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Pediatric Cervical Spine Clearance: A 10-year Evaluation of Multi-Detector Computed Tomography at a Level 1 Pediatric Trauma Center

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Disclosures

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Social Media

In this retrospective review, the sensitivity of MDCT in detecting clinically significant injuries that required an operative intervention is 100%. In patients with a normal MDCT, MRI failed to detect any previously missed unstable injuries.

#c-spine #c-spine clearance #pediatric trauma

@katierussellmd @drstephenfenton @kinabamd @steph_iantorno

Authorship

KWR, SEI, RRI, DLB, TMB, SJF, KI, RAS participated in study design. KMS, NEP, KEL, KLB participated in data acquisition. SEI, TMB, RAS participated in data analysis. KWR, SEI, RRI, DLB, TMB, SJF, KI, RAS, KMS, NEP, KEL, KLB participated in article development and critical revisions.

Abstract

Introduction

Efficient and accurate evaluation of the pediatric cervical spine for both injury identification and post-traumatic clearance remains a challenge. We aimed to determine the sensitivity of multi-detector computed tomography (MDCT) for identification of cervical spine injuries (CSIs) in pediatric blunt trauma patients.

Methods

A retrospective cohort study was conducted at a level 1 pediatric trauma center from 2012 though 2021. All pediatric trauma patients age <18 years who underwent cervical spine imaging (plain radiograph, MDCT, and/or magnetic resonance imaging (MRI)) were included. All patients with abnormal MRIs but normal MDCTs were reviewed by a pediatric spine surgeon to assess specific injury characteristics.

Results

A total of 4,477 patients underwent cervical spine imaging and 60 (1.3%) were diagnosed with a clinically significant CSI that required surgery or a halo. These patients were older, more likely to be intubated, have a Glasgow Coma Scale score less than 14, and be transferred in from a referring hospital. One patient with a fracture on XR and neurologic symptoms got an MRI and no MDCT before operative repair. All other patients who underwent surgery including halo placement for a clinically significant CSI had their injury diagnosed by MDCT, representing a sensitivity of 100%. There were 17 patients with abnormal MRIs and normal MDCTs, none underwent surgery or halo placement. Imaging from these patients were reviewed by a pediatric spine surgeon and no unstable injuries were identified.

Conclusion

MDCT appears to have 100% sensitivity for detecting clinically significant CSIs in pediatric trauma patients, regardless of age or mental status. Forthcoming prospective data will be useful to confirm these results and inform recommendations for whether pediatric cervical spine clearance can be safely performed based on the results of a normal MDCT alone.

Level of evidence: IV, retrospective cohort study

Keywords: Pediatric; cervical spine injury; cervical clearance; c-collar; cervical spine imaging.

Background

Significant cervical spine injury (CSI) occurs in approximately 1% of pediatric blunt trauma patients. (1–3) CSI can cause neurologic compromise and paralysis, making it critical to identify these injuries for expeditious treatment. Trauma patients are placed in cervical collars (c-collars) for immobilization while waiting for either treatment of a CSI or clearance. The purpose of a c-collar is to prevent motion that may make an existing injury worse. While cervical immobilization may be important in preventing neurological deficits in patients with unstable injuries, (4) 99% of trauma patients do not have destabilizing spinal injuries. Therefore, timely cervical spine (c-spine) clearance is imperative because prolonged c-collar utilization can lead to iatrogenic complications such as pressure ulceration at the c-collar, anxiety, discomfort, and nursing challenges such as airway and respiratory management. There is some evidence that they may also increase intracranial pressure, a significant concern in our patients with traumatic brain injury. (5)

Conventional radiography (XR) and multi-detector computed tomography (MDCT) are both used for initial c-spine imaging in pediatric trauma patients, depending on their presenting characteristics. In general, XR is used in stable and alert children to limit radiation. (6–8) MDCT is reserved for critically injured children, because it is quick and reliable. Critically injured children typically require cranial imaging and therefore it is efficient to perform the head and c-spine MDCT at the same time. Currently, with normal screening imaging, a normal physical examination (consisting of normal, pain free neck motion in a neurologically intact patient) or a normal magnetic resonance imaging (MRI) is necessary for c-spine clearance and collar removal. This approach is based on published expert consensus by the Pediatric Cervical Spine Study

Group. (9) The evidence for recommending an MRI in addition to a normal MDCT is limited, and based on data from a previous era of imaging technology. (10,11) Advancements in the quality of MDCT make images from current 64-slice helical scans with sagittal and coronal reconstructions far superior to historical single-slice CT. (12) In 2015, the Eastern Association for the Surgery of Trauma (EAST) published an evidence-based practice guideline that recommends removal of the c-collar in an obtunded adult blunt trauma patient with a normal MDCT of the c-spine without the addition of an MRI. (13) In children, injury patterns are different than in adults. (14,15) Young children may have ligamentous injuries that are not detectable by MDCT. A missed injury may cause morbidity, and because of this the use of MRI to clear the c-spine remains standard practice in certain pediatric trauma scenarios.

We hypothesize that clinically significant injuries are detected by MDCT and that there are not clinically significant injuries found on MRI that were missed by MDCT. MDCT cannot characterize ligamentous injuries and MRI is a necessary tool in diagnosing these injuries, but we hypothesize that a patient with an unstable ligamentous injury will have some abnormality on MDCT that can guide further imaging. It is our hypothesis that MDCT is an excellent screening test for clinically significant CSI and that routine MRI may be unnecessary if MDCT is normal. We are not attempting to define who should be screened for CSI. This question is being worked on by the Pediatric Emergency Care Applied Network and is beyond the scope of this paper. We are not trying to promote overutilization of MDCT. The goals of this paper are to determine the incidence of clinically significant CSIs in our pediatric patient population and to determine the sensitivity of MDCT in detecting these injuries.

Methods

Following exemption from the Institutional Review Board (IRB #00147202), we performed a retrospective cohort study using the trauma registry from a level 1 pediatric trauma center. Our center sees approximately 1,400 pediatric trauma patients per year and has a catchment area with a 500-mile radius. Inclusion criteria were all trauma patients <18 years old with any c-spine imaging (XR, MDCT, MRI) from January 2012 through December 2021. Once registry patients were identified, we performed a granular chart review. Charts were reviewed for patient demographics, injury mechanism, injury severity, and management. C-spine imaging studies were reviewed in detail. In order to ensure data quality, we performed a 5% review of all data entered into our data collection tool to confirm accuracy (K.R.). We followed the STROBE reporting guideline (Supplemental Digital Content, http://links.lww.com/TA/C987).

The primary outcome of this study was the occurrence of a clinically significant CSI, defined as a CSI requiring surgical intervention, including halo placement. Radiographic definitions of spinal instability were avoided; instead, MDCTs and MRIs were interpreted in a binary fashion as either normal or abnormal based on radiologist interpretation. Two pediatric spine surgeons (R.I./D.B) reviewed abnormal MRIs in patients with normal MDCTs in order to further assess specific injury characteristics.

During the study time period, an institutional protocol was followed that recommended post-traumatic c-spine imaging for those with the following risk factors: midline cervical pain, neurologic deficit, torticollis, limited range of motion, distracting injury, obtundation, substantial injury to the torso, or significant mechanism including diving, and high-risk motor vehicle crash.

(16) Children with a GCS ≥14 typically underwent a 2-view XR and those with a GCS ≤13 underwent MDCT. Criteria for c-spine clearance included a normal physical examination or a negative MRI of the c-spine. Spine service consultation was employed for neck clearance in all trauma patients <3 years old and for any abnormal imaging or neurologic findings. (17)

All statistical analyses were performed using R (Version 4.2.1). All variables were categorical and presented as frequencies (percentage). Univariate analyses were performed using chi-squared tests or Fisher's exact tests where appropriate. Hypotheses were evaluated using a two-sided test with $p<0.05$ considered significant.

Results

A total of 4,477 patients underwent c-spine imaging during the study period. Of those, 53% (n=2,368) underwent initial imaging with XR. A total of 52% (n=2,306) got a MDCT in addition to their XR or a MDCT alone as part of their trauma work-up. Of the 2,306 MDCTs performed, 86% (n=1,989) were normal. Of the 317 abnormal MDCTs, 59 patients were diagnosed with clinically significant CSIs that required surgery or a halo. (Figure 1) One patient with a fracture on XR and neurologic symptoms got an MRI and no MDCT before operative repair. All other patients who underwent surgery for a clinically significant CSI had their injury diagnosed by MDCT. There were no false negative MDCTs defined as a normal MDCT that had a clinically significant injury diagnosed by either physical examination or MRI. The sensitivity of MDCT for diagnosing clinically significant CSI is 100% in our study.

In total, there were 60 (1.3%) clinically significant CSIs. One child was placed in a halo brace and the other 59 underwent operative fusion. Compared to the rest of the cohort, clinically significant CSI patients were older, more likely to be intubated, more likely to have a GCS score less than 14, and more likely to have been transferred in from another hospital. (Table 1)

The majority, 86% (n=1989), of patients that underwent MDCT had a normal study. Of those normal MDCTs, 12% (n=232) went on to get MRIs. These children were either obtunded several days into their hospital stay because of traumatic brain injury or had persistent pain, paresthesia, or weakness despite a normal MDCT. Of these, 7% (n=17) had abnormal MRI findings. None of these patients underwent operative intervention or required a halo brace. Furthermore, post hoc review of these patients by the spine team did not detect any unstable injuries. (Table 2) In these 17 patients, 7 underwent c-spine clearance in the hospital, and 10 were discharged in a hard collar for between 2 days and 6 weeks. Eight underwent flexion-extension XRs before being cleared.

Conclusions

In this large single center study at a level 1 pediatric trauma center we found that MDCT was 100% sensitive for diagnosing clinically significant CSIs. While this sensitivity is compelling, it does need to be interpreted with caution given the constraints of this single center retrospective review. That said, we also found that in a small cohort of patients with normal MDCT findings and an abnormal MRI, none of these injuries went on to require surgical intervention or were deemed unstable on imaging reevaluation by our spine team (R.I./D.B). While this does not preclude the use of MRI in evaluating post-traumatic spine injury, these findings suggest that the vast majority of clinically significant CSIs can be detected by MDCT alone. It raises into question the utility of MRI when a MDCT is normal.

While MRI certainly plays an important role in CSI, especially in evaluation of the spinal cord, specific injuries to the discoligamentous complex, the presence or absence of compressive hematomas, and the detection of unique patterns of injury in cases of suspected child abuse (18), its utility has been previously questioned in the setting of a normal post-traumatic MDCT. (12,19,20) Historically, they were likely important for screening, (11,28) but the contemporary additional diagnostic yield of c-spine MRI in patients who have a negative MDCT is unclear, and based on these data, probably unnecessary. Derderian et al. reviewed 160 patients with normal MDCTs and they identified 76 stable CSIs (47.5%) on MRI that were missed, but no unstable CSIs by radiologic definition (disruption of 2 or more contiguous spinal columns) nor that were clinically significant (requiring surgery or a halo). (19) Qualls et al. reviewed 63 children with traumatic brain injuries that had both a MDCT and an MRI. They identified 7 children (11%) with a normal MDCT that had a CSI identified by MRI, but none of those were deemed clinically significant by the pediatric spine team. (20) Gargas et al. similarly reported zero missed unstable injuries after upgrading their CT scanner in 2005. We have also previously reported on the high sensitivity of MDCT and high rate of false positive CSIs detected by MRI. (21) The evidence is mounting that MRI does not add value to a normal high quality MDCT.

After the 2015 EAST Guideline, Cervical Spine Collar Clearance in the Obtunded Adult Blunt Trauma Patient, many centers changed their practices and began clearing the adult c-spine based on normal MDCTs without the addition of an MRI. This guideline was based on a review of

1,017 patients with a 9% incidence of stable ligamentous CSI detected on MRI, and a 0% incidence of unstable ligamentous CSI not detected by MDCT. (13) Given the unique anatomical considerations in children, including underdeveloped spinal osseous structures and a higher reliance on ligamentous structures for stability, these findings in adults require careful study prior to their application in the pediatric population.

In this study, we chose to focus on the ability of MDCT to detect clinically significant CSI, rather than using the terms stable and unstable for injury patterns. The rationale for this is that consensus definition for stable and unstable injuries are difficult to achieve, can vary amongst providers, and is beyond the scope of this study. We acknowledge that this may cause some debate among readers. In a prospective adult study by Inaba et al, the definition of a clinically significant CSI was any injury requiring surgery, halo placement, or use of a cervicothoracic orthosis (CTO). (22,23) While CTO braces are occasionally used for high thoracic injuries at our institution, they were not utilized it in our isolated CSI population. Therefore, we excluded CTO brace from our definition and instead defined a clinically significant CSI as that which required surgical intervention (including halo placement), similar to a recent study by Derderian et al. (19)

Prolonged c-collar usage, especially in the ICU setting, is not without risk. While the incidence of pressure ulceration related to the c-collar has not been well established in children, pressure injuries have been reported in 7-38% of adult trauma patients, pointing to the importance of efficient collar removal when not clinically necessary. (24,25) Additionally, the safety and technical aspects of obtaining a c-spine MRI are not benign. Trauma patients can be very sick making transport to the MRI and the MRI itself not without risk. (26,27) Some children with invasive neuromonitoring or unstable intracranial pressure are not immediately eligible for an MRI and c-collar clearance can be delayed even further. Finally, c-collars can be uncomfortable for patients and may complicate nursing care and given all of these factors, it is incumbent on trauma surgeons to champion early removal of these devices when deemed clinically safe. The clinical implications of our data indicate that clearance of the pediatric c-spine may be safe based on a negative MDCT alone and that additional MRI imaging may be unnecessary. If future data is consistent with our findings, we propose the following algorithm. (Figure 2)

The intention of this article is not to promote the overutilization of MDCT in children, as radiation should be minimized whenever possible. (8) In contrast, we are highlighting that over 50% of our patients underwent c-spine XR, which has been shown to be at least 90% sensitive for detecting clinically significant injuries. (7) We do not intend for providers to use this data as an excuse to overutilize MDCT in pediatric patients. Rather, for children who require MDCT, which are typically those patients with a GCS ≤13 and a significant traumatic mechanism, our data would support cervical clearance with CT imaging alone. Another point that needs to be addressed is our access to pediatric radiologists, as there have been studies that document improved accuracy in interpretation of pediatric c-spine MDCTs by pediatric specialists. (29) Our radiologists interpreted every MDCT in this study, as is our policy, which is important considering that greater than 64% of our patients are transferred in from referring facilities. There are radiologic differences in the pediatric spine that our radiologists are attune to, and their input is important to our trauma system.

This study has several limitations. The impact of the study is limited by the retrospective nature of the review and the potential for bias. Post hoc review of images also has the potential for bias. We do not clearly define which children require imaging, but instead used the presence of imaging as our inclusion criteria. There are children discharged in hard collars without intervention and this group is difficult to define. This treatment is often for patient comfort, but It is possible that some CSIs, such as odontoid fractures, are treated with this nonoperative approach and we may have missed these children in our analysis. Our hospital is the only level I pediatric trauma center in a large geographic area and we are afforded resources such as pediatric radiologists and pediatric spine surgeons that are not available at all institutions. We do not have long term follow-up on these patients. These data represent the experience from a single center, and thus may not be generalizable nationally.

In conclusion, no pediatric CSIs that required operative intervention were missed by MDCT in a large single institutional retrospective review. Furthermore, none of the small number of patients with an abnormal MRI following a normal MDCT had clinically significant CSIs. These data question the utility of routine MRI utilization or waiting for improvement in mental status when a MDCT is negative. Larger multicenter reviews and forthcoming prospective data will clarify best practice for c-spine clearance in children.

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Figure 1: Patient cohort

Figure 2: Proposed algorithm for clearance of the pediatric c-spine

Supplemental Digital Content

SDC 1. STROBE checklist

Figure 1

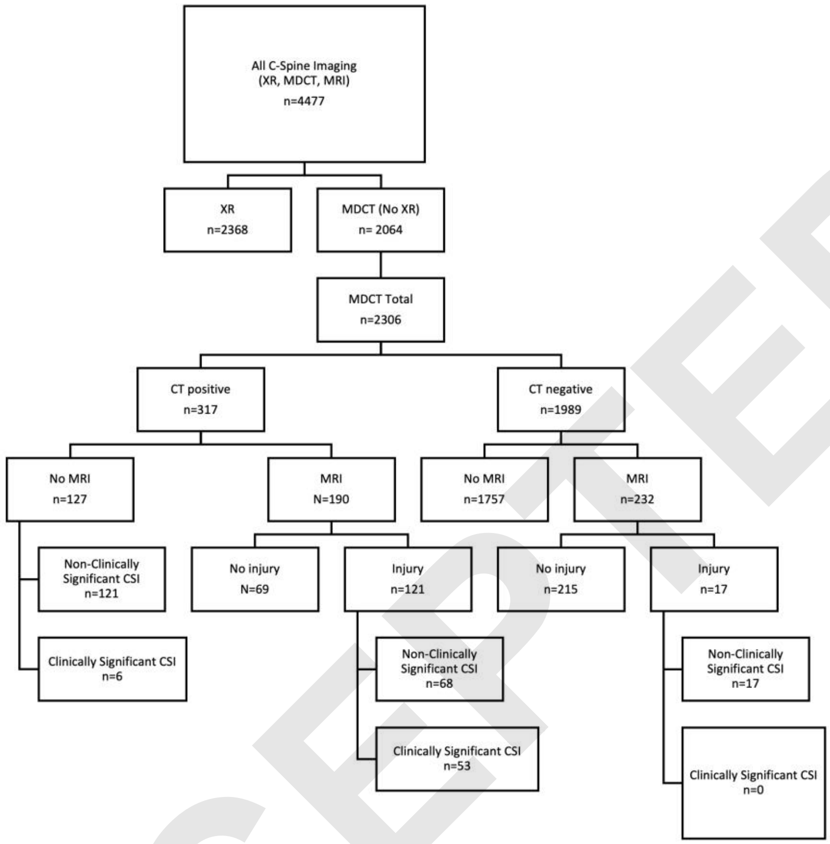
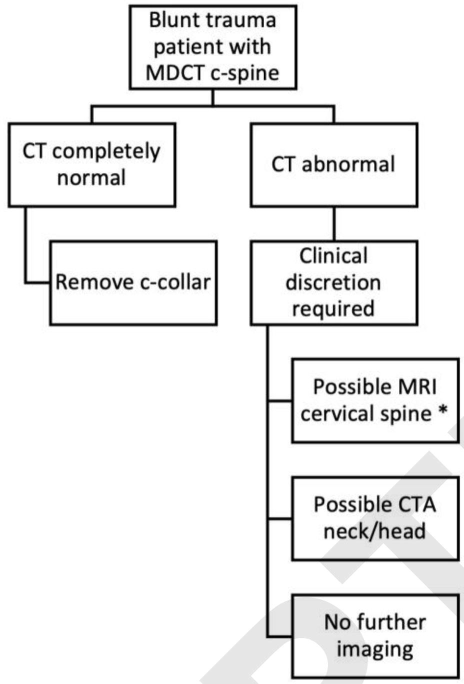

All C-Spine Imaging
(XR, MDCT, MRI)
n=4477
XR
n=2368
MDCT (No XR)
n= 2064
MDCT Total
n=2306
CT positive
n=317
CT negative
n=1989
No MRI
n=127
MRI
N=190
No MRI
n=1757
MRI
n=232
Non-Clinically Significant CSI
n=121
Clinically Significant CSI
n=6
No injury
N=69
Injury
n=121
No injury
n=215
Injury
n=17
Non-Clinically Significant CSI
n=68
Clinically Significant CSI
n=53
Non-Clinically Significant CSI
n=17
Clinically Significant CSI
n=0

Figure 2



Blunt trauma patient with MDCT c-spine
CT completely normal
CT abnormal
Remove c-collar
Clinical discretion required
Possible MRI cervical spine *
Possible CTA neck/head
No further imaging

Table 1: Demographics and injury characteristics of patients with and without clinically significant c-spine injury

	No C-Spine Injury N = 4,417[1]	Clinically Significant C-Spine Injury N = 60[1]	p-value[2]
Age Group			<0.001
<1	466 (11%)	0 (0%)	
1-4	945 (21%)	9 (15%)	
5-9	1,021 (23%)	11 (18%)	
10-14	1,285 (29%)	16 (27%)	
15-17	699 (16%)	24 (40%)	
Sex			0.2
Male	2,745 (62%)	42 (70%)	
Female	1,670 (38%)	18 (30%)	
Race			0.008
White	3,864 (88%)	52 (87%)	
Asian	44 (1.0%)	1 (1.7%)	
Black or African American	82 (1.9%)	1 (1.7%)	
American Indian	57 (1.3%)	2 (3.3%)	
Native Hawaiian or Other Pacific Islander	81 (1.8%)	3 (5.0%)	
Hispanic or Latino	3 (<0.1%)	1 (1.7%)	
Other	5 (0.1%)	0 (0%)	
Unknown	280 (6.3%)	0 (0%)	
Ethnicity			0.4
Not Hispanic or Latino	3,541 (80%)	52 (87%)	
Hispanic or Latino	610 (14%)	7 (12%)	
Not recorded/ Unknown	265 (6.0%)	1 (1.7%)	
Glasgow Coma Scale			0.016
GCS 1-13	849 (19%)	19 (32%)	
GCS 14-15	3,562 (81%)	41 (68%)	
Were they intubated in the trauma bay or prior to arrival?			<0.001
Yes	633 (14%)	20 (33%)	
No	3,783 (86%)	40 (67%)	
Injury Mechanism			
Fall	1,403 (32%)	9 (15%)	
Foreign Body	1 (<0.1%)	0 (0%)	
Gun Shot	19 (0.4%)	0 (0%)	
Hanging	16 (0.4%)	0 (0%)	
Farm or Heavy Equipment	6 (0.1%)	0 (0%)	
Motorcycle Crash	154 (3.5%)	2 (3.3%)	
Motor Vehicle Crash	791 (18%)	27 (45%)	
Other Vehicular (Includes ATV)	402 (9.1%)	3 (5.0%)	
Pedestrian	349 (7.9%)	4 (6.7%)	
Sporting Injury	376 (8.5%)	9 (15%)	

Table 1: Demographics and injury characteristics of patients with and without clinically significant c-spine injury

	No C-Spine Injury N = 4,417[1]	Clinically Significant C-Spine Injury N = 60[1]	p-value[2]
Stab Wound	3 (<0.1%)	0 (0%)	
Struck Against Object	216 (4.9%)	2 (3.3%)	
Caught on Object	10 (0.2%)	0 (0%)	
Diving	2 (<0.1%)	1 (1.7%)	
Child Abuse	118 (2.7%)	0 (0%)	
Assault	46 (1.0%)	0 (0%)	
Bicycle Crash	327 (7.4%)	3 (5.0%)	
Burn	5 (0.1%)	0 (0%)	
Animal	147 (3.3%)	0 (0%)	
Other	16 (0.4%)	0 (0%)	
Unknown	9 (0.2%)	0 (0%)	
Transferred from another hospital?	2,823 (64%)	49 (82%)	0.004

[1] n (%)

[2] Pearson's Chi-squared test; Fisher's exact test

Number	Age	Sex	Initial GCS	Mechanism	MRI Injury	Treatment	Clearance	Stable
1	5.6	M	8	Fall	Probable microtrabecular compression fx C7-T4	Discharged hard collar 2 days	Flex-ex	Y
2	10.3	M	15	MVC	Suspected injury to the apical and alar ligaments, retroclival hematoma	Discharged hard collar 2 weeks	Flex-ex	Y
3	7.9	M	9	MVC	C4-5 interspinous ligament and ligamentum flavum	Discharged hard collar 2 weeks	Left the State	Y
4	12.5	F	15	ATV	Suspected ligamentous strain interspinous ligaments	None	None	Y
5	16.4	F	15	Sports	Edema involving the C5 through C8 right nerve roots	Discharged hard collar 2 weeks	Lost to follow-up	Y
6	4.2	F	3	MVC	Minimal edema within the cervical interspinous and supraspinous ligaments	Discharged hard collar 5 weeks	Lost to follow-up, MRI 3 months and cleared	Y
7	0.8	M	6	NAT	Interspinous ligament stretching injury	Discharged hard collar 4 weeks	Flex-ex	Y
8	15.4	M	3	Horse kick	Edema C1-C2 spinous ligamentous complex	Hard collar 2 weeks, still inpatient	None	Y
9	15.2	F	4	MVC	Mild edema posterior interspinous ligament	Hard collar 1 week, still inpatient	Flex-ex in hospital	Y
10	12.8	M	3	ATV	Edema C3-C5 interspinous ligament	Discharged hard collar 2 weeks	Flex-ex	Y

11	1.5	M	6	NAT	Edema interspinous & nuchal ligaments upper cervical region	None	None	Y
12	6.1	M	3	Fall	Edema interspinous & nuchal ligaments upper cervical region	None	None	Y
13	10.9	F	3	Horse kick	Minimal compression C7	None	None	Y
14	17	M	14	MVC	Bone bruise C2 with possible fx on CT review, chord contusion C4-C5	Discharged hard collar 6 weeks	Left state	Y
15	14.6	M	8	MVC	Edema interspinous ligaments C1-C2, suspected atlantoaxial membrane avulsion	Discharged hard collar 6 weeks	Flex-ex	Y
16	8.6	M	4	MVC	Edema posterior interspinous ligaments upper cervical spine	Discharged hard collar 2 weeks	Flex-ex	Y
17	16.5	M	3	MVC	Edema interspinous ligaments C1-C2, C5-C7	Hard collar 2 weeks, still inpatient	Flex-ex	Y

Table 2: 17 patients with normal CTs that had abnormal MRIs.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8

Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	8
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	NA
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	NA
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA

Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

Visual Abstract

Pediatric Cervical Spine Clearance: A 10-year Evaluation of Multi-Detector Computed Tomography at a Level 1 Pediatric Trauma Center