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Cervical Spine Imaging and Injuries in Young Children with Non-Motor Vehicle Crash-Associated Traumatic Brain Injury

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Abstract

Objectives—To evaluate cervical magnetic resonance imaging (MRI) and computed tomography (CT) practices and cervical spine injuries among young children with non-motor vehicle crash (MVC)-associated traumatic brain injury (TBI).

Methods—We performed a retrospective study of a stratified, systematic random sample of 328 children < 2 years with non-MVC-associated TBI at 4 urban children's hospitals from 2008-2012.

We defined TBI etiology as accidental, indeterminate, or abuse. We reported the proportion, by etiology, who underwent cervical MRI or CT, and had cervical abnormalities identified.

Results—Of children with non-MVC-associated TBI, 39.4% had abusive head trauma (AHT), 52.2% had accidental TBI, and in 8.4% the etiology was indeterminate. Advanced cervical imaging (CT and/or MRI) was obtained in 19.1% of all children with TBI, with 9.3% undergoing MRI and 11.7% undergoing CT. Cervical MRI or CT was performed in 30.9% of children with AHT, 11.7% of accidental TBI, and in 10.7% of indeterminate-cause TBI. Among children imaged by MRI or CT, abnormal cervical findings were found in 22.1%, including 31.3% of children with AHT, 7.1% of children with accidental TBI, and 0% of children with indeterminate-cause TBI. Children with more severe head injuries who underwent cervical imaging were more likely to have cervical injuries.

Conclusions—AHT victims appear to be at increased risk of cervical injuries. Prospective studies are needed to define the risk of cervical injury in children with TBI concerning for AHT and to inform development of imaging guidelines.

Keywords

Traumatic Brain Injury; Child Abuse; Spinal Injuries

Introduction

Despite the common occurrence of pediatric traumatic brain injury (TBI) in young children,¹ we know surprisingly little about co-occurrence of injuries to the cervical spine in this group. Cervical spine injuries include spinal hemorrhages and injuries to the ligaments, vertebrae, and soft tissue of the cervical spine. The anatomy of the developing spine in young children may predispose to certain types or patterns of cervical spine injuries,²⁻⁵ yet reliable clearance of the cervical spine from physical exam alone can be particularly difficult in the young and preverbal child,⁶ especially if symptomatic from intracranial trauma.

In contrast to older children for whom motor vehicle crash (MVC)-associated TBI is common,⁷ abusive head trauma (AHT) and non-MVC-associated injuries are the predominate causes of TBI in young children.^{8,9} We have little information on the percentage of children younger than 2 years of age with non-MVC-associated TBI and concurrent cervical spine injuries. Although there has been increasing awareness in recent years that children with AHT are at particular risk for cervical spine injuries,¹⁰⁻¹² no clear guidelines exist for imaging beyond a lateral cervical plain radiograph among these children.^{13,14} Estimates of the prevalence of cervical spine injuries in victims of AHT who undergo cervical magnetic resonance imaging (MRI) vary widely, ranging from 36-78%.^{10,11,15} These studies are limited by small single-center sample sizes and unexplored selection biases regarding which children were imaged.

Accordingly, the purpose of this study was to: describe cervical imaging practices across 4 urban children's hospitals among children younger than 2 years of age with non-MVC-associated TBI; report cervical imaging findings stratified by injury etiology (abuse,

accidental, and indeterminate) among those children who underwent cervical CT or MRI; and explore potential selection biases in cervical imaging decisions.

Materials and Methods

Our retrospective, descriptive study of cervical spine imaging performance and abnormal imaging findings combined administrative data (from the Pediatric Health Information System [PHIS], which was also used to identify cases) at 4 children's hospitals with data from detailed chart review. IRB approval was obtained at each participating institution.

Pediatric Health Information System

Our study was based on data from PHIS,¹⁶ an administrative dataset managed by the Child Health Corporation of America. PHIS captures International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) diagnosis codes and procedures codes, demographic information, and daily hospital resource utilization. Subjects were first identified in PHIS from the 4 study sites based on ICD-9-CM injury codes after which detailed clinical information was abstracted on chart review from a sample of eligible subjects.

Study Population and Sampling Strategy

Our subjects with TBI were drawn from a larger study that sampled children younger than two years of age who presented to one of 4 participating hospitals that contribute data to PHIS with ICD-9-CM codes for non-MVC-associated injury types that may raise concern for inflicted trauma: fracture (800-29), TBI (803-4, 850-4), internal injury (860-9), burn (940-9), or contusion (920-4). Hospitalizations following birth and readmissions for previously diagnosed injuries were excluded to generate the PHIS Sample (Figure 1). A smaller "Chart Review Sample" was created using stratified, random systematic sampling to ensure adequate representation by age, gender, injury, injury etiology (abuse or non-abuse), and hospital (Figure 1). Sampling weights were assigned to each child to allow for representative hospital-level estimates. Following sampling, each child's PHIS record in the Chart Review Sample was linked to his or her medical record. We then used information obtained by chart abstraction to further limit our cohort to children with TBI, which was defined as an intracranial hemorrhage or parenchymal injury documented within a CT or MRI report.

Data Abstraction and Quality

Chart abstractors at each hospital recorded physical exam findings, initial Glasgow Coma Scale (GCS), imaging performed, the child's disposition after hospitalization, and abnormal imaging reports for each child in the Chart Review Sample. Instructions for chart abstractors were imbedded within data forms and reviewed with all chart abstractors. To ensure data quality, a series of quality checks was performed, including searches for fields with missing data, out of range numerical fields, and cases for which billing codes suggested TBI without corresponding imaging. To assess inter-rater reliability of abstracted data, double data entry was performed on a 10% random sample of the Chart Review Sample. Kappa statistics were calculated for the following key variables: inclusion, skeletal survey results, likelihood of

abuse, spine imaging and head imaging performance and results classified as abnormal or normal by the chart abstractor. The strength of the agreement was measured in the following categories: < 0.20 (poor), 0.21 – 0.40 (fair), 0.41 – 0.60 (moderate), 0.61 – 0.80 (good), and 0.81 – 1.00 (very good).¹⁷

Two authors (MKH, JNW) reviewed radiology reports classified as abnormal by the chart abstractors to characterize radiographic findings of injuries. The primary investigator (JNW) re-reviewed 50% of radiology reports among children with TBI coded by another author (MKH) to ensure consistent coding was used. When questions arose about interpretation of imaging reports, the reports were discussed, and consensus was achieved. In the review of radiology reports, injuries described as probable or definite were categorized as present. Radiology findings described as equivocal or possible were not considered abnormal.

The medical team's documented assessment of etiology was abstracted from each child's medical record. When a child protection team's assessment of etiology was not available, the assessment of the primary team was used. When abuse was considered, the etiology was recorded as definite abuse, likely/probable abuse, indeterminate, likely accident/not abuse, or definite accident/not abuse. For purposes of analysis, the definite and likely categories were collapsed so there were three etiologies: abuse (AHT), indeterminate, and accidental. When abuse was not considered in the differential, the injuries were considered accidental.

Measure of severity of injury

Head injury severity was measured several ways. GCS was either directly abstracted, derived from exam findings, or unable to be determined. Because initial GCS was frequently not documented or derivable, we also quantified head injury severity using the Maximum Abbreviated Injury Scale (MAIS) severity score of the head.¹⁸ MAIS is an ordinal scale of injury severity ranging from minor injury (1) to maximal/untreatable injury (6) for discrete body regions. Each ICD-9-CM code associated with the encounter was mapped to the 1998 version of the Abbreviated Injury Scale (AIS) codes using the ICDMAP-90 software.¹⁹ To ensure use of current severity scores, these codes were then manually re-mapped to the most recent AIS 2005/2008 versions and the ICD-9-CM injury descriptions.¹⁸⁻²⁰ Children with a head MAIS score of 3 or greater were considered to have moderate or severe head injuries.

Study Outcomes

We report on the performance and findings from advanced cervical imaging defined as CT or MRI. Abnormal findings included vertebral injuries (fractures, dislocations, other), extra-axial spinal hemorrhages (subdural, epidural, subarachnoid, unspecified), cord injuries, and ligamentous injuries, and soft tissue injuries with associated hemorrhage. We elected to include these soft tissue injuries in our definition because these injuries may be of forensic importance in children with AHT. While some imaging studies included other regions of the spine, we restricted our assessment of spine injury to the cervical region. Recognizing that MRI is more sensitive for some cervical spine injuries than CT, we elected to report abnormal imaging findings among children who underwent cervical MRI and/or CT. We made this decision due to concern for selection biases in which patients would be selected to

undergo cervical MRI either alone or following an abnormal CT. We explored the implications of these potential selection biases.

Data Analysis

Sampling was performed in SAS 9.3 (SAS Institute Inc; Cary, NC). All additional analyses were performed in Stata 13.1 (StataCorp; College Station, TX). We report unweighted frequencies and report percentages from the weighted sample (weighted percentages). In order to understand whether selection biases played a role in imaging decisions, chi squared tests were performed to identify associations between imaging performance and head injury severity, head injury severity and cervical spine injuries, and to identify associations between abnormal cervical CT findings and performance of MRI.

Results

A total of 21,211 children discharged between 2008 and 2012 were identified with ICD-9-CM injury codes for fracture, TBI, internal injury, burn, or contusion (Figure). From the 19,865 children (PHIS Sample) who remained after application of our exclusion criteria, we sampled 2,027 charts for review (Chart Review Sample; Figure). Upon completion of the chart review, 328 children with TBI met inclusion criteria for this analysis (Final TBI Cohort).

Inter-rater reliability in the Chart Review Sample

Inter-rater reliability was good for spine imaging performed and results classified as normal or abnormal (0.71) and was very good for inclusion criteria ($\kappa=0.89$), skeletal survey results ($\kappa=0.94$), likelihood of abuse ($\kappa=1.0$), and head imaging performed and results classified as normal or abnormal (0.91).

Final TBI Cohort Characteristics

Of the TBI cohort, 39.4% had AHT, 52.2% had accidental TBI, and 8.4% had TBI from indeterminate mechanisms (Table 1). The TBI cohort was predominately less than 6 months of age, male, publicly insured, and white. Of the overall TBI cohort, 99.0% underwent head CT and 33.2% underwent brain MRI (Table 2). Brain MRI was more commonly obtained among children with AHT (62.2%) vs. accidental (8.6%) and indeterminate-cause TBI (50.8%).

In regards to injury severity, 79.1% of the overall cohort had a head MAIS score ≥ 3 . Children with AHT were generally more severely injured than those with accidental injuries. A total of 90.6% of children with AHT had a head MAIS score of 3 or greater, compared to 68.8% of children with accidental mechanisms of TBI (Table 2).

Cervical Spine Imaging Practices

Cervical CT or MRI was obtained in 19.1% of the overall TBI cohort, 30.9% of children with AHT, 11.7% with accidental TBI, and 10.7% of children with indeterminate mechanisms (Table 2). No statistically significant differences were found between the percentage of children with minor head injuries (head MAIS score < 3) who underwent

cervical CT or MRI (14.0%) and those with moderate to severe head injuries (head MAIS score ≥ 3 ; 20.5%) who underwent cervical CT or MRI ($p = 0.41$). There was an association between head injury severity and cervical MRI use. A total of 2.7% of children with minor head injuries and 11% of children of moderate to severe head injuries underwent cervical MRI ($p < 0.01$).

Cervical Spine Injuries detected by CT or MRI

Of those who underwent cervical CT or MRI, 22.1% had an abnormality identified (Table 3). Abnormalities were identified in 31.3% of children with AHT and 7.1% of children with accidental mechanisms. The most common abnormal findings were extra-axial spinal hemorrhages, which occurred in 15.1% of the cervical spine-imaged TBI cohort, 23.2% of the cervical spine-imaged AHT cohort, and 1.3% of the cervical spine-imaged accidental TBI cohort. Ligamentous injuries occurred in 7.4% of the cervical spine-imaged TBI cohort, 8.7% of the cervical spine-imaged AHT cohort, and 5.8% of the cervical spine-imaged accidental TBI cohort. Cervical cord injuries were identified in 3.5% of the cervical spine-imaged TBI cohort, all of whom had AHT. Vertebral injuries occurred in less than one percent of the cervical spine-imaged TBI cohort. Children with abnormal findings on cervical CT were not more likely to also undergo MRI. One-third (32.7%) of children with an abnormal cervical CT also underwent a cervical MRI compared to 15.5% of children with a normal cervical CT who also had cervical MRI ($p = 0.49$), but small sample size limits identification of statistically significant differences.

Head Injury Severity and Cervical Spine Injury

There was an association between abnormal GCS and cervical spine injuries ($p = 0.03$) as well as moderate to severe head injuries (head MAIS score ≥ 3) and cervical spine injuries ($p = 0.02$). Among cervical spine-imaged TBI with a derived or abstracted GCS, 6.7% (95% CI: 1.2, 25.1) with a normal GCS had cervical spine injuries compared to 27.8% (95% CI: 15.0, 45.6) of those with a GCS < 15 . Similarly, in the cervical spine-imaged TBI cohort, 4.7% (95% CI: 0.9, 21.6) with a minor head injury had cervical spine injuries compared to 25.2% (95% CI: 14.5, 40.2) among those with moderate to severe head injuries.

Ligamentous and spinal cord injuries detected by MRI

Given that MRI is the preferred modality for the identification of ligamentous and spinal cord injuries²¹ and that prior studies have focused exclusively on MRI, we calculated the percentage of ligamentous and spinal cord injuries detected among children who underwent cervical MRI to permit valid comparisons across studies. Of the 59 children in the cervical spine-imaged TBI cohort who underwent MRI, 15.3% (95% CI: 7.0, 30.3) had ligamentous injuries. Of the 52 children in the cervical spine-imaged AHT cohort who underwent MRI, 13.4% (95% CI: 5.7, 28.2) were found to have ligamentous injuries. Ligamentous injuries were detected in 26.6% (95% CI: 4.1, 75.6) of the 7 children with accidental TBI who underwent cervical MRI. Among children who underwent cervical MRI, cord injuries were detected in 7.2% (95% CI: 1.3, 31.5) with TBI and in 8.5% (95% CI: 1.5, 35.3) of children with AHT.

Discussion

In this multicenter retrospective study of 91 young children with non-MVC-associated TBI who underwent cervical CT or MRI, we demonstrated that abnormal cervical findings are found in 22.1% percent of children TBI and 31.3% of children with AHT. If we were to assume that all those who were not imaged did not have cervical abnormalities, 4.2% of the entire cohort of children with TBI and 9.6% of children with AHT, and 0.8% of children with accidental TBI would be expected to have abnormal findings. In this context, the finding that nearly 1 in 10 children with AHT imaged under the above assumptions would have an abnormal finding suggests that advanced cervical imaging should be more commonly used, though additional research is needed to clarify which children with AHT would benefit most from imaging.

Our study detected fewer injuries, and in particular fewer ligamentous injuries, than prior work. A retrospective cohort of 74 children younger than 36 months of age undergoing evaluation for AHT detected cervical spine injuries in 36% of children.¹⁰ These injuries were reported as most commonly ligamentous. A separate retrospective cohort detected ligamentous injuries in 78% of the 67 children with AHT younger than 48 months of age who underwent cervical MRI.¹¹ In a retrospective review of 89 children younger than 5 years of age hospitalized with non-accidental trauma, cervical ligamentous injuries were detected in 67% percent of patients.¹⁵ A study of 91 children imaged via MRI with non-accidental trauma, many of whom had head injury, detected cervical spine abnormalities in 30.8%, and 14.3% of these 91 children had ligamentous injuries.²² A recent prospective cohort study of 53 children less than 36 months of age with inflicted head trauma identified cervical spine injuries in 15.1 percent of children; 2 of the 53 children had ligamentous injury.²³ By comparison, we detected ligamentous injuries in 8.7% of children with AHT. Because ligamentous injuries are not detected on CT, one could hypothesize that our inclusion of both children who underwent CT and/or MRI in the denominator falsely lowered these estimates. When we focused just on children who underwent MRI, however, these estimates only rose to 13.4%. If the most common injury in the first study mentioned above was ligamentous injuries,¹⁰ the upper limit of the confidence interval of the 13.4% (95% CI: 5.7, 28.2) of children with AHT in our study may not be significantly different. Our finding, however, is far below the estimates of 67%¹⁵ and 78%.¹¹ Sample sizes are small across these studies, including our cohort, so the confidence intervals would likely be large and complicate comparisons of point estimates. These studies do not provide data on injury severity, so we are unable to determine if injury severity varies across study populations and whether certain centers were more likely to image more severely injured children. Variation in interpretations of imaging findings, such as determination of whether an injury is definite or probable, may account for some differences across studies. Our sensitivity analyses also demonstrated that exclusion of possible injuries did not significantly raise our estimates, though these analyses are limited by wide confidence intervals.

The most common abnormal findings in this study were cervical spine extra-axial hemorrhages; the clinical significance of this finding is unknown in this cohort. Prior work has demonstrated that cervical spine subdural hematomas (cervical only or cervicothoracolumbar) were present in 11 of 63 children with AHT who underwent cervical

MRI or CT.²⁴ Whether these spinal hemorrhages derive from extension of blood from an intracranial hemorrhage or a separate spinal injury is debated.²⁴ We could not reliably extrapolate from radiology reports whether these spinal hemorrhages were of clinical significance nor could we clarify whether they were contiguous with intracranial hemorrhages.

Strengths of our study include the multicenter design and detailed chart review, but our study has limitations that warrant discussion. First, we relied on radiology reports generated for purposes of clinical care and were unable to pursue measures of inter-rater reliability between radiologists within and across centers. These radiologists were not blinded to the concerns of the team or other imaging results, which could introduce bias in their interpretations. The medical team was also not blinded to the spinal imaging findings. The knowledge of these findings could influence determination of injury etiology and introduce circular reasoning in our injury classification of accidental or abuse. Second, we are also limited by our ability to describe potential clinical concern for cervical spine injury and clinical indicators of spinal trauma. Clinical exam findings concerning for spinal trauma were not abstracted from the chart. Initial GCS was not reliably documented in the charts so we elected to additionally use a commonly used billing code-derived metric of head injury severity, which relies on ICD-9-CM codes gathered at the end of an admission. Therefore, this score may not represent injuries known at the time cervical imaging decisions are being made. Third, our ability to determine statistically significant differences between groups is limited by our sample size of 91 children who underwent cervical imaging. Fourth, this was a retrospective chart review and therefore limited by selection biases. We know from prior work that children with more severe TBI are more likely to undergo advanced cervical imaging⁹ which is consistent with our association between head injury severity and performance of cervical MRI. Observational studies reporting injuries among children imaged by cervical MRI should therefore be interpreted with this caveat. Lastly, due to concern for these selection biases we elected to report the imaging findings among children who underwent either cervical CT or MRI. Because we recognize MRI is more sensitive for certain findings, we also reported yield among children who underwent MRI.

These limitations notwithstanding, our study's finding of relatively high rates of cervical spine injury in children with AHT is important. Current cervical spine imaging recommendations are limited to children younger than 2 years of age with concerns for abusive injuries and include a lateral cervical plain radiograph as part of a complete skeletal survey.^{13,14} MRI has been found to detect injuries missed by plain radiography in pediatric trauma victims with suspected spinal injuries in 23% of cases.²⁵ Our study demonstrates that vertebral injuries and dislocations are rare, so plain radiography could miss certain findings among children with intracranial injuries and concern for AHT, yet no formal recommendations exist as to the use of cervical CT or MRI in this high risk population. In addition, a finding of a cervical injury in the absence of a reported history of trauma may be of forensic importance by supporting a diagnosis of non-accidental trauma. Cervical spine injuries, however, are not pathognomonic for AHT nor are such injuries required for a diagnosis of AHT. Our findings suggest that prospective studies are needed to avoid selection biases to define which children benefit most from advanced cervical imaging and

whether the injuries detected influence the clinical care of the child and the medical team's abuse determination.

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Abbreviations

AHT	Abusive Head Trauma
CT	Computed Tomography
GCS	Glasgow Coma Scale
ICD-9-CM	International Classification of Diseases, 9 th revision, Clinical Modification
MRI	Magnetic Resonance Imaging
MVCs	Motor Vehicle Crashes
OR	Odds Ratio
PHIS	Pediatric Health Information System
TBI	Traumatic Brain Injury

Figure 1.

Flow diagram and generation of cohort, Abbreviations: TBI: Traumatic Brain Injury; MVCs: Motor Vehicle Crashes; PHIS: Pediatric Health Information System

Table 1
Demographic characteristics of Final TBI Cohort

	TBI Cohort (%) <i>N</i> = 328	AHT (%) <i>N</i> = 233	Accidental (%) <i>N</i> = 77	Indeterminate (%) <i>N</i> = 18
Age				
< 6 mo	60.3	62.1	63.2	34.4
6 mo - < 12 mo	20.6	15.1	23.1	31.1
12 mo - < 18 mo	11.0	15.7	6.1	19.2
18 mo - < 24 mo	8.0	7.1	7.6	15.3
Sex				
Female	35.7	38.8	31.9	45.2
Male	64.3	61.2	68.1	54.8
Payer Type				
Private	43.0	27.0	54.4	47.7
Public/Uninsured	57.0	73.0	45.6	52.3
Race				
White	66.9	56.1	79.9	36.7
Black	14.0	16.4	8.4	37.0
Other	19.1	27.5	11.7	26.2

Abbreviations: TBI: Traumatic Brain Injury; mo: Month; AHT: Abusive Head Trauma

The first column displays the percentage with each characteristic in the total weighted sample. The second, third, and fourth columns display the same information within weighted subgroups as indicated. All column totals are unweighted.

Table 2
Brain imaging, intracranial injuries, and severity of injury of cohort

		TBI Cohort (%)* <i>N = 328</i>	AHT (%)* <i>N = 233</i>	Accidental (%)* <i>N = 77</i>	Indeterminate (%)* <i>N = 18</i>
Brain Imaging					
	CT	99.0 (95.6, 99.8)	99.3 (97.1, 99.8)	100	91.1 (56.5, 98.8)
	MRI	33.2 (27.1, 40.0)	62.2 (52.4, 71.0)	8.6 (4.1, 16.9)	50.8 (23.5, 77.6)
Intracranial Injuries					
	Subdural hemorrhage	53.6 (45.5, 61.5)	87.2 (77.9, 92.9)	28.7 (19.2, 40.5)	51.3 (24.0, 77.9)
	Subarachnoid hemorrhage	28.9 (22.2, 36.8)	18.3 (13.0, 25.0)	40.2 (28.7, 52.9)	9.1 (1.3, 43.9)
	Epidural hemorrhage	9.1 (4.9, 16.2)	0.9 (0.2, 4.3)	13.9 (7.0, 25.8)	17.1 (3.0, 57.5)
	Extra-axial hemorrhage, unspecified	12.2 (7.5, 19.3)	5.0 (2.1, 11.2)	18.0 (10.0, 30.3)	10.5 (2.3, 36.0)
	Intraventricular hemorrhage	4.9 (2.7, 8.8)	8.1 (3.9, 15.9)	2.4 (0.7, 8.3)	6.0 (1.2, 25.0)
	Parenchymal contusion or hemorrhage	13.3 (5.6, 20.2)	14.6 (8.6, 23.6)	14.5 (7.4, 26.5)	0
	Ischemic injury	8.9 (6.7, 11.9)	20.6 (15.5, 26.8)	1.1 (0.3, 4.1)	2.8 (0.6, 12.9)
MAIS Head					
	0 or incalculable	4.8 (2.1, 10.6)	4.8 (1.5, 14.6)	4.8 (1.3, 16.0)	4.5 (1.2, 15.3)
	1	1.4 (0.4, 5.0)	0.4 (0.1, 2.5)	2.5 (0.6, 9.5)	0
	2	14.7 (9.5, 22.1)	4.2 (1.5, 11.0)	24.0 (14.8, 36.5)	6.6 (0.9, 35.5)
	3	76.4 (68.5, 82.9)	88.0 (78.4, 93.7)	65.7 (52.8, 76.6)	89.0 (66.0, 97.1)
	4	2.1 (0.7, 6.2)	1.8 (0.3, 11.8)	2.6 (0.6, 9.7)	0
	5	0.6 (0.2, 1.9)	0.7 (0.2, 2.5)	0.6 (0.1, 4.0)	0
	6	0	0	0	0
Glasgow Coma Scale					
	Not performed or derived	37.8 (30.3, 45.9)	40.9 (32.1, 50.2)	33.9 (22.9, 47.1)	47.4 (21.2, 75.2)
	15	37.8 (30.4, 45.7)	26.4 (19.3, 35.0)	45.0 (33.1, 57.5)	46.5 (20.3, 74.7)
	<15	24.4 (18.8, 31.2)	32.7 (25.7, 40.7)	21.1 (12.6, 33.2)	6.1 (1.6, 21.2)
Cervical Spine Imaging					
	CT	11.7 (7.8, 17.3)	14.4 (9.1, 22.1)	9.8 (4.7, 19.6)	10.7 (2.5, 35.3)
	MRI	9.3 (6.6, 12.9)	20.1 (14.3, 27.6)	2.6 (1.1, 5.9)	0
	CT and MRI	1.9 (1.0, 3.5)	3.7 (1.8, 7.5)	0.7 (0.2, 2.5)	0
	CT or MRI	19.1 (14.3, 25.1)	30.9 (23.4, 39.5)	11.7 (6.1, 21.2)	10.7 (2.5, 35.3)

Abbreviations: TBI: Traumatic Brain Injury; AHT: Abusive Head Trauma; CT: Computed Tomography; MRI: Magnetic Resonance Imaging; MAIS: Maximum Abbreviated Injury Scale

The first column displays the percentage with each characteristic in the total weighted sample with 95% confidence intervals. The second, third, and fourth columns display the same information within weighted subgroups as indicated. All column totals are unweighted. Weighted percentages are listed with 95% confidence intervals. Because percentages represent weighted samples, they cannot be used to extrapolate unweighted Ns.

Table 3
Abnormal findings among children who underwent cervical MRI or CT*

	Cervical spine-imaged TBI (%) [#] <i>N</i> = 91	Cervical spine-imaged AHT(%) [#] <i>N</i> = 74	Cervical spine-imaged Accidental TBI (%) [#] <i>N</i> = 14
<u>Abnormal cervical findings</u>			
Any cervical injury	22.1 (12.7, 35.6)	31.3 (18.3, 48.0)	7.1 (1.2, 31.5)
Vertebral (dislocation, fracture, other)	0.7 (0.2, 2.9)	1.1 (0.3, 4.6)	—
Cord injury	3.5 (0.6, 17.5)	5.5 (1.0, 25.5)	—
Extra-axial spinal hemorrhage	15.1 (7.3, 28.6)	23.2 (11.6, 40.9)	1.3 (0.2, 9.5)
Ligamentous injury	7.4 (3.2, 15.9)	8.7 (3.7, 19.2)	5.8 (0.8, 33.2)
Soft tissue injury with hemorrhage	0.7 (0.2, 3.0)	1.2 (0.3, 4.6)	—

Abbreviations: TBI: Traumatic Brain Injury; AHT: Abusive Head Trauma

The first column displays the percentage with each characteristic in the total weighted sample with 95% confidence intervals. The second and third columns display the same information within weighted subgroups as indicated. All column totals are unweighted.

* No injuries were identified in the indeterminate group

[#] Weighted percentages are listed with 95% confidence intervals. Because percentages represent weighted samples, they cannot be used to extrapolate unweighted Ns.