Clinical Clearance of the Cervical Spine in Blunt Trauma Patients Younger Than 3 Years: A Multi-Center Study of the American Association for the Surgery of Trauma

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Background: Cervical spine clearance in the very young child is challenging. Radiographic imaging to diagnose cervical spine injuries (CSI) even in the absence of clinical findings is common, raising concerns about radiation exposure and imaging-related complications. We examined whether simple clinical criteria can be used to safely rule out CSI in patients younger than 3 years.

Methods: The trauma registries from 22 level I or II trauma centers were reviewed for the 10-year period (January 1995 to January 2005). Blunt trauma patients younger than 3 years were identified. The measured outcome was CSI. Independent predictors of CSI were identified by univariate and multivariate analysis. A weighted score was calculated by assigning 1, 2, or 3 points to each independent predictor according to its magnitude of effect. The score was established on two thirds of the population and validated using the remaining one third.

Results: Of 12,537 patients younger than 3 years, CSI was identified in 83 patients (0.66%), eight had spinal cord injury. Four independent predictors of CSI were identified: Glasgow Coma Score $<$14, $GCS_{EYE} = 1$, motor vehicle crash, and age 2 years or older. A score of $<$2 had a negative predictive value of 99.93% in ruling out CSI. A total of 8,707 patients (69.5% of all patients) had a score of $<$2 and were eligible for cervical spine clearance without imaging. There were no missed CSI in this study.

Conclusions: CSI in patients younger than 3 years is uncommon. Four simple clinical predictors can be used in conjunction to the physical examination to substantially reduce the use of radiographic imaging in this patient population.

Key Words: Pediatric trauma, Cervical spine injury, Clinical decision rules, Outcomes.

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Cervical spine injuries (CSI) in blunt trauma pediatric patients are uncommon and reported to occur in <2% of seriously injured children.[1–4] Despite this low incidence, the potentially devastating consequences of a missed CSI in children coupled with the common belief that the physical examination is unreliable in patients younger than 3 years has prompted many clinicians to rely on radiographic imaging to exclude CSI. However, imaging-related short- and long-term morbidity, resource consumption, and cost have raised concerns about the liberal use of plain films, computed tomography (CT) scan, and magnetic resonance imaging (MRI) in these children. Sedation, which is often used in this population to allow completion of advanced imaging (e.g., CT and MRI), may result in overmedication, aspiration, and intubation.[5–7] The risk of fatal and nonfatal cancers associated with CT-related radiation is gaining increasing attention.[8–12] The published evidence indicates that CT in the pediatric population is not an innocuous diagnostic procedure, and as a result, both the US Food and Drug Administration Center for Devices and Radiologic Health and the National Cancer Institute have published guidelines designed to limit unnecessary imaging in children.[13,14]

Two seminal studies (NEXUS[15] and Canadian Cervical Spine Rules[16]) have used clinical criteria (absence of neurologic deficit, cervical spine tenderness, intoxication, decreased mental status, or distracting injuries) to rule out CSI in adults without the need for imaging. These criteria have been applied to pediatric patients but because of the low number of infants and toddlers included, the validity of the criteria in the very young pediatric population remains unknown.[17–21] Many clinicians resort to routine imaging for the evaluation of CSI in this age group.

Our study targets pediatric blunt trauma patients younger than 3 years and aims to identify clinical criteria that can safely exclude CSI without the need for imaging. Our hypothesis is that CSI is a rare injury in this group, and simple clinical criteria can be used at the bedside to clear the cervical spine of these patients. To amass an adequate sample size for statistically meaningful conclusions, data from 22 trauma centers treating children were analyzed.

METHODS

Population

After individual Institutional Review Board approval, the trauma registries of 22 institutions were reviewed for patients younger than 3 years who sustained blunt trauma during a 10-year period (January 1, 1995, to January 1, 2005). The participating institutions were located in the United States,[19] Canada,[2] and Brazil.[1] There were 15 pediatric level I, 6 adult level I, and 1 adult level II trauma centers, caring for pediatric patients. Patients older than the 36th month of age were excluded. There was no universal protocol for the clearance of the cervical spine in the participating institutions; 5 centers predominantly cleared the spine on the basis of physical examination, 6 depended on plain films and reserved CT imaging only for selected cases, whereas the remaining 11 used CT liberally.

Data and Outcome Measures

Data collected from the trauma registries included: age, gender, mechanism of injury (motor vehicle crash [MVC], fall, assault, and other), Injury Severity Score, Abbreviated Injury Score for head and neck, Abbreviated Injury Score face, paralysis, Glasgow Coma Score (GCS), and its three elements (GCS_{EYE}, GCS_{VERBAL}, and GCS_{MOTOR}), imaging, and mortality. The outcome was CSI, defined by any osseous or ligamentous injury to the cervical spine seen on CT, radiograph, or MRI. For patients with CSI, the medical records were reviewed and the following additional data were collected: exact circumstances of injury and presentation, physical findings on arrival, diagnostic tests, type of injury (ligamentous or fracture), and treatment to the cervical spine rendered.

Statistical Analysis

The sample was randomly split into two data sets: two thirds of the sample was used to identify the clinical predictors of CSI to develop a scoring algorithm (evaluation set) and the remaining one third to validate the algorithm (validation set). Patients with and without CSI were compared using χ^2 tests for categorical variables and Wilcoxon rank sum tests for continuous variables. Variables with a univariate $p < 0.2$ were included in a multivariable logistic regression analysis to identify independent predictors of CSI using the evaluation set data. The significant predictors in the final model were then used to establish a weighted score (WS) according to their effect sizes. The WS was created by giving each predictor 1, 2, or 3 points and then adding all the points. After this, the WS was validated in the remaining one third of the sample. Patients who had a CSI that was not predicted by the WS were examined in detail. Statistical significance was set at $p < 0.05$ for all comparisons.

RESULTS

Within the study period, a total of 12,882 pediatric blunt trauma patients younger than 3 years of age were encountered. From this group, 345 patients were excluded because they died immediately upon presentation to the emergency department and had no clinical or radiographic assessment of the cervical spine. Of the remaining 12,537 patients, 83 confirmed CSI patients (0.66%) were identified. Plain radiographs (two- or three-views) were obtained in 4,046 patients (32.3%), CT in 3,358 (30.6%), and MRI in 478 (3.8%). The 83 patients with CSI were indentified by plain films and CT. For every patient with a CSI identified, another 40 patients underwent a CT that failed to demonstrate an injury. Thirty CSI patients died after initial evaluation (35.7% of CSI population) but none because of a missed CSI injury or its related treatment. The use of cervical spine CT varied according to the type of trauma center (Table 1).

Independent Predictors and WS

The comparison of CSI and no-CSI patients is shown in Table 2. The two patient populations were significantly different in terms of age, mechanism of injury, Injury Severity Score, GCS, GCS_{EYE}, GCS_{VERBAL}, and GCS_{MOTOR}. Multiple logistic regression analysis using the evaluation data set identified four independent predictors of CSI: GCS <14,

TABLE 1. Use of Cervical Spine Computed Tomography According to the Type of Trauma Center

	CT Performed n (%)	p	Relative Risk	95% CI
Level I Pediatric Trauma Center in pediatric hospital (n = 5155)	900 (17.5)			
Level I Pediatric Trauma Center in adult hospital (n = 3174)	1210 (38.0)	<0.0001*	2.2	2.0, 2.4
Level I Adult Trauma Center (n = 5096)	1222 (24.0)	<0.0001*	1.3	1.2, 1.5
Level II Adult Trauma Center (n = 57)	26 (45.6)	<0.0001†	1.9	1.4, 2.5

Values are frequencies with percentages in parentheses * compared with level I Stand Alone Pediatric Facility † compared level II Adult Facility and level I Adult Facility * and † represent χ^2 analysis.

TABLE 2. Comparison of Patients With and Without a Cervical Spine Injury

	No CSI, N = 12449	CSI, N = 83	p
Age (mo)	(7–24)	(11–28.5)	0.013
Male (%)	7409 (59.5)	54 (61.4)	0.66
GCS_{EYE}	4 (4–4)	1 (1–4)	<0.001
GCS_{VERBAL}	5 (5–5)	2 (1–4)	<0.001
GCS_{MOTOR}	6 (6–6)	1 (1–5)	<0.001
GCS	15 (15–15)	3.5 (3–13)	<0.001
ISS	4 (2–9)	25.5 (16–42)	<0.001
MVC (%)	2620 (21)	50 (56)	<0.001
Fall (%)	6175 (49.6)	14 (15.9)	<0.001
Abuse (%)	1238 (9.9)	7 (8.0)	<0.001
Other (%)	2319 (18.6)	17 (19.3)	<0.001

Values are medians with interquartiles or frequencies with percentages.
ISS, Injury Severity Scale.

TABLE 3. Independent Predictors of Cervical Spine Injury

Variable	Odds Ratio	95% CI	p
GCS ≥14	12.5	5.0–31.6	<0.001
MVC	5.1	2.8–9.0	<0.001
GCS_{EYE} = 1	6.9	3.4–14.2	<0.001
Age >2 yr	2.2	1.2–4.0	<0.001

GCS_{EYE} =1, MVC, and age 2 years or older (24–36 months) (Table 3). The c statistic for the model was 0.92, indicating excellent model fit. On the basis of the magnitude of the effect of each predictor, we established the WS by giving three points to GCS <14, 2 points to GCS_{EYE}=1 and to MVC, and 1 point to age 2 years or older. The prevalence of CSI was 0.07% among those with a score of 0 or 1 (4 of 5,780) and 21% with a score of 7 or 8 (22 of 107) (Table 4). When the WS was validated against the remaining one third of patient data, the distribution was quite similar: the prevalence of CSI was 0.07% among those with a score of 0 or 1 (2 of 2,927) and 20% when the score was 7 or 8 (11 of 54) (Table 4).

Overall, a score of 0 or 1 had a negative predictive value of 99.93 (95% confidence interval [CI], 99.85–99.97%), a sensitivity of 92.9% (95% CI, 85.1–97.3%), and a specificity of 69.9% (95% CI, 69.1–70.7%). A total of 8,707 patients (69.5% of the entire population) had a score of 0 or 1 and could have been ruled out for CSI without any imaging.

TABLE 4. Presence of Potentially Clinically Significant Cervical Spine Injury According to a Weighted Score of 0 to 8

Weighted Score	Evaluation Set (2/3 of Sample)		Validation Set (1/3 of Sample)	
	N	CSI (%)	N	CSI
0	4,947	2 (0.1)	2,514	1 (0.0)
1	833	1 (0.1)	413	1 (0.2)
2	1,155	3 (0.3)	556	2 (0.4)
3	781	3 (0.4)	379	5 (1.3)
4	90	1 (1.1)	39	1 (2.6)
5	341	15 (4.4)	178	7 (3.9)
6	100	6 (6.0)	46	2 (4.3)
7	81	12 (14.8)	42	8 (19.0)
8	26	10 (38.5)	12	3 (25.0)

Outliers

Five patients with a score <2 had a clinically important CSI (Table 5). Of these five patients, two presented with neck splinting and the remaining three had evidence of facial or skull fractures on examination or had a documented loss of consciousness. In addition, two of these patients had concomitant long bone fracture. Due to the constellation of injuries or symptoms that portended a neck injury, all five patients underwent CT and their CSI was identified and treated promptly.

DISCUSSION

Each year, over 20,000 toddlers are evaluated in emergency departments across North America for blunt trauma.[3] Despite a low incidence of CSI in this patient population, the issue of a missed cervical spine injury remains of major concern to clinicians who treat these children, and the tendency to image the cervical spine is routine.

This manuscript reveals several important insights into the management of patients younger than 3 years with possible cervical spine trauma. First, the data show that the incidence of post-traumatic CSI in this age group is quite low, with only 0.66% of the study population suffering a traumatic osseous or ligamentous injury. Second, these injuries were identified with the relatively liberal use of radiographic screening studies (32.3% of patients had plain X-rays, 30.6% had CT scans, and 3.8% had MRI) at the participating institutions. However, it is clear that less imaging was done at pediatric trauma centers compared with adult trauma centers or adult centers with pediatric designation. Approximately one third of the patients in this study did not undergo imaging

TABLE 5. Characteristics of Five Patients With a Cervical Spine Injury Despite a WS of 0 or 1

Patient	WS	Age (mo)	Mechanism of Injury	GCS	ISS	Injury and Intervention	Clinical Findings
1	0	7	Fall off bed	15	16	C3/4 subluxation—hard collar	LOC, FF, SDH, SAH
2	0	18	Fall off shelf	15	10	C2/3 subluxation—orthosis	LOC, SF
3	0	10	Fall (unspecified)	15	5	C2 fracture—minerva brace	NS
4	1	29	Rotational injury	15	4	C2/3 subluxation—hard collar	NS
5	1	30	Fall (unspecified)	15	14	C3 fracture—hard collar	FF, DAI

LOC, loss of consciousness; FF, facial fracture; SAH, subarachnoid hematoma; SDH, subdural hematoma; SF, skull fracture; NS, neck splinting; DAI, diffuse axonal injury.

and their cervical spines were clinically cleared. Interestingly, most patients who were cleared without imaging were evaluated in level I pediatric trauma centers.

Third, using multiple logistic regression analysis on two thirds of the study population, four independent clinical predictors of CSI in patients younger than 3 years were identified: GCS $<$14 (3 points), $GCS_{EYE} = 1$ (2 points), MVC (2 points), and age 2 years or older (25–36 months; 1 point). These predictors were then validated with the remaining one third of patients, yielding a WS system using clinical predictors that ranged from 0 to 8. Importantly, a score of 0 or 1 on the WS had a negative predictive value of 99.93% in ruling out CSI in the study population, thereby providing clinicians a valuable clinical tool to use in conjunction with the physical examination as they manage CSI in patients younger than 3 years after trauma.

The well-known multicenter NEXUS study, published in 1998 and designed to investigate the necessity of imaging the cervical spine in blunt trauma patients, identified five clinical parameters, which allowed the cervical spine to be cleared in the post-traumatic setting without an X-ray: normal mental status, lack of midline cervical tenderness, normal neurologic examination, lack of intoxication, and absence of a painful, distracting injury.[15] The negative predictive value for a CSI in an adult with these findings was 99.4%. A similar multicenter study from Canada confirmed the validity of the NEXUS criteria.[16] However, it also included tenderness during active rotation of the neck as an additional parameter.[16] The negative predictive value of the combination of all criteria in the Canadian study was 100%. Despite these negative prediction rates, 16 patients were missed in the NEXUS study and 1 in the Cervical Spine Rules study, indicating that no perfect rule exists.

Previous studies regarding pediatric CSI have reported low numbers of injuries in young children. For example, Viccellio et al.[21] evaluated 3,065 blunt trauma patients younger than 18 years of age and identified 603 (19.6%) "low-risk" patients in whom imaging could have been avoided. This study described 30 patients with CSI, but only four of the 30 were younger than 9 years of age and none were younger than 2 years of age.[21] In another retrospective review of 206 pediatric patients (from birth to 16 years of age), Jaffe et al.[19] suggested that the absence of eight clinical criteria (neck pain, neck tenderness, abnormal reflexes, weakness, sensory deficit, direct trauma to the neck, limitation of neck mobility, and abnormal mental status) enabled a clinician to detect cervical spine injury in children with a sensitivity of 98% and a specificity of 54%. There were few patients younger than 3 years in this study and none had a CSI. Other studies added a high-risk mechanism of injury, the presence of closed head injury, or a painful distracting injury to the earlier criteria and brought the reported negative predictive value to 100%.[22,23] Again, there were few young children included in the previous studies and no conclusions were made regarding management this vulnerable group of patients.

An important topic, previously alluded to, concerns the harmful effects of radiation exposure during imaging for trauma in children. Although the benefits of efficient clinical imaging in the pediatric trauma evaluation have been well described, it is generally believed that the practice of liberal imaging presents considerable risks to children and should be applied judiciously, especially in children with rapidly growing and metabolically robust tissues. Kim et al.[24] have reported that 97% of ionizing radiation exposure in pediatric trauma patients was due to CT scanning. Several authors have suggested a potential risk of fatal cancers to be as high as 1 in 1,000 patients undergoing CT.[25,26] In a response to the growing concerns of radiation exposure risks in children, both the US Food and Drug Administration Center for Devices and Radiologic Health and the National Cancer Institute have published guidelines designed to limit unnecessary imaging in children.[13,14]

In addition to the risk of ionizing radiation, other safety concerns are raised with indiscriminant imaging in children. For example, it is frequently necessary to sedate patients younger than 3 years to obtain a clinically interpretable CT or MRI. Complication rates from imaging-related sedation have been reported.[5,7] For instance, the authors of one study, evaluating the effectiveness of pentobarbital for sedation of pediatric patients undergoing CT, found that of 149 cases, 36 complications occurred in 22 sedated patients.[27] Furthermore, even if technically adequate CT images are obtained, their interpretation may be challenging because of the well-known anatomic differences seen in children. These include, but are not limited to, pseudosubluxation of C2–C3, absence of lordosis, C3 vertebral wedging, widening of the atlanto-dental interval, prevertebral soft-tissue widening, intervertebral widening, and pseudo–Jefferson fracture.[28,29] In fact, several studies document that helical CT scans, which have a sensitivity of 97% to 100% in identifying CSI in adults, are reported to be only 81% to 100% sensitive in children.[30–34] This information must be taken into consideration when one realizes that the most common CSI in the very young child, ligamentous injury, may go completely undetected by CT imaging. Clearly, the diminished use of CT imaging in the trauma setting would benefit pediatric patients on several levels. It would serve the threefold purpose of decreasing radiation exposure, sedation administration, and the number of potentially misinterpreted studies.

Finally, there is no debate that the cost and resource consumption for radiographic imaging in trauma is significant.[35] Although proponents of liberal imaging argue that a single missed CSI may cost more than multiple diagnostic tests, the use of nonevidence-based decision making and the ordering of unnecessary tests constitutes defensive and, therefore, suboptimal practice with an undefined risk-benefit ratio. Therefore, there is an obvious need to establish criteria that allow the rational use of imaging tests for the evaluation of the cervical spine of patients younger than 3 years.

In light of previous work, our study focuses solely on clearing the cervical spine after trauma in patients younger than 3 years. After a traumatic injury, these patients may require imaging because of an unreliable or unobtainable clinical examination. At the same time, these are the patients that are most likely to be harmed by unnecessary irradiation, transportation, sedation, and contrast administration. We identified simple clinical predictors which could be used to rule out CSI in the majority of patients younger than 3 years at the bedside. Our WS, developed by using the magnitude of effect of the four independent predictors (GCS <14, $GCS_{EYE} = 1$, MVC, age 2 years or older), offered an escalating probability for CSI as the score increased. A score of 0 or 1 predicted correctly the absence of CSI with a 99.93% negative predictive value, which is equivalent to the negative predictive value of standard cross-sectional imaging in this population[16,21,36–44] (Table 6). Therefore, it is as likely to miss a clinically important injury in a patient with a score of 0 or 1 depending only on physical findings as it is depending only on radiographic imaging. There were no missed injuries in this study. Furthermore, 8,738 (68%) of patients could have had their cervical spine cleared based on this scoring system alone.

TABLE 6. Sensitivity, Specificity, and Predictive Values of Clinical Criteria for Clearance of the Cervical Spine According to Major Previous Studies and the Current One

Study	Year	Age Group (yr)	Sensitivity (%)	Specificity (%)	NPV (%)
PEDSPINE	2009	<3	92.9	69.9	99.9
Diaz et al.[39]	2005	All	32	NA	78
Brohi et al.[38]	2005	>16	98.1	98.8	99.7
Sanchez et al.[44]	2005	All	99	100	99
Holmes and Akkinepalli[42]	2005	All	98	NA	NA
Dickinson et al.[40]	2004	>18	92.7	37.8	N/A
Stiell et al.[16]	2003	>16	99.4	45.1	100
Holmes et al.[43]	2002	All	81	NA	NA
Viccellio et al.[21]	2001	<18	90.7	36.8	99.4
Hoffman et al.[41]	2000	All	99	12.9	99.8
Berne et al.[36]	2000	>18	90	100	95
Blackmore et al.[37]	1999	All	98	95	NA

NA, not applicable; NPV, negative predictive value.

Of the entire population of 12,537 patients, 83 clinically important injuries were identified. Seventy eight patients were captured by the clinical decision rules, having scores >2 and five patients (6%) had a score 0 or 1 but were found to have a clinically important CSI (Table 5). It is important to note that all five outliers presented with physical findings or suspected nonaccidental trauma that prompted imaging of their head and neck. Despite having a documented GCS of 15 with normal neurologic findings, two of the five presented with neck splinting following suspicious mechanisms of injury, the remaining three had evidence of facial or skull fractures on examination or had a documented loss of consciousness. Additionally, two patients had distracting long bone fractures. Despite the fact that these five patients were not captured by our model, all had signs on physical examination that were concerning for head and neck injury and all five patients underwent CT scanning of their head and cervical spine where their CSI was identified in a timely and appropriate fashion.

Because of its retrospective design and a multi-institutional, multinational collaboration, our study has limitations. First, we analyzed only basic data, because the collection of more complex parameters was subject to wide variability among the registries. Potentially useful information on hemodynamic presentation, associated injuries, detailed clinical signs and symptoms, or prehospital and early in-hospital treatment was not collected. Second, the classification of each CSI as stable or unstable was difficult to decipher. Although we reviewed the imaging studies for each of the injured children, the interventions applied (i.e. surgical stabilization, halo vest, and hard collar) and the duration of orthosis application, if applicable, it was difficult to clearly identify elements that could label an injury "stable" or "unstable" at the time of presentation. Therefore, with the exception of sprains and spinal cord injury without radiologic abnormalities (SCIWORA), we elected to account for all CSI (fractures, subluxations, and ligament injuries) and eliminate the dilemma of having to determine which CSI is clinically significant and which one is not. It is likely that only a small proportion of our 83 CSI patients had unstable injuries. Finally, we have reported that there were no missed injuries in the group of patients that we reviewed. Although this is a possible point of contention, we would argue that because of the fact that there are limited pediatric facilities that cover the geographic areas that participated in the study, admission of the same child to another institution was unlikely.

The common belief that is shared by many clinicians that the physical examination can be unreliable in a child younger than 3 years of age causes some to include routine imaging in the clinical decision rules for cervical spine clearance. We have demonstrated that clinical evaluation of these youngest trauma patients with suspected CSI in fact is quite effective in predicting, which subset of patients will benefit from cross-sectional imaging. Four simple clinical criteria used in concert with the physical examination can safely predict CSI in patients younger than 3 years. A WS of

0 or 1 offers a very high negative predictive value for CSI (99.9%), which is similar to what has been reported for imaging modalities when they are applied to this age group. In this study, more than two thirds of children younger than 3 years who presented after blunt trauma would have had their cervical spines cleared using our scoring system and physical examination alone without being subjected to the risks of imaging studies. Although there is greater tendency for CSI to occur inpatients with higher scores, it is clear that even in this population, the incidence of CSI is very low. Therefore, cross-sectional imaging for patients with scores higher than 1 should be performed based on the individual assessment of the patient and the clinical judgment of the provider. To definitively demonstrate the effectiveness of the clinical decision rule (PEDSPINE) in this population (patients younger than 3 years of age), we would support a multicenter prospective randomized clinical trial.

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DISCUSSION

Dr. Therese M. Duane (Richmond, Virginia): Thank you very much for the opportunity to discuss this paper. It is truly an honor.

The authors accomplished a major undertaking by combining retrospective data from multinational sites in order to address a problem that is seen infrequently but has major consequences when missed.

They set out to determine if in children under the age of three clinical examination was adequate to rule out these c-spine injuries. Now I have a multifactorial reason for being concerned about this topic.

One, as an academician we presented three years ago our research in adults where we found that our clinical exam was not as good as CT scan.

And as a mother with four children under the age of six I need to know about this because occasionally my children fall down and go “boom.” So, what did they find?

Out of over 12,500 patients only 84 or .67 percent actually had a c-spine injury. They did not go into how many of them were clinically significant.

They were able to validate their algorithm for c-spine radiographs using one-third of their population with a sensitivity of over 92 percent. I have a number of questions.

1. How did they decide what data points to obtain during the study? It seems that they were biasing their own results by the fact that they focused on mechanism and GCS as opposed to other findings.

Number 2. What does a GCS of 14 mean in an under 36-month old? When my two year old is asked a question by a stranger she puts a hand to her face, puts her head down and doesn’t talk to them.

Does that give her a GCS of 8? I don’t know. How did they come to the cut-off of 14 and not 13 which is usually used in the adult literature?

Do they plan on now applying this prospectively to older children since the studies they continue to refer to in the manuscript, including the NEXUS trial and the Canadian c-spine trial, focused on adults and may not be applicable to those Age 3 to 8 years old?

Since six of the missed injuries were found after falls and most had associated facial trauma, how should they be incorporated into the algorithm if at all?

And, Number 5, for those patients who you determine need radiographic evaluation; your algorithm suggests using a CT. Does that mean that you are also eliminating plain films?

And based on your findings it seems that my bias is proven – that when my child falls down on occasion or rolls down the steps and they get up and they look okay, they don’t need a whole bunch of x-rays and that mommy’s kisses is all that it takes.

Dr. Sheldon Brotman (Pittsfield, Massachusetts): George, a simple but elegant study. Enjoyed it. A mother’s description of a child falling down crying, that’s what we usually get to see. That’s fine.

But how about a child with two points who has been in a motor vehicle accident? Should every child with two points have CT of the neck?

Dr. Richard J. Mullins (Portland, Oregon): I think all surgeons are familiar with the concept of “acceptable risk.” If a surgeon performed 100 appendectomies and we asked the surgeons are you willing to accept a certain number of normal appendices being removed most would respond yes with the intent avoiding delayed surgery on a perforated appendix?

Dr Velmahos what is the acceptable risk, using your protocol, of clearing the cervical spine in a patient who is subsequently determined to have a cervical spine injury? There is clearly a risk to children exposed to unnecessary radiation.

Will you testify in my behalf if I follow your protocol and one or two of the thousand children I cleared turn out to have a cervical spine fracture?

Is there a legal precedence that allows trauma surgeons to have an acceptable risk that is less than perfect in the diagnostic evaluation of children whose mechanism of injury may have injured their cervical spine?

Dr. Michael Lekawa (Irvine, California): Thank you very much for that presentation, George. I agree wholeheartedly with that last comment.

Are we stating then that CT scan alone is adequate to evaluated pediatric spines and MRI is not indicated? Why was MRI not addressed at all? Thank you.

Dr. George C. Velmahos (Boston, Massachusetts): Well, thank you for the meaningful questions. And I particularly thank Dr. Duane for being kind enough to send me her questions in advance so that I can think about them and provide meaningful answers. Thank you.

So your first question was how we decided which variables to use. And, as you may imagine, these were 22 different trauma centers that used their own trauma registries with data collected by various methods. As expected, we had a lot of missing data. Actually, our initial sample size was 22,000 patients but only 12,000 patients had complete data to allow the current analysis. If we analyzed additional fields, more patients would be excluded due to incomplete information, and the sample size would decrease more.

You asked what does a Glascow Coma Scale of 14 mean for infant and toddlers. My response will also answer Dr. Mullin's question. Essentially, a GCS less than 14 means anything less than perfect. It is possible that the child is just afraid or not behaving appropriately, despite a normal mental status. However, we do not want to take any chances and would evaluate these children further. Of course, we keep in mind that a 14 for many infants and toddlers equals to a 15 for adults. These kids may still be non-verbal due to age and, therefore, a GCS of 14 is the highest score they can achieve.

The six missed injuries had facial injuries or neck pain, should these findings be taken into account when clearing the c-spine? Absolutely yes.

It stands to reason that if an infant or a toddler cannot move the neck, a sign that possibly indicates severe neck pain, or has major fractures then one needs to remember all the NEXUS criteria and avoid cervical spine clearance.

And, finally, should evaluation be with plain films or CT? It is well proven that plain films miss significant injuries and CT is a more accurate test. For this reason, CT is the preferred test in most instances, when there is true concern about the c-spine.

Dr. Brotman asked if every child less than three years old with a point score of more than two should have a CT. And, again, it seems that in most cases the answer is yes.

Dr. Mullins' argument is that we may be setting the bar too high; Dr. Brotman's that it is too low. There is no perfect answer here. Based on the outcomes of this study I would evaluate radiographically.

Rich, you correctly point out that there is no overriding and uniformly-accepted standard. I think it is our obligation to realize what is good practice and to be prepared to defend it even legally. And our community should offer support, if such a case occurred. If we just accept to practice in a climate of fear, dreading that we may miss an injury in every million patients, we are just reinforcing negative medicine, which is ultimately damaging for the patients and the health care system as a whole. So, we have to create our standards, based on reliable evidence. With the negative predictive value of 99.89 percent we should be prepared to take as stance and practice according to the findings of this study.

And, finally, I was asked if MRI is better than CT, if I understood the question well. For soft tissue injuries MRI may be better, while CT is superior for the bones. It is possible that new generation helical CT scanners evaluate all tissues adequately. MRI availability is not comparable to CT's.

EDITORIAL COMMENT

Although the incidence of spinal cord injury in the toddler is very low, it can and does occur with and without boney or ligamentous spinal column disruption. This report addresses what is often a nerve wracking challenge for the trauma surgeon responsible for determining potential presence of spine injury and/or a cerebral spine injury in an obtunded child. The proposed algorithm seems to be a statistically valid adjunct to determining need for computed tomography and is grounded on the commitment to minimize unnecessary radiation to young children. Although the statistical validation is adequate, clinical application must be tempered by the realization that the population evaluated in this report was toddlers younger than 3 years. Whether this approach will be equally applicable for older children, especially those exposed to higher energy injury mechanisms is indeterminate. It is interesting to note that all four measures of the proposed algorithm are components of what should be a complete history and physical examination and two are mathematically linked as gross coma scale. The assessment of eye opening, particularly in a 3 year old, is sometimes a bit subjective. It is critical, therefore, that the reader recognize both the limited age strata that this proposal addresses, and, most importantly, that complete and repeat physical examination still remains the best determinant for the existence of a child's spine and/or spinal cord injury as well as the need for additional imaging.

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