is the principal predictor of collar-related complications in multiple injured adult patients³³. The risk of collar-related complications such as pressure ulceration appears lower in paediatric multi-trauma patients. In children, the risk of collar-related complications increases with obtundation/traumatic brain injury, longer ICU stay, and delayed clearance; 10% of obtunded children show pressure injury after 6 days of

cervical collar immobilisation³⁴. The risk of ulceration in alert children or non-severe trauma is likely very low.

The authors consider concentrated efforts towards standardisation of paediatric cervical spine assessment guidelines to be a priority. Whilst the relative lack of literature confounds the wish to be truly evidence-based, it is reasonable to consider such guidelines would inform which children can be safely assessed without any imaging, standardise plain x-ray views when indicated, avoid use of CT in favour of MRI imaging, and provide concise and unambiguous recommendations regarding collar requirement, spinal stability and mobility restrictions. Without paediatric-specific standardised guidelines, the ambiguity and heterogeneity typified by our physician cohort will likely continue to characterise clinical practice. This may, in turn, present ongoing barriers to safe, consistent and efficient care for children with suspected CSI.

Limitations

The key limitation of this survey pertains to the size and representative nature of its sample. The sample is self-evidently small in size, representing only half of the physician cohort identified as eligible for recruitment. Physician experience, as measured by years of post-graduate practice, may not necessarily represent the frequency with which a clinician manages the paediatric spine, or whether they are solely in paediatric practice. The

adoption of voluntary participation exposes the study to selection bias, and may have resulted in a sample whose views are not truly representative. Adding further to potential for bias, the sample is also derived from a single institution. This notwithstanding, RCH is the only paediatric trauma centre for the state of Victoria, Australia. In an attempt to counter this bias and promote a sample representative of the physicians responsible for cervical spine assessment following trauma, all relevant specialties engaged in acute clinical trauma care were included. Unfortunately, this strategy may have paradoxically compounded the heterogeneity due to differing emphases in education and practice between specialties.

Conclusions

This study reveals marked heterogeneity in specialists' knowledge and approach when assessing an injured child with a suspected CSI. This heterogeneity is surprisingly seemingly unrelated to familiarity with paediatric trauma, given the study sampled experienced physicians actively engaged in paediatric trauma within a high-volume, dedicated paediatric trauma centre. This heterogeneity is also pervasive, being evident at multiple points along the paediatric trauma patient journey and reflected by across specialties groups. This reflects a lack of sufficient evidence or guidelines pertaining to the management of the paediatric cervical spine in the setting of trauma. In

moving forward, it is anticipated this study will contribute meaningfully to future targeted cross-faculty education in paediatric cervical spine trauma, with the aim of informing and standardising assessment of injured children. A validated, paediatric decision-making tool for cervical spine assessment will represent an important advance in paediatric trauma.

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All authors declare no competing interests relevant to this study.

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Table 1:

Question: *Which of these clinical factors are contraindications to the clinical clearance of the cervical spine in the paediatric population?* (Tick all that apply)

Response Options	% Physicians
Altered mental state	99%
Intoxication	97%
Distracting injury	93%
Midline tenderness	84%
Recent opioid analgesia (<6hrs)	33%
Mechanism of injury	30%
Fall from >1.5 metres	20%

Table 2:

Question: *Which of the following constitutes a 'Distracting Injury?'* (Tick all that apply)

Response Options	% Physicians
Any abrasion or bruise	3%
Any injury of (or above) the clavicle	45%
Long bone fracture	82%
Soft tissue Injury	19%
Hand or foot fracture	40%
Rib fracture or chest contusions	79%
Chest injury with visceral injury	87%
Blunt abdominal trauma without visceral injury	51%
Blunt abdominal trauma with visceral injury	85%

Table 3:

Question: *What constitutes adequate imaging on plain x-rays?*

Responses	% Physicians
3-views (AP, Lateral and Odontoid)	54%
Age-stratified 3-views (AP, Lateral and only Odontoid if >5 years of age)	10%
2-view (AP & Lateral only)	9%
Lateral Only	7%
Views not Specified	15%
Physician stated 'do not know'	5%

AP, anterior-posterior

Table 4:

Question: *What is the incidence of missed cervical spine injury (with instability) with a normal lateral and AP cervical spine x-ray?*

Response Options	% Physicians
0.01%	6%
0.1%	13%
1%	45%
5%	26%
10%	10%

AP, anterior-posterior

Figure legends

Figure 1

Summary of the 'Canadian c-spine rules' ^{1, 2} and the NEXUS low-risk criteria (NLC) ³⁻⁵ decision-making tools to guide imaging in adults with suspected CSI.

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Canadian C-spine Rules

NEXUS Criteria

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1. **How many years of clinical experience do you have?**
 - < 5 years
 - 5-10 years
 - 10-20 years
 - >20 years
2. **What is your current position?**
 - Registrar
 - Fellow
 - Consultant
3. **Which unit do you work for?**
 - Emergency Department
 - Paediatric Intensive Care
 - Anaesthetics
 - Orthopaedics
 - Neurosurgery
 - Paediatric (General) Surgery
4. **Which of these clinical factors are contraindications to C-spine clearance in the paediatric population? (choose all that apply)**
 - Mechanism of injury
 - Distracting injury
 - Altered mental state
 - Intoxication
 - Recent opioid analgesia (within 6 hours)
 - Fall from >1.5 metres
 - Midline Posterior Tenderness
5. **Which of the following do you consider do you consider to be a "distracting injury?" (choose all that apply)**
 - Any abrasion or bruise
 - Any injury of or above the clavicle
 - Long bone fracture
 - Soft tissue injury
 - Hand or foot fracture
 - Rib fracture or chest contusions
 - Chest injury with visceral injury
 - Blunt abdominal trauma without visceral injury
 - Blunt abdominal trauma with visceral injury
6. **What constitutes adequate imaging on plain x-rays?**
 - Please describe
7. **What is the most sensitive test for an unstable C-spine injury? (choose one answer)**

- Computed Tomography (CT)
- Magnetic Resonance Imaging (MRI)
- Flexion-Extension Radiographs at the time of injury
- Flexion-Extension Radiographs six weeks after injury

8. What statement best defines "clearance" of the C-spine?

(choose one answer)

- Removal of the cervical collar
- Absence of bony injury to the cervical spine
- Absence of soft tissue or ligament injury to the cervical spine
- The patient is able to move the neck safely
- Spinal precautions are not required
- Absence of pain on active or passive movement

9. What is SCIWORA?

- Please write

10. What is the incidence of missed cervical spine injury (with instability) with a normal lateral and AP C-spine X-ray?

(choose one answer)

- 0.01%
- 0.1%
- 1%
- 5%
- 10%

11. In what time frame should a rigid (stiff neck) collar be changed to an Semi-rigid (Aspen/ Miami J/ Philadelphia) collar? *(choose one answer)*

- <4 hours
- <6 hours
- <8 hours
- <12 hours
- <24 hours

12. What best describes the function of the semi-rigid (Aspen/ Miami J/ Philadelphia) cervical collar? *(choose one answer)*

- Prevention of instability
- Pain relief
- Fracture immobilization
- Relief of muscle spasm

13. What is the incidence of adverse events related to semi rigid (Aspen/ Miami J/ Philadelphia) cervical collar in children immobilised < 48 hours? *(choose one answer)*

- 0.01%
- 0.1%
- 1.0%
- 5%

14. **What is the incidence of adverse events related to semi rigid (Aspen/ Miami J/ Philadelphia) cervical collar in children immobilised > 48 hours?** *(choose one answer)*
- 0.01%
 - 0.1%
 - 1%
 - 5%
 - 10%
15. **Does the patient in a cervical collar need to have FULL spinal precautions?**
- Yes
 - No
16. **According to Hospital Cervical spine guidelines, who can clear a C-spine with NO suspicious criteria?** *(choose all that apply)*
- Emergency Registrar/Fellow/Consultant
 - Trauma Registrar/Fellow/Consultant
 - Orthopaedic Registrar/Fellow/Consultant
 - Neurosurgery Registrar/Fellow/Consultant
17. **According to RCH C-spine guideline, which of the following staff may clear IF ANY suspicious criteria exist?** *(choose all that apply)*
- Emergency Registrar/Fellow/Consultant
 - Trauma Registrar/Fellow/Consultant
 - Orthopaedic Registrar/Fellow/Consultant
 - Neurosurgery Registrar/Fellow/Consultant
18. **For Anaesthesia and PICU staff only: How does an unstable cervical spine injury affect your clinical management?**
- Airway management
 - Intubation/extubation
 - Positioning
19. **For Anaesthesia and PICU staff only: How does an unclear and undetermined cervical spine injury change your clinical management?**
- Airway management
 - Intubation/extubation
 - Positioning
20. **For Anaesthesia and PICU staff only: How does an unclear cervical spine with no radiological abnormality change your clinical management?**
- Airway management
 - Intubation/extubation
 - Positioning

Appendix B: Levels of evidence for clinical studies

Level 1: High quality randomised controlled trial (RCT) or prospective study; testing of previously developed diagnostic criteria on consecutive patients; sensible costs and alternatives; values obtained from many studies with multiway sensitivity analyses; systematic review of Level 1 RCTs and Level 1 studies.

Level 2: Lesser quality RCT; prospective comparative study; retrospective study; untreated controls from an RCT; lesser quality prospective study; development of diagnostic criteria on consecutive patients; sensible costs and alternatives; values obtained from limited studies; with multiway sensitivity analyses; systematic review of Level 2 studies or Level 1 studies with inconsistent results.

Level 3: Case control study (therapeutic and prognostic studies); retrospective comparative study; study of nonconsecutive patients without consistently applied reference “gold” standard; analyses based on limited alternatives and costs and poor estimates; systematic review of Level 3 studies.

Level 4: Case series; case control study (diagnostic studies); poor reference standard; analyses with no sensitivity analyses.

Level 5: Expert opinion.

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