

# Use of Skeletal Surveys to Evaluate for Physical Abuse: Analysis of 703 Consecutive Skeletal Surveys

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## KEY WORDS

skeletal survey, child physical abuse, apparent life-threatening event, abusive head trauma

## ABBREVIATIONS

SS—skeletal survey  
CPT—child protection team  
ALTE—apparent life-threatening event  
AAP—American Academy of Pediatrics

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**WHAT'S KNOWN ON THIS SUBJECT:** The skeletal survey (SS) is part of the evaluation of suspected physical abuse. Previous studies focused on the use of the SS for children whom the diagnosis of abuse was strongly suspected before completion of the SSs.



**WHAT THIS STUDY ADDS:** This is the first study to describe the use of SSs in a large, consecutive population of children being evaluated because of concerns regarding physical abuse.

## abstract

**OBJECTIVES:** The goals were to assess the use of the skeletal survey (SS) to evaluate for physical abuse in a large consecutive sample, to identify characteristics of children most likely to have unsuspected fractures, and to determine how often SS results influenced directly the decision to make a diagnosis of abuse.

**METHODS:** A retrospective, descriptive study of a consecutive sample of children who underwent an SS at a single children's hospital over 4 years was performed. Data on demographic characteristics, clinical presentation, SS results, and effects of SS results on clinical diagnoses were collected. A positive SS result was defined as a SS which identified a previously unsuspected fracture(s).

**RESULTS:** Of the 703 SSs, 10.8% yielded positive results. Children <6 months of age, children with an apparent life-threatening event or seizure, and children with suspected abusive head trauma had the highest rates of positive SS results. Of children with positive SS results, 79% had  $\geq 1$  healing fracture.

**CONCLUSIONS:** This is the largest study to date to describe the use of the SS. Almost 11% of SS results were positive. The SS results influenced directly the decision to make a diagnosis of abuse for 50% of children with positive SS results. These data, combined with the high morbidity rates for missed abuse and the large proportion of children with healing fractures detected through SS, suggest that broader use of SS, particularly for high-risk populations, may be warranted. *Pediatrics* 2011;127:e47–e52

In 2006, >140 000 children in the United States were victims of physical abuse.<sup>1</sup> Fractures are a common manifestation of physical abuse. Although abusive fractures rarely are fatal, the importance of early recognition of child abuse cannot be overemphasized. A significant proportion of children who die as a result of abuse were evaluated previously by medical professionals for injuries and/or symptoms that were very likely attributable to abuse but were not recognized as being abusive.<sup>2–5</sup> Clinicians are faced with 2 distinct challenges, that is, to determine whether a fracture may be the cause of a child's symptoms and, if a fracture is identified, to determine whether abuse may be the cause of the fracture.

The skeletal survey (SS) is the standard screening tool for detecting clinically unsuspected fractures. The American Academy of Pediatrics (AAP) recommends a SS for all children <2 years of age for whom abuse is suspected and for selected children 2 to 5 years of age.<sup>6</sup> The term "suspected" is intentionally vague and likely is interpreted differently by different physicians, depending on their own experiences, backgrounds, and perceptions of the potential benefits of the SS, relative to the risks.<sup>7–9</sup>

The number of studies that evaluated the use of the SS is remarkably limited, and they generally included only children for whom there was already strong suspicion or a diagnosis of abuse before a completed SS.<sup>10–12</sup> Not surprisingly, large proportions of children in those studies had fractures identified on the SS; for example, 24% and 33% of the subjects in the studies by Day et al<sup>12</sup> and Merten et al,<sup>10</sup> respectively, had fractures identified on SS.

The aim of the current study was to describe the use of the SS to screen for clinically unsuspected fractures in a

**TABLE 1** Reasons for Presentation to Hospital (*N* = 703)

	No. (%)	
	Cases	Positive SS Results
History of trauma	243 (35)	27 (11)
Symptom suggesting injury (eg, swelling or decreased movement)	145 (21)	16 (11)
Request by child protective services to evaluate for abuse	112 (16)	7 (6)
Nonspecific symptoms (eg, fussiness or vomiting)	64 (9)	6 (9)
ALTE	66 (9)	12 (18)
Seizure	24 (3)	6 (25)
Increased occipitofrontal circumference	13 (2)	0 (0)
Respiratory distress	7 (1)	0 (0)
Other	29 (4)	2 (7)

consecutive, rather than selective, sample of children. By using a consecutive sample, we minimized the enrollment bias of previous studies. Our objectives were to describe (1) the number of SSs performed over time, (2) the reasons children who underwent an SS presented to the hospital, (3) the reasons an SS were performed, and (4) the proportions of SSs that resulted in the identification of unsuspected fractures. For the subset of patients with positive SS results, we also sought to describe how often the SS results influenced directly the decision to make a diagnosis of abuse.

## METHODS

### Study Design

This was a retrospective, descriptive study approved by the University of Pittsburgh institutional review board with a waiver of informed consent requirements. Children were eligible if they underwent an SS, because of concerns regarding abuse, at the Children's Hospital of Pittsburgh of UPMC between April 1, 2002, and April 1, 2006. The SS performed at Children's Hospital of Pittsburgh meets the AAP recommendations.<sup>6</sup>

### Data Collected

Each subject's medical record was reviewed for the following information: gender, age, reason for presentation to the hospital, reason for SS, and SS

results. The race of children is not documented as part of our hospital's records. Age was categorized into 5 categories (<6 months, 6–11.9 months, 12–23.9 months, 24–58.9 months, or >59 months) on the basis of a combination of the AAP recommendations related to the SS, previous studies that demonstrated that ages of <12 months were associated with a greater probability of positive SS results,<sup>10–12</sup> and our own belief that, within the <12-month-old age group, those <6 months of age would be most likely to have positive SS results. By using an iterative process involving a review of 50 randomly selected cases, 2 investigators (Ms Duffy and Dr Squires) developed categories for reasons for presentation to the hospital (Table 1) and reasons for the SS (Table 2). Categorization of each case was made by a single investigator (Ms Duffy). For assessment of interrater reliability, a random sample of 5% of the records was reassessed by an independent investigator (Dr Fromkin).

Data on the location and age (acute versus healing) of each fracture identified by SS were collected. Each case in which the SS results were positive was classified as definite abuse, probable abuse, possible abuse, or not abuse on the basis of the conclusion of the Children's Hospital of Pittsburgh child protection team (CPT). Use of the findings of a CPT to define whether an

**TABLE 2** Reasons for SS (*N* = 703)

	No. (%)	
	Cases	Positive SS Results
Recognized fracture	257 (37)	24 (9)
Features of child abuse (eg, bruising, burns, sexual abuse)	135 (19)	12 (9)
Suspected abusive head trauma	88 (13)	20 (23)
Social concerns (eg, abused sibling, child protective services request, neglect)	88 (13)	4 (5)
Symptoms of injury	38 (5)	5 (13)
Nonspecific symptoms	30 (4)	3 (10)
ALTE	26 (4)	3 (12)
Unexplained death	23 (3)	4 (17)
Other	18 (3)	1 (6)

In cases in which there was >1 reason for the SS, the reason that raised the most concern regarding abuse (eg, bruising for an infant with bruising and vomiting) was recorded.

injury is attributable to abuse is a commonly used standard<sup>13–15</sup> and one that our group used in previous studies.<sup>16–18</sup> The CPT was consulted in every case in which there was a positive SS result, and there was no disagreement within the CPT about the classification of abuse for any of the subjects in the study. For purposes of analysis, children with definite abuse or probable abuse had a diagnosis of abuse; children with possible abuse or no abuse had no diagnosis of abuse. Our decision to subcategorize in this way was based on data from a previous study by our group that evaluated the cost of child maltreatment.<sup>19</sup> In this study, children with possible abuse were most similar to subjects with no abuse, whereas subjects with probable abuse were most similar to subjects with definite abuse.

The medical record for each case in which the SS results were positive was reviewed by a single investigator (Dr Berger), to determine whether the SS results influenced directly the decision to make a diagnosis of abuse. Cases in which the SS results influenced the clinical diagnosis directly were those in which the SS results changed the clinical assessment from possible abuse to probable or definite abuse. Cases in which the SS results did not influence the clinical diagnosis directly were those in which a diagnosis

of definite or probable abuse was not made despite positive SS results (eg, a case in which a healing clavicle fracture identified through the SS was thought to be birth-related and not attributable to abuse) and those in which the diagnosis of abuse would have been made even if the SS results had been negative (eg, a case of abusive head trauma). To assess interrater reliability for this variable, 50% of the records were selected randomly for independent review by a second investigator (Dr Squires).

### Definitions

Recognized fractures were fractures diagnosed before the SS was completed. Positive SS results were those that identified a fracture that was not suspected clinically or recognized previously. For example, a SS that demonstrated an arm fracture in a child with arm swelling would be considered to have positive results only if there was an additional, unsuspected fracture. Suspected abusive head trauma was documented as the reason for a SS only if abnormal neuroimaging results were obtained before the SS was completed. Multiple rib fractures were considered a single fracture, because multiple rib fractures frequently occur as part of a single action. In cases in which the radiologist reported a possible fracture, subsequent imaging re-

sults were reviewed. If a fracture was confirmed with follow-up radiographs or bone scans, then the SS results were considered positive. If follow-up test results refuted the initial suggestion, if no follow-up testing was performed or if the results of additional testing were inconclusive, then the SS results were considered negative. Child abuse was defined by the Children's Hospital of Pittsburgh CPT as discussed above.

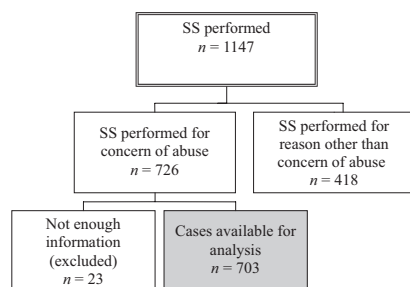
### Statistical Analyses

SPSS 16.0 (SPSS, Chicago, IL) was used for all analyses. Descriptive statistics were used to describe the study population,  $\chi^2$  tests were used to compare dichotomous variables, and *t* tests and Mann-Whitney tests were used, as appropriate, to examine group differences. Analysis of variance was used to evaluate changes over time. A  $\kappa$  statistic was calculated to assess the interrater reliability for 3 variables: reason for presentation to the hospital, reason for SS, and whether the SS results influenced the clinical diagnosis directly. *P* < .05 was considered significant.

## RESULTS

### Demographic Features

During the 4-year study period, 1147 children underwent an SS. After exclusion of children who underwent a SS for a reason other than suspected abuse and those for whom there was not enough information to determine the reason for the SS, 703 subjects were eligible for inclusion (Fig 1). In 97.2% of cases, the SS was performed in the emergency department or another outpatient setting. The median age of the subjects was 8.0 months (range: 4 days to 12 years). Eighty-four percent of subjects were <2 years of age, 15% of subjects were 2 to 5 years of age, and the remaining 1% of subjects were >5 years of age. Fifty-seven percent of subjects were male. The



**FIGURE 1**  
Flowchart for subject selection.

mean  $\pm$  SD number of SSs performed in each year of the study period was  $177 \pm 29$ . There was no change in the number of SSs performed over time.

### Reasons for Hospital Presentation and Reasons for SS

The most common reason for presentation to the hospital was a history of trauma (35%), followed by a symptom(s) of injury (21%) (Table 1). The most common reason for the SS was recognized fracture (37%), followed by features of child abuse (19%) (Table 2). There was high interrater reliability for reasons for presentation to the hospital ( $\kappa = 0.96$ ) and reasons for the SS ( $\kappa = 0.92$ ).

### Rates of Positive SS Results

Of the 703 SSs performed, 76 (10.8%) yielded positive results. The proportion of positive SS results ranged from 8.0% in the first study year to 15.9% in the last year, but the overall increase was not significant. Children  $<6$  months of age had a higher rate of positive SS results than did children  $>6$  months of age (16.4% vs 6.8%;  $P < .00$ ,  $\chi^2$  test). There was no difference in the rates of positive SS results for children 6 to 11.9 months of age, compared with those 12 to 23.9 months of age or 24 to 58.9 months of age (Table 3). Among subjects with positive SS results, 42 (55%) had a single fracture, 18 (24%) had 2 fractures, and 16 (21%) had  $\geq 3$  fractures. The most common location of the unsuspected fractures was the ribs.

**TABLE 3** Positive SS Results According to Age

Age	No. (%)	
	SS Performed	Positive SS Results
0–5.9 mo	292	48 (16.4)
6–11.9 mo	165	12 (7.2)
12–23.9 mo	135	9 (7.3)
24–59 mo	105	6 (5.7)
$>60$ mo	6	1 (16.7)

Fracture age (eg, acute versus non-acute/healing) was included in the radiology report in 82% of cases (62 of 76 cases). Of the subjects for whom fracture age was noted by the radiologist, 13 (21%) had only acute fractures, 35 (56%) had only healing fractures, and 14 (23%) had both acute and healing fractures. Therefore, 79% of all children (49 of 62 children) for whom fracture age data were available had  $\geq 1$  healing fracture.

### Comparison of Clinical Characteristics of Subjects With Positive and Negative SS Results

The median age of subjects with positive SS results was lower than that of subjects with negative SS results (4.0 vs 8.0 months;  $P = .001$ , Mann-Whitney test). Children who presented to the hospital with an apparent life-threatening event (ALTE)/apnea or a seizure had higher rates of positive SS results than did those who presented for other reasons (ALTE, 18.2% [12 of 66 children];  $P = .05$ ; seizure, 33% [6 of 18 children];  $P = .02$ ). The rate of positive SS results for subjects who underwent the SS because of suspected abusive head trauma was higher than the rate of positive results for subjects who underwent the SS for other reasons (23% [20 of 88 children] vs 9.1% [56 of 615 children];  $P < .00$ ). Contrary to previous studies, children with recognized fractures were not more likely to have positive SS results than were children who had SSs performed for other reasons.

### Use of the SS to Aid Evaluation of Suspected Physical Child Abuse

Fifty-eight of the 76 subjects with positive SS results were diagnosed with physical abuse. In 50% of cases (38 of 76 cases) in which there were positive SS results, the SS results influenced directly the decision to make a diagnosis of abuse. In the remaining 38 cases, either a diagnosis of abuse was not made (20 of 38 cases) or a diagnosis of abuse would have been made even if the SS results had been negative (18 of 38 cases). There was almost perfect interrater reliability ( $\kappa = 0.90$ ) for determination of whether the SS results influenced directly the decision to make a diagnosis of abuse.

### DISCUSSION

This is the largest study performed to date to describe the use of SSs for children with suspected physical abuse. Unlike previous studies, all children who underwent an SS during a 4-year period were included. Our definition of a SS with positive results is considerably more restrictive than those used in several previous studies; a child with arm swelling and an isolated arm fracture, for example, was not considered to have positive SS results in the current study. For this reason, the 10.8% rate of positive SS results in our sample is probably more accurate for current clinical practice than rates observed in previous studies of children hospitalized because of abuse.<sup>10–12,20</sup>

The large proportion of subjects with healing fractures detected through SSs is consistent with our knowledge that abuse is a cycle and that children who are returned to abusive homes often are abused again. It also suggests that there might have been previous opportunities to make a diagnosis of abuse for these children. A recently published study by Ravichandiran et al<sup>21</sup> suggested that  $\geq 20\%$  of children with healing fractures had  $\geq 1$  previ-



ous visit to a medical professional during which the diagnosis of abuse was missed.

The significantly higher rate of positive SS results for children <6 months of age, compared with older children, is noteworthy, given the previous data and current AAP recommendations. Three previous studies demonstrated that age of <12 months was associated with higher rates of positive SS results,<sup>10–12</sup> whereas the AAP recommendation is that an SS be performed for children <2 years of age, without specific recommendations for younger infants. Our study is the first study, to our knowledge, to have a large enough sample size for analysis of different age cohorts within the group of children <12 months of age. On the basis of these data, we would advocate more-liberal use of SSs for very young infants rather than more-restrictive use of SSs for older children, because the rate of positive SS results for children between 6 months and 2 years of age was still close to 7%.

The high rate of positive SS results among children who presented with ALTEs was unexpected, although perhaps not surprising. The relationship between ALTEs and child abuse is well documented, and the literature suggests that up to 10% of ALTEs may be attributable to abuse.<sup>22–25</sup> We caution, however, against making recommendations for changes in clinical practice on the basis of our findings; although the rate of positive SS results in this population was higher than expected, the proportion of children with ALTEs who underwent an SS was small. During the same 4-year time period as in the current study, 421 children were discharged from our ED with a diagnosis of ALTE. Therefore, ~15% of children with ALTEs underwent an SS. In a smaller study of children with ALTEs performed by Brand et al,<sup>26</sup> a SS was completed for only 6.6% of subjects

with ALTEs (16 of 243 subjects) and was positive in 19% of cases (3 of 16 cases). It is likely that there are differences between children with ALTEs who do and do not undergo an SS (eg, severity of ALTE, age of the child, and presence or absence of other findings concerning regarding abuse). As a result, we think that it would premature to make a recommendation about the evaluation of all children with ALTEs. A prospective study is currently underway at our hospital to identify characteristics of children with ALTEs that are associated with obtaining a SS.

Among the 38 children for whom positive SS results influenced the clinical diagnosis directly were 3 infants who presented with a history of a fall, had isolated skull fractures on head computed tomographic scans, and had no stigmata of abuse, as defined by Wood et al.<sup>27</sup> In that study, the authors suggested that children who meet these criteria (ie, history of a fall, isolated skull fracture, and no stigmata of abuse) might not need a SS. In our series, the diagnosis of abuse for these infants would have been missed if the SS had not been completed. These cases highlight the need to continue performing an SS for young children with isolated skull fractures and a history of trauma, until additional data are available.

The study has several limitations. First, it was retrospective. Collecting data retrospectively is challenging because the reasons for presentation to the hospital and the reasons for SS require assessment. Use of a single data extractor contributed to internal consistency, as the high  $\kappa$  values suggest. A prospective study with a waiver of informed consent would allow better assessment of the reason for a SS and likely would improve our ability to identify characteristics of children who are most likely to have positive SS results. Another limitation is related to the inability to account for physician

bias in the ordering of SSs. Therefore, it is not possible to draw conclusions about the true rate of positive SS results for any given group of children. Enrollment bias of this type is unavoidable without a SS being performed for every child who presents with each of the presenting symptoms. This approach would be difficult to justify from an ethical perspective, because of the radiation risk from the SS.

## CONCLUSIONS

This study used a restrictive definition of positive SS results (ie, finding of a fracture that was completely unsuspected) in a large sample and found a rate of positive SS results close to 11%. In 50% of cases in which the SS results were positive, the SS results influenced directly the decision to make a diagnosis of abuse. Given the high morbidity and mortality rates of child abuse and our finding that the highest rate of positive SS results was for children <6 months of age, we recommend that a SS be completed for all infants <6 months of age for whom there is any suspicion of abuse. Additional data are needed to determine which subset of children presenting with ALTEs should undergo an SS.

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