Research Article

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Diagnostic Yield of Skeletal Survey in Pediatric Trauma Patients by Age

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Abstract

Introduction: Non-accidental Trauma (NAT) is a major cause of morbidity and mortality in children. Younger children are at greater risk of NAT. In this observational study, we determine if there is an association between a child's age, frequency of positive of skeletal surveys and the types of injuries discovered in pediatric patients undergoing a trauma work up.

Methods: The study sample consisted of all pediatric trauma patients <3 years old, who had skeletal surveys performed at a tertiary care center between 2005 and 2015. Patients were divided into two age groups: ≤6months old (n=98) and >6months old (n=86). The utilization of a skeletal survey, frequency of confirmed NAT, and injuries were compared between these 2 age groups.

Results: The average age of this population was 8.4 months, 56.0% were boys, and 62.5% were Caucasian. A positive skeletal survey was found in 14.3% of patients ≤6months old and 18.6% of patients >6months old (p=0.43). The most common fractures identified were long bone (50.0%), torso (30.4%), and skull (13.0%). Similar frequencies of NAT were observed between those less than and older than 6 months (58.2% vs. 57.0%). Head computed tomography (CT) scans were performed in the majority (95.9%) of patients ≤6 months old and in 66.3% of patients >6 months old (p < 0.01).

Conclusion: Skeletal surveys identify additional injuries at comparable rates in pediatric trauma patients regardless of age. Advanced imaging differs in younger and older pediatric trauma patients undergoing skeletal survey.

Keywords: Child abuse; Clinical care; Pediatric trauma; Non-Accidental trauma

Introduction

In 2014, the rate of child abuse or neglect was 9.4 per 1,000 children living in the United States. Approximately 3.2 million children were subjects of at least one report from Child Protective Services and nearly 1,600 children die from maltreatment each year [1]. Younger children are at the greatest risk of non-accidental trauma and are more likely to be harmed by their primary caretakers [2].

Non-accidental trauma (NAT) is a major cause of childhood traumatic injury commonly resulting in skeletal fractures [3,4,5]. Although not as common as contusions, skeletal fractures have also been associated with serious intracranial injuries in pediatric NAT victims [3,5]. According to the American Academy of Pediatrics, skeletal survey is the gold-standard in identifying fractures in children that are too young to communicate [6]. In addition, skeletal surveys are recommended for

young children with findings suspicious for NAT and in older children who cannot communicate the location of their pain[7].Skeletal surveys diagnose obscure, new and healing fractures. They not only have significant clinical impact, but also help identify victims of NAT and remove them from dangerous environments [8,9].

Previous studies have demonstrated the importance of skeletal surveys in the identification of NAT in pediatric patients with a frequency of fracture detection ranging from 11% to 33% [6,10,11,12]. While these studies have failed to show an association between race and gender with the risk of NAT [13,14,15,16], earlier studies have indicated that children younger than 2 years of age are more likely to be victims of NAT [13,17,18,19]. In fact, one study has suggested that children less than 6 months of age have more than two fold higher rates of a positive skeletal survey compared with children older than 6 months [11]. However, a more recent study demonstrated that skeletal surveys could have a similar diagnostic yield among patients as old as 36 months compared with younger children [20]. Inasmuch, further investigation into the role of the skeletal survey in identifying NAT in pediatric trauma patients is warranted.

Children under the age of 6 months are potentially the most vulnerable population of pediatric patients to experience NAT due to their high level of dependence on their caregivers. Therefore, we hypothesized that among pediatric patients undergoing a trauma work-up for NAT, younger children (≤ 6 months of old) would have a higher positive yield of skeletal survey and rates of NAT compared with older children (>6 months to 3 years old).

Methods

Patient population

All trauma evaluations were performed at the University of Massachusetts Medical Center from January 2005 to December 2015. Using the Trauma Registry database records, we identified all pediatric patients (≤ 3 years old) who underwent a skeletal survey during this period. This age cutoff was based on the utility of skeletal surveys in the pediatric population demonstrated in previous clinical studies [20]. A medical chart review collected data on patient's demographic characteristics, 51A (initiation of a formal investigation for abuse or neglect in Massachusetts) status, skeletal survey results, additional imaging results, specific injuries, injury severity score, and patient's hospital course, mortality, and disposition (e.g., home, into custody). Confirmed NAT was defined as

patients who satisfied all of the following criteria: 51-A filed, injuries inconsistent with history or mechanism of injury and child was removed from parental custody/ legal guardianship as per our institutional child protective program. In cases of suspected or confirmed NAT, the perpetrator was also identified. Institutional review approval was obtained for this study.

Data collection

All study data were managed using RED Cap electronic data capture tools hosted at the University of Massachusetts Medical School [21]. RED Cap (Research Electronic Data Capture) is a secure, web-based application designed to support data capture for research studies, providing 1) an intuitive interface for validated data entry; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for importing data from external sources.

Data analysis

Patients were divided into 2 groups for purposes of analysis: ≤ 6 months old and > 6 months old. Comparisons between these 2 study groups were performed using Chi-square tests for categorical variables and the Student's-t test for continuous variables. Statistical analysis was performed using *Stata Statistical Software: Release 13* (College Station, TX).

Results

Study population characteristics

Our study identified 184 patients out of a total of 5,937 total pediatric trauma patients at our institution during the years under study (2005-2015). Of these, 98 (53.2%) were ≤ 6 months old. Overall, the mean age of the children studied was 8.4 months, slightly more than half were male (56.0%), and almost two-thirds (62.5%) were Caucasian. Children in the ≤ 6 -month-old group were on average 12 months younger than the older group (Table 1).

Characteristics of presenting injury

Most of the children presented to our institution with falls/assault related injuries (75.5%), over half of which occurred at home (Table 2). More than one half of the study population were transported to the hospital via ambulance, with over three-quarters (77.2%) of the injuries occurring between the hours of 4pm and 4am.

Table 1: Patient Demographic Characteristics According to Child's Age

	0-6 months old (n = 98)	>6 months old (n = 86)	p-value
Child Age (months)	2.9 (1.7)	15 (7.7)	<0.01
Male	53 (54.1)	50 (58.1)	0.58
Race			0.73
Asian	1 (1.0)	3 (3.5)	
African-American	10 (10.2)	7 (8.0)	
Hispanic	21 (21.4)	19 (22.1)	
Native American	1 (1.0)	0 (0.0)	
White/Caucasian	61 (62.2)	54 (62.7)	
Other	4 (4.1)	2 (3.5)	

There were no differences in the injury profiles between the younger and older children, as well as severity of injury, Glasgow Coma Scale (GCS) on arrival, and in the length of the total hospital and intensive care unit stay. However, more children in the >6-month-3-year-old group were intubated upon arrival (Table 2).

Diagnostic imaging

A Skeletal Survey was performed in all 184 patients with the majority (71.7%) being performed on the pediatric wards. A positive skeletal survey was found in 16.3% of all patients. Long bone (50.0%), torso (30.4%), and skull (6.7%) fractures were the most common findings on skeletal surveys with no between group differences (Table 3). There has been an increase in the frequency of skeletal surveys during the most recent study years, with one-third of all skeletal surveys performed in the 2 most recent study years of 2014 and 2015.

Patients underwent a variety of additional imaging studies with Head CT scans performed in most patients (82.1%). Extremity X-rays (22.8%), CT Abdomen/Pelvis (12.5%), MRI of the Head (11.4%), and focused assessment with sonography for trauma [FAST] (10.3%) were the next most common imaging modalities carried out (Table 4). Head CT scans were performed in almost all children ≤6 months old compared with approximately two-thirds of patients > 6 months old ($p < 0.01$). On the other hand, three times as many children >6months to 3 years old had a CT of the Abdomen and Pelvis performed compared with children less than 6months old ($p<0.01$).

Injury diagnoses and final disposition

The most frequent locations of the final injuries were Head (63.6%), Extremity (47.3%), and Abdomen and Pelvis (11.4%) with no differences between our 2 study groups

(Figure 1).

In over half of the patients NAT was confirmed based on the review of data contained in hospital medical records. Mothers were the most common perpetrator of NAT. Children were removed from the custody of at least one parent in 57.6% of all patients. In addition, 42.0% of all children with confirmed NAT were taken into state custody with no differences between groups (Table 5). All patients were alive at the end of the study.

Figure 1: Final Injury Locations According to Child's Age

Table 2: Characteristics of Presenting Injury According to Child's Age

	0-6 months old (n = 98)	>6 months old (n = 86)	p-value
Initial Stated Mechanism of Injury			0.28
Fall	40 (40.8)	29 (33.7)	
Assault	41 (41.8)	29 (33.7)	
Accident	3 (3.1)	6 (7.0)	
Burn	1 (1.0)	5 (5.8)	
Not Specified	11 (11.2)	14 (16.3)	
Neglect	1 (1.0)	3 (3.5)	
Location			0.06
Home	62 (63.3)	44 (51.1)	
Public Building	1 (1.0)	6 (7.0)	
Residential area	2 (2.0)	0 (0.0)	
Street	2 (2.0)	0 (0.0)	
Not Specified	31 (31.6)	36 (41.8)	
Transportation			0.046
Ambulance	61 (62.2)	38 (44.2)	
Helicopter	3 (3.1)	5 (5.8)	
Parent/Guardian	34 (34.7)	43 (50.0)	
Trauma			0.09
Level 1	2 (2.0)	8 (9.3)	
Level 2	11 (11.2)	8 (9.3)	
Level 3	51 (52.0)	35 (40.7)	
Level 4	34 (35)	35 (40.7)	
Injury Severity Score	8.8 (7.7)	9.7 (8.8)	0.47
GCS on arrival	14 (2.5)	13 (3.8)	0.25
Intubated on arrival	3 (3.1)	9 (10.5)	0.04
Cervical collar present on arrival	7 (7.1)	10 (11.6)	0.30
Length of Stay (days)	3.4 (4.7)	3.8 (5.1)	0.51
Intensive care unit stay(days)	1.0 (3.4)	1.6 (4.6)	0.35

Values are N (%) or mean (standard deviation) unless otherwise specified

Discussion

We examined the hospital medical records of pediatric patients who had skeletal surveys performed over a recent decade long period at our tertiary care, level

one pediatric trauma center. Our study identified 184 patients who had a skeletal survey for suspicion of NAT out of a total of 5,937 total pediatric trauma patients. The majorities of patients were less than 1-year-old, white, and were male.

Table 3: Characteristics of Skeletal Survey According to Child's Age

	0-6 Months Old (n = 98)	>6 months old (n = 86)	p-value
Patient Location at time of Skeletal Survey			0.85
Emergency department	3 (3.1)	4 (4.7)	
Intensive care unit	24 (24.5)	21 (24.4)	
General Inpatient Unit	71 (72.4)	61 (70.9)	
Positive Skeletal Survey	14 (14.3)	16 (18.6)	0.43
Fractures on Skeletal Survey	n=23	n=23	1
Skull fracture	2 (8.7)	4 (17.4)	0.38
Facial fracture	0	2 (8.7)	-----
CTL spine fracture	0	1 (4.3)	-----
Torso fracture (rib/scapula/clavicle)	8 (8.2)	6 (26.1)	0.52
Upper extremity fracture	6 (26.1)	5 (21.7)	0.73
Lower extremity fracture	7 (30.4)	5 (21.7)	0.50

Values are N (%) or mean (standard deviation) unless otherwise specified

Utility and findings of skeletal survey

A positive skeletal survey was found in one sixth of all patients: 14% of patients' $\leq$ 6 months old and 19% of patients >6 months to 3 years old, falling within the range of detection rates found in prior studies [10,11,12,20]. The most common fractures identified on the skeletal surveys were those of the long bone (50%), torso (30%), and skull (13%), with no differences noted between age groups. This pattern of injury follows similar trends previously reported [22,23,24]. For example, in a retrospective study reviewing all patients with NAT at a Pediatric Trauma

Center in Texas over the period between 2007 and 2011, investigators identified 267 patients who presented with over 473 injuries. Among patients presenting with isolated injuries, extremity (49%), torso (20%) and skull fractures (13%) were the most common, consistent with our findings [23]. These injuries continue to be more prevalent in victims of NAT and the skeletal survey identifies them consistently, demonstrating its utility in the pediatric trauma population.

Table 4: Non-Skeletal Survey Imaging and Final Injury Locations According to Child's Age

	0-6 months old (n = 98)	>6 months old (n = 86)	p-value
Additional imaging			
CT head	94 (95.9)	57 (66.3)	<0.001
MRI head	11 (11.2)	10 (11.6)	0.93
CT/MRI of Spine	7 (7.1)	10 (11.6)	0.3
CT chest	2 (2.0)	4 (4.7)	0.32
CT abdomen/pelvis	6 (6.1)	17 (19.8)	0.005
Extremity x-ray	20 (20.4)	22 (25.6)	0.44
Pelvis x-ray	4 (4.1)	7 (8.1)	0.24
Chest x-ray	6 (6.1)	9 (10.5)	0.28
Abdominal x-ray	1 (1.0)	1 (1.2)	0.93
Focused Assessment with Sonography for Trauma	14 (14.3)	5 (5.8)	0.06
Abdominal ultrasound	4 (4.1)	2 (2.3)	0.50
Electroencephalogram	5 (5.1)	5 (5.8)	0.83

Values are N (%) or mean (standard deviation) unless otherwise specified

*not exclusive, so % may add to more than 100%

We found no significant differences in the yield of a skeletal survey between children ≤ 6 months old compared with children >6 months-3 years old. This was contrary to our initial hypothesis, as well as the results of earlier retrospective studies which showed that children under the age of 6 months had the highest rates of positive findings on skeletal survey [3,11,12].

In a recent retrospective study of more than 2,500 children investigated by child abuse specialists for suspicion of NAT, patients were selected from the Examining Siblings to Recognize Abuse (ExSTRA) research database. Investigators found that the overall diagnostic

yield of skeletal survey was 23% and it was similar between children 12-24 and 24-36 months old [20].

Table 5: Characteristics of NAT According to Child's Age

	0-6 months old (n = 98)	>6 months old (n = 86)	p-value
Non-accidental Trauma Confirmed	57 (58.2)	49 (56.9)	0.87
Relationship of Perpetrator			0.13
Mother	13 (22.8)	7 (14.3)	
Father	5 (8.8)	3 (6.1)	
Both parents	6 (10.5)	4 (8.2)	
Mother's significant other	1 (1.2)	8 (16.3)	
Foster Parent	0 (0.0)	1 (2.0)	
Daycare/Babysitter	2 (3.5)	2 (4.1)	
Not specified	30 (52.6)	24 (49.0)	
Disposition			
Home with both parents	41 (41.8)	36 (41.9)	
Family member other than parents	7 (7.1)	4 (4.7)	
Taken into custody	43 (43.9)	38 (44.2)	
Taken out of custody of 1 parent	7 (7.1)	6 (7.0)	
Rehab	0 (0.0)	2* (2.3)	

Values are N (%) or mean (standard deviation) unless otherwise specified

*One of the rehab patients was taken out of parental custody

Our study did not demonstrate a significant difference in frequency of positive skeletal surveys between patients in our 2 age strata, suggesting equal utility of skeletal survey in children ≤ 6 months and those >6 months-3 years of age. Currently, the American Academy of Pediatrics and American College of Radiology state that skeletal surveys are mandatory in children under the age of 24 months [6,25]. However, the findings of the aforementioned retrospective cohort utilizing the ExSTRA database [20], demonstrate that skeletal surveys might be beneficial in detecting NAT in children older than 24 months as well. Therefore, our study results along with those in the ExSTRA study convey that skeletal survey has utility in detecting NAT in children as old as 3 years of age, although future investigation is necessary to confirm this.

Institutional trends in the use of skeletal survey

Skeletal surveys were performed with the greatest frequency during the 2 most recent study years at our institution. The number of skeletal surveys has nearly tripled within a 5-year time frame, with 23 skeletal surveys performed in 2015. Skeletal surveys have been recommended for the detection of injuries suspicious for NAT as far back as the early 1990's [26]. However, in 2009, our institutional policy was modified so that all patients with traumatic injuries who are preverbal or unable to explain what happened are referred to the Child Protection Program (CPP, consisting of pediatricians who are fellowship trained in NAT). Although a skeletal survey is not automatically done when a CPP referral is placed, CPP will recommend skeletal surveys after their review if indicated. Our increasing use of the skeletal survey in suspected pediatric NAT victims may reflect not only our general hospital policy, but also heightened clinical awareness and knowledge of NAT.

Additional imaging trends

The most common additional imaging performed was a Head CT. These scans were performed in nearly all patients ≤ 6 months old and in two thirds of patients > 6 months old. Although the rate of CT head utilization in NAT varies between 19-66% depending on institutional neurologic imaging protocols [27], we found that the youngest patients were significantly more likely to have a head CT scan performed. This trend is similar to the rate of head CT scans for all cause minor head injuries in children presenting to the emergency department which has been between 32-38% for children <1 year and between 25 and 30% for children ages 1-5 years [28]. This finding may be related to the inability of children ≤ 6 months to communicate injury locations and symptoms or that these children experience the more severe head injuries.

On the other hand, we found that almost three times as many children > 6 months-3 years old had an Abdomen/Pelvis CT compared with younger children. A recent retrospective study performed in 2015 at a Pediatric Trauma Center in Houston Texas evaluated 404 patients admitted for suspected NAT over an 8-year period found that abdominal injuries were more common in children older than 12 months compared with those under 12 months of age (25% vs 7%) [29]. These differences may represent how children of different ages suffer distinct mechanisms of injury. For instance, children under the age of 6 months might be more likely to experience NAT by shaking compared with striking in older children.

Therefore, children in these different age groups have dissimilar diagnostic work ups.

Injury presentation, diagnosis and disposition

Most children presented to our institution with fall/assault injuries that occurred at home. Almost all children were transported to the hospital via ambulance or by a parent/guardian, with a majority of the injuries occurring between the hours of 4pm and 4am. Injury severity scores were comparable between children in our 2 age groups and are similar to previous literature [24]. More older children in our study were intubated upon arrival compared to the ≤ 6 month old group, which when used as a measure of injury severity, is contrary to prior findings where younger victims of NAT had more severe injuries [30]. These differences in results could be attributed to the power of the present study, since the aforementioned investigation included more than 2,500 patients.

The most prevalent locations of final injuries were the head, extremity, and abdomen/pelvis, similar to prior findings [24,31]. In over one half of the patients, NAT was confirmed resulting in removal of a child from the custody of at least one parent/guardian. In fact, 42% of children with confirmed NAT were taken into state custody. A prior study had shown that 40% of children who were victims of abuse excluding non-accidental head trauma were placed into foster care [32]. Our study did not show a difference in the frequency of confirmed NAT after receiving a skeletal survey between younger (≤ 6 months old) and older (> 6 months- 3 years old) trauma patients, suggesting that clinicians must remain vigilant in diagnosing NAT in pediatric patients regardless of age.

Study strengths and limitations

This study offers insights into the workup for NAT in pediatric trauma patients. In addition, it highlights the utility of the skeletal survey in pediatric patients under the age of 3 years old, who are already receiving an extremely comprehensive workup. We identified differences in the utilization of head and abdomen and pelvis CT scans among children ≤ 6 months old and > 6 months old. On the other hand, this study has several limitations that need be kept in mind in interpreting our study results. Our study reviewed pediatric trauma patients who came to our institution over a 10-year period. This may have excluded other patients who had skeletal surveys performed due to suspicion of NAT but were not trauma patients. Finally, the power of our study may not have

been sufficient to detect differences between the two principal study groups.

Conclusions

Pediatric patients represent vulnerable populations that are at risk for NAT with severe injuries. Knowledge of patterns and mechanisms of injury, in conjunction with clinical data, may provide guidance in the management of these patients with concern for NAT. In our study, advanced imaging modalities differed between the 2 age groups. Neurologic imaging (CT Scan) was more frequently performed in patients ≤ 6 months old, whereas abdominal CT scans were performed more often in children > 6 months old. Head and extremity injuries were most often identified, with a similar detection rate between patients in both age groups. Skeletal survey is a valuable tool in assessing for injuries of NAT in pediatric trauma patients undergoing extensive workup, regardless of the child's age.

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Competing Interests

The authors have no competing interests.

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