The American Journal of Surgery 213 (2017) 606–610

Contents lists available at ScienceDirect

The American Journal of Surgery

journal homepage: www.americanjournalofsurgery.com

Examining the role of follow-up skeletal surveys in non-accidental trauma

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ARTICLE INFO

Article history:
Received 1 June 2016
Accepted 9 December 2016

Keywords:
Skeletal survey
Non-accidental trauma

ABSTRACT

Background: Diagnosing NAT (non-accidental trauma) includes a skeletal survey to identify injuries. A follow-up survey is performed for missed injuries. This study examines the necessity of follow-up surveys.

Methods: The trauma database identified cases of suspected NAT in <4 years olds (2013–2014). Data were stratified by survey, age, injury, then analyzed for the prevalence of findings. All analyses (relative risk, prevalence and odds ratios) utilized RealStats Resource Pack (Trento, Italy).

Results: 79% positive initial findings and no new follow up findings. Those with negative initial imaging, had no missed injuries. Initial scans were 27.6X more likely to be positive. Fractured skull (31.3), femur (17.2) and ribs (15.7) were the most prevalent. No pelvic fractures and <1% spinal injuries despite both having the greatest radiation exposure. Repeat scans rarely identify findings for age >12 months.

Conclusions: Follow-up skeletal surveys maybe unnecessary without clinical evidence. Uncommon pelvic and spinal fractures may warrant exclusion from surveys unless clinically indicated.

1. Background

More than 170,000 children per year are physically abused in the United States.[1] Non-accidental trauma (NAT) remains an ongoing epidemic that continues to worsen. Failure to diagnose NAT carries significant risk for morbidity, particularly in non-ambulatory and nonverbal children under the age of two. Contrastingly, false positives can lead to psychological strain and social destabilization for both the child and the family. As such, there has been historical concern for missing diagnoses due to the significant risks to children. When NAT is unrecognized, the estimated risk of re-abuse is 35% with a 10% associate mortality.[2–4] The Skeletal Survey (SS) is used to document fractures and help determine if the pattern of injury is consistent with the child's age and development, as well as the history provided by the caregiver.

The SS is a tool that is widely employed to assist clinicians in identification of abuse related injuries. The SS is often the strongest physical evidence of abuse. In children less than 12 months of age who present with a fracture, 25% are diagnosed with a NAT related injury.[5] Abusive fractures that go undetected can lead to devastating consequences, including additional and progressive abuse related injuries when a child is unknowingly returned to an abusive environment.

The SS consists of a series of 23 radiographs of the axial skeleton, long bones, skull, hands, and feet. It is used to identify fractures and differentiate them from developmental changes and other anatomical variances. Whenever NAT is suspected, the American Academy of Pediatrics (AAP) recommends obtaining a SS in children under 2 years of age. Additionally, the AAP recommends obtaining a follow-up skeletal survey (FUSS) within 10–21 days after the initial screening if "abuse is strongly suspected on clinical grounds" and "when the initial findings are abnormal or equivocal".[6] If the possibility of NAT is eliminated, no FUSS is recommended.

This recommendation from the AAP was based on two studies in 1996 (n = 23) and 2005 (n = 48) of children with demonstrated fractures on the initial SS in whom physical abuse was strongly suspected.[7,8] New fractures were discovered on FUSS in 61% and 33% of the cases respectively. Given the size and selectiveness of the original study population, some have questioned if the AAP

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http://dx.doi.org/10.1016/j.amjsurg.2016.12.004
0002-9610/

recommendations for repeating SS may have been too broad.[9] The current rationale for obtaining FUSS has been to insure that the initial survey did not fail to identify acute rib and metaphyseal fractures which can be difficult to see in young children. With callous formation that occurs during the healing process, these fractures become more apparent over time. To date, the exact criteria for obtaining a FUSS remain unclear and there is broad disparity in its use. At Carolinas Healthcare System (CHS), an initial SS is mandatory in all cases of suspected non accidental trauma in children ages 0–2 years and considered in children age 2–4 years.[10] As children age, the recommendation for FUSS changes, and its use is eliminated entirely in children over the age of five. When abuse is strongly suspected, a FUSS in two weeks is recommended. In practice, however, unless NAT is ruled out completely in the initial survey and clinical evaluation, children who are treated at CHS undergo an automatic two-week FUSS.[9] These SS, while helpful for clinical diagnosis of NAT, are not without risk. These children are exposed to high levels of radiation at a crucial stage in biological development.

Given the broad disparity in use and the apparent risk to children, the objective of this study was to determine the incidence and pattern of injury in initial surveys, the amount of radiation inherent in a SS, options for minimizing this exposure, the cost effectiveness of the current policy, and ultimately, whether the FUSS continues to have clinical and forensic relevance.

2. Methods

This was a retrospective descriptive study approved by the institutional review board at Carolinas Medical Center with a waiver of informed consent. The protocol queried the in-house trauma registry database for children under the age of four who underwent an initial SS at the Level II Pediatric Trauma Center, Carolinas Medical Center in the Carolinas Healthcare System from January 2013–June 2014. Data on demographics, clinical presentation, results of initial and follow-up (if applicable) SS, radiation exposure, and cost analysis were collected. Children undergoing SS for reasons other than suspected NAT were excluded, as were cases where NAT was definitively ruled out. Electronic medical records for each child underwent manual review, and data was stratified by age, type of injury, frequency of injury type, clinical impact of SS findings, and changes observed between initial SS and FUSS. In both initial and follow-up surveys, "*new findings*" are characterized as injuries not previously observed in any imaging capacity. The term "*confirmation findings*" refers to injuries that appear on FUSS that were previously documented on initial SS and are healing. Data were analyzed for prevalence, relative risk, and comparative occurrence, utilizing epidemiological prevalence statistical analysis via RealStats (Trento, Italy).

3. Results

There were 110 children under the age of 4 who were subject to a SS due to suspected NAT over the aforementioned time period. Seventy nine percent (79%) of studies revealed positive findings in the initial SS.

3.1. Initial skeletal surveys

Eighty-seven (87) of 110 patients (79%) demonstrated one or more positive findings on initial SS. Characterizing by injury, the results demonstrated the skull, femur and ribs (33%, 18% and 17%, respectively) to be the most prevalent types of injuries. No pelvic injuries were observed, while spinal injuries accounted for approximately 1% of cases. These findings were fairly consistent across all age groups with clavicle fractures only becoming prevalent after 12 months of age (Table 1).

3.2. Follow-up skeletal surveys

In FUSS, an average of 13% of cases had confirmed findings. Twenty percent (20%) confirmed findings in the first year and 6% in the second year of the study period. In patients with negative initial imaging, surveys remained negative on follow-up, and there was no incidence of new findings on FUSS in any case, regardless of initial results.

A comparison of initial and follow-up SS indicates initial scans are nearly six times more likely to identify a positive finding (OR 27.6; 95% CI: 11.7–64.9; $p < 0.001$) (Table 2).

3.3. Injury patterns and prevalence

Prevalence ratios indicate the skull (31.3, 95%CI 22.62–40.15), femur (17.2, 95% CI 10.09–24.98), tibia (6.33, 95% CI 1.23–12.27), humerus (8.7, 95% CI 3.08–15.17), and ribs (15.7, 95% CI 8.82–23.30) are 6–31 times more likely to have pathology on initial scan. ($p < 0.01$) (Table 3).

3.4. Injuries stratified by age

Prevalence ratios indicate the greatest likelihood of having positive findings on an initial scan is in the 0–6 month age group. (39.2, 95% CI 25.63–51.27; $p < 0.0001$) (Table 4). The prevalence of new findings decreases with increasing patient age. If the patient is 12 months of age or older, the prevalence of injury decreases approximately seven-fold from 39.2 to 5.4 (95% CI -3.8–14.7).

3.5. Radiation exposure

Each scan in a skeletal survey has a pre-determined radiation exposure. Pelvic images result in the greatest radiation exposure (70 mrem), followed by lumbar and c-spine films (30 and 27 mrem). Collectively, a complete SS results in 173 mrem of radiation exposure (Fig. 1).

3.6. Cost analysis

The overall institutional cost of a skeletal survey, including the radiologist's interpretation, is US $980. Over the 18-month study period, the total cost of SS and FUSS, regardless of result was US $167,580. Of this amount, US $59,780 was spent for FUSS, which yielded no new significant clinical findings.

Table 1
Skeletal injury distribution across infant and toddler age ranges.

Injury type	0–6 months	6–12 months	12–18 months	18 + months
Skull	40%	37%	13%	8%
Femur	10%	26%	38%	31%
Tibia	5%	11%	13%	0%
Fibula	0%	3%	0%	0%
Humerus	8%	11%	0%	15%
Ulna	1%	3%	0%	8%
Radius	4%	6%	0%	8%
Rib	23%	0%	25%	15%
Wrist/Fingers	1%	3%	0%	0%
Mandible	0%	0%	0%	8%
Clavicle	3%	0%	13%	8%
Foot	3%	0%	0%	0%
Spine	1%	0%	0%	0%
Pelvis	0%	0%	0%	0%

Percentage (%) of specific skeletal injuries stratified by age.