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Use and Utility of Skeletal Surveys to Evaluate for Occult Fractures in Young Injured Children

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Contributor's Statement

Dr. Wood conceptualized and designed the study, acquired the data, analyzed and interpreted the data, drafted the initial manuscript, and approved the final manuscript as submitted.

Mr. Song and Drs. Henry, Berger, Lindberg, Anderst, Localio and Feudtner contributed to the study design and data acquisition, reviewed and revised the manuscript, and approved the final manuscript as submitted.

Dr. Wood, corresponding author, had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors approved the final manuscript and take public responsibility for the content presented in the manuscript.

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Abstract

Objectives: To describe the percentage and characteristics of children <24 months old with non-motor vehicle crash (non-MVC)-related injuries who 1) undergo a skeletal survey and 2) have occult fractures.

Methods: We performed a retrospective chart review of a stratified, systematic random sample of 1769 children <24 months old with non-MVC-related bruises, burns, fractures, abdominal injuries, and head injuries at 4 children's hospitals from 2008–2012. Sampling weights were assigned to each child to allow for representative hospital-level population estimates. Logistic regression models tested for associations between patient characteristics with outcomes of skeletal survey completion and occult fracture identification.

Results: Skeletal surveys were performed in 46.3% of 0–5 month olds, 21.1% of 6–11 month olds, 8.0% of 12–17 month olds and 6.2% of 18–24 month olds. Skeletal surveys were most performed in children with traumatic brain injuries (64.7%) and rib fractures (100%) and least in burns (2.1%) and minor head injuries (4.4%). In adjusted analyses, increased age, private insurance and reported history of accidental trauma were associated with decreased skeletal survey use (all $p < 0.001$). The prevalence of occult fractures on skeletal survey ranged from 24.6% in infants 0–5 month olds to 3.6% in 18–24 month olds, and varied within age categories based on the presenting injury ($p < 0.001$).

Conclusions: The high rate of occult fractures in infants 0–5 months old underscores the importance of increasing the use of skeletal surveys in this population. Further research is needed to identify the injury characteristics of older infants and toddlers most at risk for occult fractures.

Keywords

child abuse; child maltreatment; skeletal survey

Background

Over 120,000 children are victims of physical abuse each year in the U.S.^{1,2} The youngest children face the highest risk of severe maltreatment, with more than 70% of hospitalizations for physical abuse, and over 50% of maltreatment fatalities, occurring in children <24 months old (m.o.).^{1–3} Delays by medical providers in diagnosing abuse contribute to the high morbidity and mortality in this age group. One study of children with abusive fractures found that 21% of the children had a prior medical encounter during which the diagnosis of abuse was missed, and prior to the diagnosis of abuse being made, 17% of the children suffered additional injuries.⁴ Similarly, studies of children diagnosed with abusive head trauma (AHT) found that 25%–31% had a prior medical encounter opportunity during which abuse could have been diagnosed.^{5,6} Among the missed cases of AHT, 28% of the children were reinjured prior to being diagnosed with AHT and 41% experienced medical complications related to the delay in diagnosis.⁵

Due to these and other findings of missed opportunities to diagnose abuse, clinicians and researchers have advocated for increased use of skeletal surveys (SS) to evaluate for occult fractures in young children presenting with specific types of injuries.^{7–10} SSs have been

reported to reveal occult fractures in 11% to 34% of children evaluated due to concern for or with the diagnosis of abuse.^{11–16} Accordingly, the American Academy of Pediatrics recommends that SSs be performed in all of cases of suspected physical abuse in children < 24 m.o.^{17,18} Despite this recommendation, there is wide variation regarding which young injured children are evaluated. Variation in rates of SS completion, as well as disparities based on patient demographics, provider characteristics, and location of care, have been identified.^{7,8,10,19–23} Standardizing SS performance in young children with specific injury types may be an effective strategy for decreasing missed opportunities to diagnose abuse and protect children as well as decrease unnecessary imaging of other children.

In order to understand the potential impact of standardizing SS use in young children presenting with specific injuries, we sought to better understand rates of utilization and yield of SSs. Multiple studies have described the frequency of SS completion and the yield of SS among children in whom there is a strong suspicion of abuse including children referred to hospital-based child protection teams (CPT).^{12–14,24–27} Few studies, however, have examined SS completion and yield among the larger population of injured children, the majority of who are not evaluated by a CPT. Studies examining SS use in the population of children not evaluated by a CPT have been primarily limited to single center studies of a single injury type^{8,21} or have relied on administrative data and lacked clinical information.^{10,20,22} The objectives of this study, therefore, were to describe in a multicenter sample of children < 24 months of age with non-motor vehicle crash (non-MVC) related injuries the percentage and characteristics of children who underwent a SS and were found to have occult fractures.

Methods

Study Design Overview

We performed a retrospective study of children <24 m.o. with non-MVC-associated injuries cared for at the Children's Hospital of Philadelphia, Children's Hospital of Pittsburgh of UPMC, Children's Mercy Kansas City and Children's Hospital Colorado from 2008–2012. The study combined administrative data (from the Pediatric Health Information System [PHIS], which was also used to identify cases) with detailed data from chart review. The four hospitals contributed International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) diagnosis codes, demographic information and resource utilization data to PHIS, an administrative database of coded diagnostic data from pediatric hospitals in the U.S.²⁸ Through a joint effort between Children's Hospital Association, Thomson Reuters (Ann Arbor, MI), and participating hospitals, PHIS data are subjected to reliability and validity checks.²⁸ Subjects were first identified in PHIS from the four hospitals based on ICD-9-CM injury codes after which a subset of subjects were sampled using the strategy described below. Detailed clinical information was then extracted on chart review from the sampled eligible subjects. Institutional review boards at the four institutions approved this study.

Study Population & Sampling Strategy

Children <24 m.o. discharged between 1/1/2008 and 12/31/2012 from the four hospitals with an ICD-9-CM code for any of the following injury types that may raise concern for abuse were identified in PHIS using the injury ICD-9-CM codes listed in Appendix A: fracture, head injury, internal injury, burn, or bruising. We excluded hospitalizations with ICD-9-CM codes for birth or MVC-associated injuries as well as readmissions for previously diagnosed injuries to generate the PHIS Sample (Figure 1). Next, we used stratified, random systematic sampling to ensure adequate representation by age, gender, injury type, injury etiology (abuse or non-abuse) and hospital.²⁹ The presence of an ICD-9-CM or E-code for child abuse or assault was used to identify cases as abuse for sampling purposes (Appendix A).^{30,31} Twenty-six sampling strata were defined by a combination of age, injury type, injury etiology and hospital. All sampling frequencies were integers in the interests of simplicity and transparency in application. Frequencies were chosen to produce an adequate number of sampled observations for each diagnosis category so that the confidence bounds of resulting rates would support estimates by diagnosis subgroups. In addition, the varying frequencies ensured that no hospital would be overburdened by an unduly large sample for which medical records needed to be abstracted. All sampling programs were written and implemented in SAS v 9.3 (SAS Institute, Cary NC).

To permit estimation of hospital-level population estimates of proportions, the sampling program assigned to each sampled observation a weight equal to the inverse of the sampling frequency. For example, a discharge selected with a sampling frequency of 1 in 5 would carry a sampling weight of 5, to represent the child whose discharge was sampled and the four other children represented by the selected child. Once completed, the sum of the weighted sample equaled the total population of all children who met the inclusion and exclusion criteria defined by hospital and diagnosis. Inferences from weighted analysis of the sample thus were representative of the population from which the sample was drawn.

Data Abstraction and Quality

Each sampled child's PHIS record was linked to his or her medical record. Chart abstractors at each hospital reviewed charts to ensure cases met inclusion criteria and abstract detailed clinical data. Cases with an ICD-9-CM diagnosis code for an injury but no injury documented on physical exam or imaging were excluded. Children who on chart review were found to have iatrogenic injuries occurring in the hospital or were admitted for management of 1) previously diagnosed injuries, 2) birth injuries, or 3) ingestions were excluded.

For each included case, chart abstractors reviewed the medical record including imaging reports and entered data on study outcomes and predictor variables (described below) in a data abstraction form created in REDCap (Research Electronic Data Capture), a secure, web-based application.³² Instructions were imbedded within data forms and reviewed with chart abstractors. Quality checks were performed, including searches for missing data, out of range numerical fields, and inconsistencies in data entry. To assess inter-rater reliability of abstracted data, double data entry was performed by a second data abstractor at each site on a 10% random sample of the Chart Review Sample for key variables. Inter-rater reliability

was perfect for likelihood of abuse ($\kappa=1.0$) and was substantial to near perfect for the following: inclusion ($\kappa=0.89$), SS results ($\kappa=0.94$), reason for presentation ($\kappa=0.68$), first identified injury ($\kappa=0.75$).

Study Outcomes

Primary study outcomes were 1) completion of an initial SS to evaluate for occult fractures and 2) positive initial SS. Completion of a standard SS was confirmed based on review of radiology reports. SSs were considered to be positive and identify occult fracture(s) if fracture(s) not previously suspected clinically or detected on prior imaging were identified. Two authors (MKH, JNW) reviewed abnormal radiology reports. Occult fractures described as probable or definite were categorized as present. Findings described as equivocal or possible fractures were not considered occult fractures. Disagreements were resolved by consensus. Data were collected on secondary outcomes of likelihood of abuse and disposition. The likelihood of abuse was recorded as definite abuse, probable abuse, indeterminate, probable accident, or definite accident based on the CPT's documented assessment or assessment of the primary medical team if CPT was not consulted. We collapsed the definite and probable categories for the analyses. Disposition on discharge from the hospital was categorized as home, out of home placement, deceased or other. Children discharged home were categorized as home with services if at the time of discharge CPS planned to provide in home services.

Predictor Variables

Predictor variables included demographic and clinical characteristics previously identified as predictors of SS completion and/or predictors of occult fracture detection: age in months (0–5, 6–11, 12–17, or 18–23), insurance type (private or public/uninsured), race (Non-Hispanic white, Hispanic, black, other/unknown), reason for presentation, first identified injury, and hospital.^{4,16,20,33,34} The reason for presentation was based on the primary reason the caregiver provided for bringing the child for care and was categorized as 1) reported history of accidental trauma, 2) reported history of inflicted trauma, 3) abnormal symptoms or signs suggestive of injury, or 4) medical concerns unrelated to injury. For example, a child who presented with leg swelling and no history of trauma and was found to have a tibia fracture would be category 3 (abnormal symptoms or signs suggestive of injury), while a child who presented with signs of pneumonia and was incidentally found to have rib fractures on chest radiograph would be category 4 (medical concerns unrelated to injury). The first identified injury was categorized as burn, bruise, minor head injury, skull fracture (without intracranial injury), TBI, abdominal injury, extremity fracture, rib fracture or other. Minor head injuries included bruises, abrasions or swelling of the head/scalp without a skull fracture or intracranial injury. All head injuries with any type of intracranial hemorrhage or parenchymal injury were categorized as TBI. Hospital was included as a predictor variable based on research demonstrating variation in SS utilization across hospitals.^{10,20,35}

Analysis

Data analysis was conducted using Stata 13.0 software (Stata Press, College Station, TX). Study population characteristics were described using frequencies for categorical variables. Logistic regression models tested for associations between demographic and clinical

characteristics with the primary outcomes of 1) SS completion and 2) positive SS for occult fractures. Sibling evaluations and cases with other injury types or other/unknown race were excluded from the regression analyses. Marginal standardization was implemented in logistic regression to generate the standardized estimated proportions of children receiving a SS (and having a positive SS) for each predictor variable.^{36,37} Next, the regression model was repeated, testing for an interaction between age category and injury type as the association between age and occult fractures may vary depending on injury type. We then calculated and graphed the predicted probabilities of SS completion and positive SS based on patient age category and injury type.

Results

Study Population Characteristics

A total of 21,211 encounters were identified with ICD-9-CM codes for fractures, head injuries, internal injuries, burns, or contusions (Figure 1). After excluding readmissions and encounters with diagnosis codes for birth and MVC-related injuries, 19,856 encounters remained from which we sampled 2027 encounters for chart review. Upon chart review completion, 1769 encounters (88.5% of the weighted sample) met inclusion criteria. The majority of cases excluded based on chart review had an ICD-9-CM code for an injury but no documented injury on physical examination or imaging (Figure 1).

In the weighted study cohort, 54.5% of children were non-Hispanic white and 55.2% had public insurance/uninsured (Table 1). The majority of children presented with a history of accidental trauma (86.4%) or abnormal symptoms and signs suggestive of an injury with no history of trauma (11.5%). The most common presenting injuries were extremity fractures (23.6%) and TBI (22.7%) while the least common were abdominal injuries (0.3%) and rib fractures (0.3%). A report was made to Child Protective Services (CPS) in 13.8%.

Skeletal Survey Completion

Overall, 16.6% of the weighted sample of children < 24 m.o. underwent a SS, but the percentage was dependent on age decreasing from 46.3% among infants 0–5 m.o. to 6.2% among toddlers 18–24 m.o. (Table 1). In unadjusted analyses, children with public insurance/no insurance were more likely to have a SS than those with private insurance (20.3% versus 12.0%, $p<0.001$), but there was no difference by race ($p=0.09$). The frequency of SS completion was highest in children whose first identified injury was a rib fracture (100%), TBI (64.7%) or abdominal injury (52.3%) and lowest in children with burns (2.1%) and minor head injuries (4.4%, $p<0.001$). SS were performed in >60% of children with no history of trauma but only 9.1% of children with history of accidental trauma. The frequency of SS completion was higher among children referred to a CPT compared to children not referred (88.1% vs. 5.7%, $P<0.001$, Table 1) and varied by hospital (Table 2). In adjusted analyses, younger age, insurance type, presenting injury, and hospital all remained associated with likelihood of SS ($p<0.001$, Table 3).

Analyses examining the interaction of injury type and age demonstrated that for some injuries, the percentage of children receiving SS declined sharply with increasing age but for

other injury types the rate of SS remained fairly constant across the age range (Figure 2). For example, the percentage of children with extremity fractures receiving a SS decreased from 72.6% in infants 0–5 m.o. to 8.4% in toddlers 18–23 m.o. while the percentage of children with TBI receiving a SS decreased from 67.0% in infants 0–5 m.o. to 51.3% in toddlers 18–23 m.o. (Figure 2, $p<0.001$).

Occult Fracture Detection on Skeletal Survey

Overall, 15.3% of children undergoing a SS had a positive SS. The unadjusted percentage of SS that were positive ranged from a high of 24.6% in infants 0–5 m.o. to a low of 3.6% in toddlers 18–24 m.o. (Table 1). Positive SSs were more common in children with public / no insurance compared to children with private insurance (18.4% versus 9.0%, $p=0.004$). The percentage of positive SS was highest in children presenting with medical concerns unrelated to the injury (32.3%) and lowest in children with reported history of inflicted (11.4%) or accidental trauma (11.5%). In adjusted analyses, young age and public/no insurance remained associated with positive SS but presenting history did not (Table 3).

As shown in Figure 3, among children with extremity fractures and to lesser degree children with bruises, the prevalence of occult fractures decreased with increasing age (Figure 3). In Figure 4, the prevalence of occult fractures by age and injury type are presented, but in contrast to Figure 3 all children, including those children not receiving a SS are included in the denominator. Among infants 0–5 m.o. with extremity fractures, the prevalence of occult fractures remains high at 31.2% (95% CI 16.7–45.6). In contrast, the prevalence of occult fractures infants 0–5 m.o. with burns decreases from 30.2% to 2.9% (95% CI, 0.0–6.6) when all children including those not receiving a SS are included in the denominator (Figure 3, Figure 4).

Discussion

Results from this multicenter study demonstrate that the majority of children <24 m.o. with non-MVC-related injuries cared for at four pediatric hospitals were not evaluated by a CPT and did not receive a SS. Only 16.7% of children received a SS which is in striking contrast to the high rates of SS reported in prior studies focusing on the subset of children evaluated by a CPT^{13,25,38} or the subset of children with severe injuries such as TBI and femur fractures.^{10,22} The low rate of SSs (<6%) among children not evaluated by a CPT combined with the 6-fold higher rate of positive SS among those evaluated by a CPT compared to those not evaluate by a CPT, suggests that caution should be taken when extrapolating results from studies of children evaluated by CPTs to the larger population of injured children presenting for care. Children with negative SSs may be more likely to be discharged home without a CPT evaluation while children with positive SS may be preferentially referred to CPTs thus enriching the yield of SS among the subset of children evaluated by CPTs. There may also be differences in the risk profiles and likelihood of occult fractures between infants evaluated by CPTs and those not evaluated as the CPT may only be consulted when there is a suspicion for abuse.

Rates of SS were high in some age and injury groups. The majority of infants 0–5 m.o. with TBI or extremity fractures received a SS. These infants had a particularly high rate of occult

fractures. Even if one conservatively assumes that all of the infants 0–5 m.o. who did not undergo a SS did not have occult fractures, the rate of occult fractures would be 31.1% in those with extremity fractures and 14.5% in those with TBI. These high rates of occult fracture demonstrate the significant risk of abuse in these infants and strongly suggest that the current rate of SS completion in these infants is too low. There is a need for a more standardized approach to ensure that cases of abuse are not being missed.

Drawing precise conclusions regarding the potential impact of standardizing SS use in other populations of injured children who had low rates of SS completion is more challenging. For example, a recent multicenter study of children with burns evaluated by CPTs found that 86.7% of infants 0–5 m.o. underwent a SS. In that study, occult fractures were identified in 23.1% of infants 0–5 m.o. receiving a SS or 20.0% of all infants 0–5 m.o.²⁷ In contrast, in our study which included infants not evaluated by a CPT, 9.6% of infants 0–5 m.o. with a burn received a SS. Occult fractures were identified in 30.2% of those receiving a SS or <3% of all infants 0–5 m.o. with burns. Unfortunately, we do not know the rate of occult fractures among the infants who did not receive a SS. Thus it is also possible that the true prevalence of occult fractures was significantly higher than 3%. Due to the low rate of SS in infants with burns, drawing conclusions regarding the potential impact of increasing SS rates is difficult.

Our findings need to be interpreted in light of the study strengths – including the multicenter design, detailed chart review, and inclusion of children not referred to CPTs – and study limitations. First, this was a retrospective study and therefore limited by selection biases in who underwent SS. Second, unobserved patient-level factors, including details of the reported history might have influenced the decision to obtain a SS. Third, the results may not be representative of care at other pediatric centers, and cannot be generalized to non-pediatric centers. Furthermore, the full spectrum of burns may not be represented as children with severe burn injuries may have been admitted to burn centers. Also, the low prevalence of positive SS in certain subpopulations limited the power to identify predictors of positive SS. Finally, the data reported in this manuscript is from 2008–2012, but the relationships between patient characteristics and likelihood of occult fractures would not be expected to change over time.

Conclusions

These limitations notwithstanding, our study demonstrates important findings. The high rate of occult fractures in injured infants 0–5 m.o. underscores the importance of SSs in this population. Efforts are needed to improve and standardize the use of SSs in young children presenting with high-risk injuries, and will need to involve ED providers as the majority of children were discharged from the ED without CPT evaluation. In a few hospital settings with infants with select injury types, implementation of child abuse evaluation pathways has been shown to increase rates of SS utilization, decrease bias in SS utilization, and increase detection of child abuse.^{7,8} Thus, clinical pathways implemented in ED and inpatient settings may be one tool for improving SS use in populations of children at high risk for occult abusive fractures. Such pathways could provide guidance on SS performance and/or on involvement of the CPT. Additional data regarding the prevalence of occult abusive

fractures among certain populations of young injured children such infants with burns and the risk factors associated with occult fractures is needed to inform the development of pathways. Furthermore, the impact of implementation of pathways on patient outcomes including detection of occult injuries, diagnoses of abuse, and any adverse outcomes including increased length of stay will need to be monitored. While concerns regarding radiation exposure from SSs have been raised, recent research has demonstrated that the risk is low.³⁹ Adjustments to the pathways may need to be considered based on the data gathered to ensure that they are appropriately targeted to identify the populations of children who are at risk of abuse. Future studies will need to include children who are and are not referred to CPTs in order to better understand the utility of SSs in these potentially different groups. Furthermore, future studies will need to follow children beyond their initial injury presentation to better understand outcomes including rates of occurrence of new abusive injuries among children not evaluated for abuse during their initial presentation.

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Appendix A -: ICD-9-CM and E-codes utilized in identifying study cohort and sampling strategy

Diagnosis Category		ICD-9-CM Codes
Injury Types		
Fracture		800–829
Head injury		850–854
Internal injury (including abdominal injury)		860–869
Bruises		920–924
Burn		940–949
Abuse or assault		995.50, 995.54, 995.55, 995.59, E960-E967, E968.0-E968.3, E968.5-E968.9
Motor vehicle crash related injuries		E800.0-E848.0
Birth related injuries/hospitalizations		V30-V39, 767.0–767.9

Abbreviations:

ED	Emergency Department
CPS	Child Protective Services
CPT	Child Protection Team

ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
MVC	Motor Vehicle Crash
SS	Skeletal Survey
TBI	Traumatic Brain Injury

References

1. U.S. Department of Health and Human Services, Administration on Children, Youth and Families, Children's Bureau. Child maltreatment 2016 2018; <https://www.acf.hhs.gov/cb/research-data-technology/statistics-research/child-maltreatment>. Accessed 4/9/2018.
2. U.S. Department of Health and Human Services, Administration on Children, Youth and Families, Children's Bureau. Child Maltreatment 2015 2017; <http://www.acf.hhs.gov/programs/cb/research-data-technology/statistics-research/child-maltreatment>. Accessed 4/9/2018.
3. Bullock DP, Koval KJ, Moen KY, Carney BT, Spratt KF. Hospitalized cases of child abuse in America: who, what, when, and where. *J Pediatr Orthop* 2009;29(3):231–237. [PubMed: 19305271]
4. Ravichandiran N, Schuh S, Bejuk M, et al. Delayed identification of pediatric abuse-related fractures. *Pediatrics* 2010;125(1):60–66. [PubMed: 19948569]
5. Jenny C, Hymel KP, Ritzen A, Reinert SE, Hay TC. Analysis of missed cases of abusive head trauma. *JAMA* 1999;281(7):621–626. [PubMed: 10029123]
6. Letson MM, Cooper JN, Deans KJ, et al. Prior opportunities to identify abuse in children with abusive head trauma. *Child Abuse Negl* 2016;60:36–45. [PubMed: 27680755]
7. Higginbotham N, Lawson K, Gettig K, et al. Utility of a child abuse screening guideline in an urban pediatric emergency department. *J Trauma Acute Care Surg* 2014;76(3):871–877. [PubMed: 24553563]
8. Rangel EL, Cook BS, Bennett BL, Shebesta K, Ying J, Falcone RA. Eliminating disparity in evaluation for abuse in infants with head injury: use of a screening guideline. *J Pediatr Surg* 2009;44(6):1229–1234; discussion 1234–1235. [PubMed: 19524746]
9. Wood JN, Fakeye O, Feudtner C, Mondestin V, Localio R, Rubin DM. Development of guidelines for skeletal survey in young children with fractures. *Pediatrics* 2014;134(1):45–53. [PubMed: 24935996]
10. Wood JN, Feudtner C, Medina SP, Luan X, Localio R, Rubin DM. Variation in occult injury screening for children with suspected abuse in selected US children's hospitals. *Pediatrics* 2012;130(5):853–860. [PubMed: 23071208]
11. Belfer RA, Klein BL, Orr L. Use of the skeletal survey in the evaluation of child maltreatment. *Am J Emerg Med* 2001;19(2):122–124. [PubMed: 11239255]
12. Merten DF, Radkowski MA, Leonidas JC. The abused child: a radiological reappraisal. *Radiology* 1983;146(2):377–381. [PubMed: 6849085]
13. Lindberg DM, Berger RP, Reynolds MS, Alwan RM, Harper NS, Examining Siblings To Recognize Abuse I. Yield of skeletal survey by age in children referred to abuse specialists. *J Pediatr* 2014;164(6):1268–1273 e1261. [PubMed: 24630357]
14. Day F, Clegg S, McPhillips M, Mok J. A retrospective case series of skeletal surveys in children with suspected non-accidental injury. *Journal of Clinical Forensic Medicine* 2006;13(2):55–59. [PubMed: 16464629]
15. Karmazyn B, Lewis ME, Jennings SG, Hibbard RA, Hicks RA. The Prevalence of Uncommon Fractures on Skeletal Surveys Performed to Evaluate for Suspected Abuse in 930 Children: Should Practice Guidelines Change? *Am. J. Roentgenol* 2011;197(1):W159–163. [PubMed: 21700979]
16. Duffy SO, Squires J, Fromkin JB, Berger RP. Use of Skeletal Surveys to Evaluate for Physical Abuse: Analysis of 703 Consecutive Skeletal Surveys. *Pediatrics* 2011;127(1):e47–52. [PubMed: 21149429]

17. American Academy of Pediatrics. Diagnostic imaging of child abuse. *Pediatrics* 2009;123(5): 1430–1435. [PubMed: 19403511]
18. Christian CW and the American Academy of Pediatrics Committee on Child Abuse and Neglect. The evaluation of suspected child physical abuse. *Pediatrics* 2015;135(5):e1337–1354. [PubMed: 25917988]
19. Wood JN, Hall M, Schilling S, Keren R, Mitra N, Rubin DM. Disparities in the evaluation and diagnosis of abuse among infants with traumatic brain injury. *Pediatrics* 2010;126(3):408–414. [PubMed: 20713477]
20. Lindberg DM, Beaty B, Juarez-Colunga E, Wood JN, Runyan DK. Testing for Abuse in Children With Sentinel Injuries. *Pediatrics* 2015;136(5):831–838. [PubMed: 26438705]
21. Wood JN, Christian CW, Adams CM, Rubin DM. Skeletal surveys in infants with isolated skull fractures. *Pediatrics* 2009;123(2):e247–252. [PubMed: 19171576]
22. Wood JN, French B, Song L, Feudtner C. Evaluation for Occult Fractures in Injured Children. *Pediatrics* 2015;136(2):232–240. [PubMed: 26169425]
23. Ziegler DS, Sammut J, Piper AC. Assessment and follow-up of suspected child abuse in preschool children with fractures seen in a general hospital emergency department. *Journal of Paediatrics and Child Health* 2005;41(5–6):251–255. [PubMed: 15953323]
24. Degraw M, Hicks RA, Lindberg D. Incidence of fractures among children with burns with concern regarding abuse. *Pediatrics* 2010;125(2):e295–299. [PubMed: 20083520]
25. Harper NS, Feldman KW, Sugar NF, Anderst JD, Lindberg DM, Examining Siblings To Recognize Abuse I. Additional injuries in young infants with concern for abuse and apparently isolated bruises. *J Pediatr* 2014;165(2):383–388 e381. [PubMed: 24840754]
26. Dorfman MV, Metz JB, Feldman KW, Farris R, Lindberg DM, Ex SI. Oral injuries and occult harm in children evaluated for abuse. *Arch Dis Child* 2017.
27. Pawlik MC, Kemp A, Maguire S, et al. Children with burns referred for child abuse evaluation: Burn characteristics and co-existent injuries. *Child Abuse Negl* 2016;55:52–61. [PubMed: 27088728]
28. Fisher BT, Lindenaure PK, Feudtner C. In-hospital databases. In: Strom BL, Kimmel SE, Hennessy S, eds. *Pharmacoepidemiology* 5th ed: Wiley-Blackwell; 2012:244–258.
29. Kish L Survey Sampling New York, London: John Wiley & Sons, Inc.
30. Hooft A, Ronda J, Schaeffer P, Asnes AG, Leventhal JM. Identification of physical abuse cases in hospitalized children: accuracy of International Classification of Diseases codes. *J Pediatr* 2013;162(1):80–85. [PubMed: 22854329]
31. Hooft AM, Asnes AG, Livingston N, et al. The Accuracy of ICD Codes: Identifying Physical Abuse in 4 Children's Hospitals. *Acad Pediatr* 2015;15(4):444–450. [PubMed: 26142071]
32. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. *Journal of Biomedical Informatics* 2009;42(2):377–381. [PubMed: 18929686]
33. Oral R, Blum KL, Johnson C. Fractures in young children: are physicians in the emergency department and orthopedic clinics adequately screening for possible abuse? *Pediatr Emerg Care* 2003;19(3):148–153. [PubMed: 12813297]
34. Sheets LK, Leach ME, Koszewski IJ, Lessmeier AM, Nugent M, Simpson P. Sentinel injuries in infants evaluated for child physical abuse. *Pediatrics* 2013;131(4):701–707. [PubMed: 23478861]
35. Wood JN, French B, Song L, Feudtner C. Evaluation for occult fractures in injured children. *Pediatrics* 2015;136(2).
36. Graubard BI, Korn EL. Predictive margins with survey data. *Biometrics* 1999;55(2):652–659. [PubMed: 11318229]
37. Korn EL, Graubard BI. Analysis of health surveys New York: Wiley; 1999.
38. Deye KP, Berger RP, Lindberg DM, Ex SI. Occult abusive injuries in infants with apparently isolated skull fractures. *J Trauma Acute Care Surg* 2013;74(6):1553–1558. [PubMed: 23694887]
39. Berger RP, Panigrahy A, Gottschalk S, Sheetz M. Effective Radiation Dose in a Skeletal Survey Performed for Suspected Child Abuse. *J Pediatr* 2016;171:310–312. [PubMed: 26831745]

What is New?

Skeletal surveys are frequently performed in young children with rib, abdominal and brain injuries, but not children with minor head injuries or burns. The prevalence of occult fractures within an age category is dependent on the type of presenting injury.

Figure 1 –.
Study Cohort Flow Diagram

Figure 2- Skeletal Survey Performance by Presenting Injury Type and Age.

Results were generated from logistic regression analysis using marginal standardization, adjusting insurance, hospital, gender, insurance type, race, history of presentation and the interaction of age category with presenting injury type. 95% CI are included. Results for rib fractures and abdominal injuries are not included due to the low number of subjects by age category.

Figure 3- Occult Fracture Detection by Presenting Injury Type and Age Category Among the Subset of Children receiving a SS.

Results were generated from logistic regression analysis using marginal standardization, adjusting insurance, hospital, gender, insurance type, race, history of presentation and the interaction of age category with presenting injury type. The denominator includes only children who underwent a SS. Results for rib fractures and abdominal injuries are not included due to the low number of subjects by age category. No data point is presented if there were 0 children with a positive skeletal survey in a given category. 95% CI are included.

Figure 4- Occult Fracture Detection by Presenting Injury Type and Age Category Among All Children Regardless of SS Performance.

Results were generated from logistic regression analysis using marginal standardization, adjusting insurance, hospital, gender, insurance type, race, history of presentation and the interaction of age category with presenting injury type. The denominator includes all children even those who did not receive a SS. Results for rib fractures and abdominal injuries are not included due to the low number of subjects by age category. No data point is presented if there were 0 children with a positive SS in a given category. 95% CI are included.

Table 1-

Unadjusted Associations of Demographic and Clinical Characteristics with Skeletal Survey Receipt and Positive Skeletal Survey (unweighted N=1769)

	Skeletal Survey Obtained %	P-value	Skeletal Survey Positive ^a %	P-value
Demographic Characteristics				
Age Category				
0 – 5 m.o. (16.3%)	46.3		24.6	
6 – 11 m.o. (21.9%)	21.1	<0.001	9.7	<0.001
12 – 17 m.o. (30.0%)	8.0		6.4	
18 –23 m.o. (31.8%)	6.2		3.6	
Sex				
Female (44.2%)	16.2	0.74	13.7	0.40
Male (55.8%)	16.8		16.5	
Race				
White Non-Hispanic (54.5%)	18.4	0.09	14.1	0.72
Black (24.6%)	13.7		15.6	
Hispanic (10.2%)	12.5		17.4	
Other/Unknown (10.7%)	17.4		20.6	
Insurance				
Private (44.5%)	12.0		9.0	
Public/uninsured (55.2%)	20.3	<0.001	18.4	0.004
Unknown (0.3%)	10.7		-	
Clinical Characteristics				
History at Presentation ^b				
History of accidental trauma (86.4%)	9.1%	<0.001	11.5	0.02
History of inflicted trauma (0.7%)	61.4%		11.4	
Signs, symptoms suggestive of injury (11.5%)	65.5%		17.7	
Medical concerns unrelated to injury (1.1%)	64.0%		32.3	
First Identified Injury				
Extremity fracture (23.6%)	19.6	<0.001	17.9	0.07
Head injury, minor (22.7%)	4.4		7.8	
Bruises (17.3%)	18.7		14.2	
Burns (13.2%)	2.1		6.0	
Other injury (9.3%)	3.1		24.9	
Traumatic brain injury (7.0%)	64.7		16.0	
Skull fracture (6.4%)	33.7		7.8	
Abdominal injury (0.3%)	52.3		16.7	
Rib fracture (0.3%)	100.0		45.9	

	Skeletal Survey Obtained %	P-value	Skeletal Survey Positive ^a %	P-value
Demographic Characteristics				
Child Abuse Evaluation & Determination				
Child Protection Team Consulted				
No (86.8%)	5.7	<0.001	3.2	<0.001
Yes (13.2%)	88.1		20.4	
Report Made to Child Protective Services				
No (86.2)	5.5	<0.001	0.5	<0.001
Yes (13.8)	85.8		21.2	
Disposition				
Home without services (87.3%)	6.7	<0.001	0.9	<0.001
Home with services (7.5%)	84.8		8.9	
Out of home placement (4.0%)	96.5		45.8	
Deceased (0.4%)	77.3		36.6	
Other (0.8%)	27.3		15.8	

The weighted percentages of the population with the characteristics are indicated in parentheses. Because percentages represent weighted samples, they cannot be used to extrapolate unweighted Ns.

CPS- Child protective services; ED – Emergency Department; m.o. – months old

^a The percentage of patients who underwent a skeletal survey and had a positive skeletal survey defined as detection of occult fractures is presented. Thus the denominator includes only children who received a skeletal survey.

^b An additional 0.03% presented because they were a close contact of a suspected victim of abuse and 0.3% presented for other or unknown reasons.

Table 2-

Unadjusted Associations of Care Setting Characteristics with Skeletal Survey Receipt and Positive Skeletal Survey (unweighted N=1769)

	Skeletal Survey Obtained %	P-value	Skeletal Survey Positive ^a %	P-value
Care Setting Characteristics				
Hospital				
A (26.7%)	11.7		16.6	
B (29.2%)	17.1	<0.001	19.7	0.13
C (21.0%)	26.6		10.5	
D (23.1%)	12.3		15.5	
Care Setting^b				
Inpatient (10.7%)	66.8		25.1	
Emergency Department (84.8%)	8.9	<0.001	9.6	<0.001
Observation (4.5%)	41.8		0.6	

The weighted percentages of the population with the characteristics are indicated in parentheses.

^aThe percentage of patients who underwent a skeletal survey and had a positive skeletal survey defined as detection of occult fractures is presented. Thus the denominator includes only children who received a skeletal survey.

^bPatients cared for in the emergency department and subsequently admitted to the inpatient setting were categorized as inpatient.

**Table 3 –
Standardized Predictors of Skeletal Survey Performance and Occult Fracture Detection**

Logistic regression models tested for associations between the listed demographic characteristics and clinical characteristics with the primary outcomes of SS completion and positive SS. Marginal standardization was implemented in logistic regression to generate the standardized estimated percentages of children receiving a SS (and having a positive SS) for each predictor variable.

Characteristic (n weighted)	SS Performance		SS Positive ^a	
	Standardized Proportion (95% CI)	P-Value	Standardized Proportion (95% CI)	P-Value
Age category				
0–5 months	27.4 (22.1–32.7)	<0.001	25.6 (18.7–32.4)	<0.001
6–11 months	20.1 (16.7–23.6)		9.5 (3.3–15.8)	
12–17 months	11.5 (8.4–14.5)		5.1 (1.1–9.1)	
18–23 months	12.4 (8.9–16.0)		2.2 (0.0–5.0)	
Sex				
Male	17.2 (14.9–19.5)	0.50	16.7 (11.1–22.4)	0.26
Female	18.4 (16.1–20.6)		12.4 (7.9–16.8)	
Race				
Non-Hispanic White	17.5 (15.5–19.5)	0.87	14.5 (10.7–18.3)	0.94
Black	18.6 (15.0–22.2)		15.9 (7.7–24.1)	
Hispanic	17.6 (11.9–23.3)		13.8 (4.1–23.5)	
Insurance				
Private	14.3 (12.0–16.6)	<0.001	8.9 (4.5–13.3)	0.01
Public/uninsured	20.8 (18.3–23.4)		17.7 (13.3–22.2)	
History at Presentation ^b				
Accidental trauma	11.4 (9.7–13.2)	<0.001	12.9 (6.7–19.1)	0.13
Inflicted trauma/abuse	58.7 (28.1–89.4)		14.3 (3.8–24.9)	
Signs or symptoms suggestive of injury	51.4 (42.9–59.9)		15.2 (10.4–19.9)	
Medical concerns	48.9 (22.80–74.9)		27.5 (14.6–40.4)	
First Identified Injury				
Extremity fracture	19.5 (15.4–23.6)	<0.001	23.4 (14.0–32.8)	0.14
Head injury, minor	6.7 (3.1–10.4)		6.3 (0.0–13.7)	
Bruises	15.4 (11.7–19.0)		15.1 (6.4–23.8)	
Burns	4.2 (0.4–8.0)		8.1 (0.0–18.1)	
Traumatic brain injury	46.2 (36.3–56.1)		11.1 (6.8–15.4)	
Skull fracture ^c	26.5 (19.0–34.0)		9.4 (0.0–19.4)	
Abdominal	32.6 (6.7–58.4)		25.4 (0.0–55.0)	
Rib fracture	100.0 (NA) ^d		20.1 (6.4–33.7)	

Characteristic (n weighted)	SS Performance		SS Positive ^a	
	Standardized Proportion (95% CI)	P-Value	Standardized Proportion (95% CI)	P-Value
Hospital				
A	15.1 (11.6–18.7)	<0.001	20.9 (12.5–29.3)	0.14
B	17.0 (14.0–20.0)		16.8 (9.5–24.1)	
C	25.9 (21.9–29.8)		9.7 (5.1–14.3)	
D	11.9 (9.1–14.7)		17.1 (10.2–24.0)	

^a Only children who received a skeletal survey were included in the model.

^b Excludes children evaluated because contact of suspected victim of abuse.

^c Includes children who presented with a skull fracture without intracranial injury.

^d All patients with rib fractures as first identified injury underwent skeletal survey. 95% CI unable to be calculated.