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Nancy S. Harper, Sonja Eddleman, Daniel M. Lindberg and for the ExSTRA  
Investigators

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# The Utility of Follow-up Skeletal Surveys in Child Abuse



**WHAT'S KNOWN ON THIS SUBJECT:** Follow-up skeletal surveys are conducted commonly in children with suspected physical abuse, despite limited evidence. Different guidelines recommend follow-up skeletal surveys in children with abnormal initial skeletal surveys or in cases with high risk.



**WHAT THIS STUDY ADDS:** Across several centers, follow-up skeletal surveys revealed new information in >20% of cases and frequently affected the perceived likelihood of abuse, even in cases where the initial level of concern for abuse was moderate.

## abstract

**OBJECTIVE:** Follow-up skeletal surveys (FUSS) are performed frequently in cases of possible physical abuse based on the evidence from small retrospective cohorts. Our objective was to determine the proportion of FUSS that identified new information in a large, multicenter population of children with concerns of physical abuse.

**METHODS:** This was a prospective secondary analysis of an observational study of all children <10 years of age (120 months) who underwent evaluation for possible physical abuse by 20 US child abuse teams. This analysis included all children in whom FUSS was recommended and measured rates of FUSS completion, results of FUSS, and the change in perceived likelihood of abuse before and after FUSS.

**RESULTS:** Among 2890 children enrolled in the Examining Siblings To Recognize Abuse research network, 2049 underwent skeletal survey and 796 (38.8%) had FUSS. A total of 174 (21.5%) subjects had new information identified by FUSS, including 124 (15.6%) with at least 1 new fracture and 55 (6.9%) with reassuring findings compared with the initial skeletal survey. Among cases with new fractures, the estimated likelihood of abuse increased in 41 (33%) cases, and 51 cases (41%) remained at the maximum likelihood of abuse.

**CONCLUSIONS:** FUSS identified new information and affected the perceived likelihood of abuse in a substantial fraction of cases in which it was completed. These data support existing guidelines and, in addition, suggest that FUSS should be considered in cases with lower initial levels of concern for abuse. *Pediatrics* 2013;131:e672–e678

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### KEY WORDS

abuse, fractures, screening, skeletal survey

### ABBREVIATIONS

AAP—American Academy of Pediatrics

CAP—child abuse physician

CPS—Child Protective Services

ExSTRA—Examining Siblings To Recognize Abuse

FUSS—follow-up skeletal survey

SS—skeletal survey

Dr Harper participated in the initial conceptualization and design of the study, planned and participated in data collection, carried out the initial data analysis/interpretation, drafted the initial manuscript, reviewed and revised the initial manuscript, and approved the final manuscript as submitted; Sonja Eddleman participated in the initial conceptualization and design of the study, planned and participated in data collection, participated in data analysis/interpretation, reviewed and revised the initial manuscript, and approved the final manuscript as submitted; and Dr Lindberg participated in the initial conceptualization and design of the study, supervised data collection, participated in data analysis/interpretation, reviewed and revised the initial manuscript, and approved the final manuscript as submitted.

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In 2011, there were 3.4 million referrals to Child Protective Services (CPS) of whom 681 000 children were found to be victims of abuse and neglect. More than 15% of these children were victims of physical abuse. The youngest and most vulnerable children were disproportionately affected; children <4 years of age represented 80% of fatalities from abuse and neglect.<sup>1</sup> Large population-based studies estimate the incidence of inflicted skeletal trauma and brain injury at 21.9 cases per 100 000 children <36 months of age and at 50.0 cases per 100 000 children <12 months of age.<sup>2</sup> Although the majority of fractures are still attributed to accidental injury, child abuse accounts for ~10% of these injuries.<sup>2,3</sup>

Abusive fractures are underrecognized in nonambulatory children with devastating consequences, including additional skeletal trauma<sup>4</sup> or abusive head trauma.<sup>5</sup> The history provided by the caregiver may be viewed as plausible in the absence of additional cutaneous or skeletal trauma. Fractures may not be appreciated on examination, because bruising near the site of skeletal trauma, excluding the skull, is seen in <10% of infants and children at the time of presentation.<sup>6,7</sup> The identification of additional occult injuries through the use of detailed skeletal imaging, such as the skeletal survey (SS), can affect both the plausibility of the history offered as well as the perceived likelihood of abuse.

The SS is recommended by the American Academy of Pediatrics (AAP) in all cases of suspected physical abuse in infants and children <2 years of age,<sup>8</sup> and it may be considered for older children in whom rates of occult fracture identification are lower.<sup>9,10</sup> Even when performed correctly, SS may fail to identify acute rib and metaphyseal fractures. Techniques to improve the identification of these fractures include the addition of oblique views of

the chest to the SS,<sup>11</sup> computed tomography of the chest,<sup>12</sup> bone scan,<sup>13,14</sup> or repeat skeletal imaging in 2 weeks.<sup>13,15–17</sup> The AAP recommends that the initial SS be repeated in 2 weeks when abuse is “suspected on clinical grounds” and initial findings are “abnormal or equivocal.”<sup>18</sup> In small, retrospective series from single centers, the follow-up skeletal survey (FUSS) has been reported to yield additional information in 38% to 61% of cases and to change the outcome of the case (ruling abuse in or out).<sup>15–17</sup> However, these series showed broad variability in the rate that FUSS was ordered and may not be widely generalizable, because they do not describe the frequency with which FUSS is recommended or obtained and because they are drawn from single centers.

Our objective was to determine the proportion of FUSS that identified new information in a large, multicenter population of children with concerns of physical abuse.

## METHODS

This was a prospectively planned secondary analysis of data from the Examining Siblings To Recognize Abuse (ExSTRA) research network, the methods of which have been described previously.<sup>19</sup> In brief, the ExSTRA research network was a prospective, observational study of 20 US child abuse teams that included all children <10 years of age who underwent subspecialty evaluation for concerns of physical abuse. Although the primary analysis of the ExSTRA network involved household contacts such as siblings or children who shared a day-care with the index child, the present analysis includes data only from index children. All participating centers and the data coordinating center obtained approval with waiver of informed consent from their local institutional review board.

Centers included in the ExSTRA research network conducted SSs according to published guidelines from the AAP and/or American College of Radiology.<sup>18</sup> Views of the skull are routinely excluded from most FUSS, because the membranous bones of the skull do not exhibit callous in the healing process and fractures are therefore less likely to become more apparent over time.<sup>20</sup> In addition, 6 participating centers routinely exclude views of the spine, and 5 of these centers also exclude views of the pelvis based on previous data suggesting that these views are unlikely to identify additional fractures.<sup>17</sup> All skeletal surveys (initial or follow-up) were interpreted as usual by experienced pediatric radiologists. In cases where findings were unclear, or when there was disagreement among specialists, the clinically responsible child abuse physician (CAP) made the ultimate determination on the presence of a fracture after review of available testing, clinical information, and subspecialty consultation. In determining the presence of a fracture, CAPs were instructed to use the standard of whether they would include the presence of the fracture in the medical record, or testify to its presence in court. A fracture was considered to be newly identified by the FUSS if it had not previously been demonstrated to this standard.

Data were entered prospectively into a secure, web-based data entry form (Quickbase, Intuit, Waltham, MA). CAPs recorded whether an initial SS was obtained and whether a FUSS was recommended, whether the FUSS was ultimately completed, and any results. CAPs were specifically asked whether the FUSS identified new fractures, any new mimics of abuse, or the FUSS determined that a concerning finding on the initial SS was, in fact, not a fracture. A FUSS was considered to provide new

information if 1 or more of the above findings was noted.

Both before and after the FUSS was obtained, CAPs estimated the likelihood of abuse by using a previously published 7-point scale of perceived abuse likelihood where a rating of 7 “Definite inflicted injury” represents the highest perceived likelihood of abuse and a rating of 1 “Definitely not inflicted injury” the lowest (Appendix).<sup>21</sup>

## RESULTS

The ExSTRA research network abstracted data from 2890 index children, the demographics of which have been published elsewhere.<sup>19</sup> Initial SSs were obtained in 2049 children and identified a new injury in 471 (23%; Table 1). Among children with an initial SS, FUSS was recommended in 1038 (50.7%) and was obtained in 796 (76.7%) subjects in whom it was recommended. FUSS was recommended more commonly in subjects <24 months of age (55.4% vs 23.1% for those >24 months; odds ratio, 4.37; 95% confidence interval, 3.09–6.19) and with higher initial perceived likelihood of abuse (Table 2). Six centers (with 264 FUSS) excluded views of the spine, and 5 of these centers (with 239 FUSS) also excluded views of the pelvis.

A new fracture was identified by FUSS in 124 (15.6%) subjects. More than half (65, 52.4%) of these subjects had multiple additional fractures identified, the majority of which were rib fractures. The location of additional fractures identified by FUSS is shown in Table 3. The exact number of fractures is not available from free text data entries because, in many cases, investigators provided only general counts, such as “multiple rib fractures.” Whereas rib fractures, long-bone fractures, and classic metaphyseal lesions were the most common fractures to be identified, fractures of the hands, feet, spine, and scapula, which are relatively

**TABLE 1** Rates of Initial SS, FUSS, and Injury Identification

	0–24 mo <sup>a</sup> (n = 1975)	>24 mo <sup>a</sup> (n = 915)	Total (n = 2890)
SS obtained	1750 (88.6)	299 (32.7)	2049 (70.9)
SS shows new injury	417 (23.8)	54 (18.1)	471 (23.0)
FUSS recommended	969 (55.4)	69 (23.1)	1038 (50.7)
FUSS obtained	752 (43.0)	44 (15.4)	796 (38.8)
FUSS shows new injury	119 (15.8)	5 (11.4)	124 (15.6)
FUSS reassuring	52 (6.9)	3 (7.1)	55 (6.9)

The values are presented as n (%). Percentages of injuries identified are calculated by using the number of completed studies as the denominator.

<sup>a</sup> Age was determined with precision. A child that was 1 hour past his 2nd birthday at the time of admission was included with the >24 month group.

**TABLE 2** Rates of FUSS Recommendation and Completion and Rates of New Fracture Identification According to Initial Perceived Level of Concern for Abuse

Initial Perceived Likelihood of Abuse	SS Obtained, n	FUSS Recommended, n (%)	FUSS Completed, n (%)	New Fracture Identified, n (%)
1. Definitely not inflicted injury	78	6 (7.7)	3 (50.0)	0 (0.0)
2. No concern for inflicted injury	345	39 (11.3)	25 (64.1)	0 (0.0)
3. Mildly concerning for inflicted injury	306	113 (36.9)	82 (72.6)	6 (7.3)
4. Intermediately concerning for inflicted injury	270	158 (58.5)	119 (75.3)	7 (5.9)
5. Very concerning for inflicted injury	312	200 (64.1)	164 (82.0)	17 (10.4)
6. Substantial evidence of inflicted injury	321	238 (74.1)	181 (76.1)	41 (22.7)
7. Definite inflicted injury	417	285 (68.3)	222 (77.9)	53 (23.8)
Total	2049	1038 (50.7)	796 (76.6)	124 (15.6)

specific for abuse,<sup>22</sup> were identified in 10 (8.1%) subjects with new fractures. New fractures were identified in 18 (7.1%) of 252 subjects with a negative initial SS who underwent FUSS.

Findings initially concerning for fractures were determined by FUSS not to be fractures in 55 (6.9%) subjects. Investigators coded 6 (0.8%) subjects as having abuse mimics identified on FUSS, including normal anatomic variants initially thought to be fractures, osteochondromatosis, stable periosteal reaction, periostitis, and a lytic lesion of the skull. Overall, new information was identified in 174 (21.9%) of subjects who had FUSS.

Among the 124 subjects with a new fracture identified by FUSS, the perceived likelihood of abuse increased in 42 (33.9%) subjects and remained at the maximum perceived likelihood of abuse in 51 (41.1%; Table 4). For example, a 2-month-old girl who presented with

chest wall crepitus had no fractures identified on SS. On FUSS, 6 healing rib fractures were identified. The perceived likelihood of abuse increased from a 3 to a 7.

Among the 55 subjects with reassuring findings on FUSS, the perceived likelihood of abuse decreased in 26 (47.3%; Table 5). This group of subjects included a 2-month-old boy who presented with chest popping. The initial SS was concerning for possible rib fractures. No rib fractures were identified on FUSS. The perceived likelihood of abuse decreased from 4 to 1. There were 9 subjects with both a reassuring finding and a new fracture identified on FUSS. The perceived likelihood of abuse increased in 4 (7.3%; Table 5).

## DISCUSSION

These data demonstrate that the FUSS is used frequently and commonly identifies additional information among

**TABLE 3** Types of Fractures Identified by FUSS

Fracture	Subjects (n = 124)
Rib	64 (51.2)
Long bone	32 (25.8)
CML	21 (16.9)
Hand/foot	8 (6.5)
Clavicle	6 (4.9)
Vertebrae	2 (1.6)
Scapula/acromion	2 (1.6)

Results do not sum to 124 because some subjects had fractures identified in multiple categories. CML, classic metaphyseal lesion.

**TABLE 4** Perceived Likelihood of Abuse for Subjects with New Fractures Identified by FUSS

Before FUSS Results	After FUSS Results							Total
	1	2	3	4	5	6	7	
1								
2								
3		1	2	1		1	1	6
4				2	3	1	1	7
5					2	8	7	17
6						21	18	39
7							51	51
Total		1	2	3	5	31	78	120 <sup>a</sup>

<sup>a</sup> Investigators did not provide likelihood of abuse data before FUSS completion in 4 subjects.

**TABLE 5** Perceived Likelihood of Abuse for Subjects with Reassuring Findings by FUSS

Before FUSS Results	After FUSS Results							Total
	1	2	3	4	5	6	7	
1								
2								
3		2	3	2				7
4		1	2	4	4			11
5		1	1	3	1	6	2	15
6			1	1	2	5	1	10
7					1	2	8	11
Total		5	7	10	8	6	9	55

Perceived likelihood of abuse increased in 4 of 9 cases where subjects had both a new fracture and a reassuring finding identified on FUSS.

children with concern for physical abuse. FUSS was recommended in approximately one-half of children who had an initial SS and revealed new information in approximately one-fifth of those subjects when it was completed. The perceived likelihood of abuse was affected by FUSS results in 15% of subjects undergoing the examination.

These data also show that FUSS is omitted in nearly one-quarter of cases where it is recommended. The unique social and legal implications of a diagnosis of child physical abuse frequently limit compliance with screening recommendations, especially if a caregiver perceives the screening to put them in legal jeopardy, or if a nonabusive caregiver is reluctant to consider the possibility of abuse by a trusted friend or family member. Ensuring compliance with the FUSS is even more challenging, because it often requires that the child return to the hospital days or weeks after they have been discharged and often requires cooperation between health care providers and CPS.

These data support protocols to increase compliance with FUSS recommendations, such as routine follow-up visits in a child abuse clinic in the weeks after hospital discharge, as well as improved collaboration between CAPs and CPS. Clinicians might also consider the use of the bone scan<sup>13,14</sup> or <sup>18</sup>F positron emission tomographic scan<sup>23</sup> to complement the initial SS in cases where compliance with delayed testing may be challenging.

Some variability in FUSS recommendations by CAPs and compliance by other clinicians and CPS agents may stem from the lack of robust data about the utility of FUSS. In the absence of such data, guidelines are equivocal. The AAP section on radiology states that FUSS be undertaken "...when abnormal or equivocal findings are found on the initial study and when abuse is suspected on clinical grounds."<sup>18</sup> Conversely, the AAP committee on child abuse and neglect recommends FUSS only for those subjects at "high risk."<sup>8</sup> Our data support the use of FUSS in children with concern for abuse and show that FUSS may add information in children with moderate concern for abuse, or when the outcome of the initial SS is normal.<sup>24</sup>

It should be emphasized that the FUSS can have important implications for abused children even when the perceived likelihood of abuse does not change. Although most identified fractures will need little in terms of medical intervention or stabilization, the identification of new injuries may affect the likelihood that criminal prosecution is undertaken, or the likelihood that it is successful. Furthermore, if fractures identified on the FUSS allow CAPs to better estimate the timing of the abusive injury, they may aid in identification of the abusive caregiver.

These data complement the results of 3 single-center retrospective cohorts that reported the utility of FUSS in potentially abused children.<sup>15–17,25</sup> These cohorts included between 23 and 101 subjects who underwent FUSS and identified new fractures in 37.6% to 61% of cases. Our rate of new fracture identification (15.6%) is lower than these previous reports. CAPs in our network may have been more likely to recommend FUSS in children with lower perceived likelihood of abuse in light of the high rates of fractures identified by these previous cohorts. For at least 1 of these studies, the analysis was restricted to subjects "strongly suspected of being physically abused."<sup>16</sup> A more recent single-center retrospective study by Singh and colleagues obtained a similar rate of new fracture identification at 14%. This larger retrospective study was able to obtain a FUSS in only 11% (169) of 1470 subjects with an initial SS.<sup>25</sup> Our study obtained skeletal surveys in 38.8% (796 of 2049) subjects with an initial skeletal survey. Both studies have similar rates of new fracture identification suggesting that high risk children at the other center may not have been imaged with a FUSS.

Recently, Harlan and colleagues<sup>17</sup> suggested that the protocol for the FUSS could be limited to exclude films of the

spine and pelvis. Our data include 539 FUSS that included views of the spine and pelvis. We identified only 2 subjects with additional vertebral fractures diagnosed by the remaining centers on FUSS, and we did not identify additional pelvic fractures. **Our results support those of Harlan and colleagues and suggest that films of the spine and pelvis, with their relatively high levels of radiation exposure to sensitive organs, could be omitted from FUSS protocols.**

Our study is subject to several limitations. Most importantly, this was an observational study, and the indications for recommending or completing FUSS varied between both centers and CAPs. CAPs almost certainly used other unmeasured factors (such as psychosocial risk factors or parental behavior) in addition to the ones reported here (age, perceived likelihood of abuse) to determine the need for FUSS. The true likelihood of an occult fracture in any particular child may therefore be different than the rates reported for groups of children at a certain age or perceived likelihood of abuse.

The scale used to rate the perceived likelihood of abuse contains subjective factors, such as whether the reported mechanism is sufficient to account for the identified injury, and has been shown to have variability between CAPs.<sup>21</sup> Rates of injury identification are likely to be higher in centers that reserve the FUSS for subjects with higher initial perceived likelihood of abuse.

FUSS was interpreted in the course of usual clinical care by pediatric radiologists at centers who saw enough children with concerns of abuse to support a child protection team. Nevertheless, images from the FUSS were not independently reviewed as part of the research protocol. It is possible that independent review may have identified even more additional fractures, or that findings thought to be fractures by clinical radiologists

might not have been appreciated on independent review.

We did not determine the time interval between initial SS and FUSS. Whereas guidelines recommend that the FUSS be undertaken ~2 weeks after the initial SS, some FUSS may have been completed before fractures developed clear signs of healing, or could have been completed after fractures had healed completely. However, given the published time course of fracture resolution,<sup>26,27</sup> we suspect the number of fractures that healed completely before the FUSS was undertaken was low. Nearly one-quarter of recommended FUSS were not obtained. Although we suspect that some FUSS were omitted because of reluctance on the part of the subject's caregivers or other factors that have little to do with the clinical suspicion of abuse, it is also likely that CAPs and CPS were more likely to ensure completion of FUSS in subjects with higher perceived likelihood of abuse, or in subjects with other unmeasured factors that increased the likelihood of new fracture identification. If all recommended FUSS were completed and no new fractures were identified, the true rate of new fractures identified by FUSS would drop to 11.9% (124/1038).

We did not determine which initial SS had findings that were considered to be concerning but inconclusive. It is possible that some new fractures identified by FUSS may have been suspected after the initial SS, which may help guide clinicians about which children need FUSS.

## CONCLUSIONS

To our knowledge, this is the first large, prospective, multicenter study of the utility of FUSS in children with concern for physical abuse. FUSS is used commonly by CAPs in the evaluation of children with concern for physical abuse and, when completed, identifies new information and affects the perceived

likelihood of abuse in an important minority of subjects. These data support the current, frequent use of FUSS by CAPs. The relatively high rates of occult fractures identified by FUSS support efforts to improve completion of recommended FUSS.

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**APPENDIX** Rating Scale for Abuse Likelihood

Rating	Criteria	Explanation
1. Definitely not inflicted injury	<ul style="list-style-type: none"> <li>* Significant, independently verifiable mechanism (MVC, pedestrian struck)</li> <li>* Disinterested witness (police, ambulance, video documentation)</li> <li>* Mimic (Mongolian spot, hemangioma)</li> </ul>	While no evaluation can completely exclude abuse, our evaluation has not raised a reasonable suspicion of abuse. The injuries or findings we have described could reasonably be explained by accidental or benign events. Please do not hesitate to renew discussion if circumstances change.
2. No concern for inflicted injury	Mechanism explains all injuries, consistent history	
3. Mildly concerning for inflicted injury	<ul style="list-style-type: none"> <li>* Somewhat concerning injuries with no offered history (multiple, nonpatterned bruises in a cruising child without bleeding diathesis, unexplained humerus fracture in 10-month-old)</li> <li>* Otherwise unconvincing injury with past suspicious injury and same caretaker.</li> </ul>	
4. Intermediately concerning for inflicted injury	<ul style="list-style-type: none"> <li>* Insufficient information to offer opinion</li> <li>* Sequence of events clear but uncertain whether they constitute abuse</li> <li>* Necessary labs/consults pending</li> <li>* Concerning injury in the setting of bone fragility/bleeding diathesis</li> </ul>	To a reasonable degree of medical certainty, the injuries/ findings we have described cannot plausibly be explained by accidental injury, preexisting medical illness, reasonable discipline, or benign events.
5. Very concerning for inflicted injury	<ul style="list-style-type: none"> <li>* Given history unlikely to produce documented injuries</li> <li>* Concerning injury with no history of trauma (4-month-old with unexplained femur fracture)</li> </ul>	
6. Substantial evidence of inflicted injury	<ul style="list-style-type: none"> <li>* Severe injury with no offered history in a child incapable of inflicting the injury upon themselves</li> <li>* History inconsistent with identified injuries</li> <li>* Serious injury with changing history or history inconsistent between caretakers</li> <li>* Inappropriate delay in seeking care</li> <li>* Multiple severe injuries of different age without plausible explanation</li> </ul>	
7. Definite Inflicted Injury	<ul style="list-style-type: none"> <li>* Pattern bruises/burns</li> <li>* Unexplained posterior rib fractures, metaphyseal fractures, characteristic retinal hemorrhages.</li> <li>* Highly suspicious injury (liver laceration, burn, pinna bruising, unexplained fracture) with definite subsequent abuse</li> <li>* Reliable eyewitness of abuse</li> <li>* Suspicious injury and concurrently abused sibling</li> <li>* Obvious injury with significant, unexplained delay in seeking care (serious burn, unresponsive child, apparent prolonged seizure)</li> </ul>	

MVC, motor vehicle collision. From Lindberg et al. *Pediatrics*. 2008;121(4):e945–e953.