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# Follow-up skeletal survey use by child abuse pediatricians☆

Nancy S. Harper[a], Terri Lewis[b], Sonja Eddleman[c], Daniel M. Lindberg[d,*], for the ExSTRA Investigators[1]

[a] Center for Safe and Healthy Children, Child Abuse Pediatrics, University of Minnesota Masonic Children's Hospital, East Building, M653, 2450 Riverside Avenue, Minneapolis, MN 55454, USA
[b] Kempe Center for the Prevention and Treatment of Child Abuse and Neglect, University of Colorado School of Medicine, 13123 E. 16th Avenue, B390, Aurora, CO 80045, USA
[c] Driscoll Children's Hospital, Child Abuse Resource and Evaluation Team, 3533 S Alameda, Corpus Christi, TX 78411, USA
[d] Department of Emergency Medicine, Kempe Center for the Prevention and Treatment of Child Abuse and Neglect, University of Colorado School of Medicine, 12401 E. 17th Avenue, B215, Aurora, CO 80045, USA

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ABSTRACT

Skeletal survey is frequently used to identify occult fractures in young children with concern for physical abuse. Because skeletal survey is relatively insensitive for some abusive fractures, a follow-up skeletal survey (FUSS) may be undertaken at least 10–14 days after the initial skeletal survey to improve sensitivity for healing fractures. This was a prospectively planned secondary analysis of a prospective, observational study of 2,890 children who underwent subspecialty evaluation for suspected child physical abuse at 1 of 19 centers. Our objective was to determine variability between sites in rates of FUSS recommendation, completion and fracture identification among the 2,049 participants who had an initial SS. Among children with an initial skeletal survey, the rate of FUSS recommendation for sites ranged from 20% to 97%; the rate of FUSS completion ranged from 10% to 100%. Among sites completing at least 10 FUSS, rates of new fracture identification ranged from 8% to 28%. Among completed FUSS, new fractures were more likely to be identified in younger children, children with higher initial level of concern for abuse, and those with a fracture or cutaneous injury identified in the initial evaluation. The current variability in FUSS utilization is not explained by variability in occult fracture prevalence. Specific guidelines for FUSS utilization are needed.



## Introduction

Child physical abuse is an important source of morbidity and mortality and carries profound costs for the child's family, the abuse perpetrator and for society at large (Fang, Brown, Florence, & Mercy, 2012; Florence, Brown, Fang, & Thompson, 2013; Russo, Hambrick, & Owens, 2008; Sedlak et al., 2010; US Department of Health and Human Services Administration for Children and Families, 2013). The radiographic skeletal survey (SS) is widely used to improve recognition of abuse by

*Abbreviations:* CML, classic metaphyseal lesions; FUSS, follow-up skeletal survey; SS, skeletal survey.

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* Corresponding author.

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identifying additional occult fractures (Kleinman et al., 2009). In several cohorts of children with concerns for abuse, the SS has been shown to identify additional fractures in 10–34% of cases in which it is obtained (Barber, Perez-Rossello, Wilson, & Kleinman, 2014; Belfer, Klein, & Orr, 2001; Duffy, Squires, Fromkin, & Berger, 2011; Karmazyn, Lewis, Jennings, Hibbard, & Hicks, 2011; Lindberg et al., 2014; Merten, Radkowski, & Leonidas, 1983). For this reason, SS is considered "mandatory" by the American Academy of Pediatrics (AAP) for any child less than two years old with concern for physical abuse (Christian & Committee On Child, & Neglect, 2015; Kleinman et al., 2009). However, in the acute phase of injury, SS has limited sensitivity for some fractures that are highly specific for abuse, including rib fractures and classic metaphyseal lesions (Harper, Eddleman, Lindberg, & for the ExSTRA Investigators, 2013; Zimmerman, Makoroff, Care, Thomas, & Shapiro, 2005). A follow-up SS (FUSS) obtained at least 10–14 days after the initial SS can identify additional fractures missed by the initial SS, clarify the importance of indeterminate findings on the initial SS, and affect the perceived likelihood of abuse (Christian et al., 2015; Harper et al., 2013; Kleinman et al., 1996; Singh, Squires, Fromkin, & Berger, 2012; Zimmerman et al., 2005).

Currently, guidelines about when FUSS should be recommended allow substantial discretion based on the perceived likelihood of abuse. Different guidelines from the AAP and American College of Radiology state that FUSS should be obtained for "high risk cases"; "equivocal cases"; when abuse is "strongly suspected" or "when abnormal or equivocal findings are found on the initial study and when abuse is suspected on clinical grounds"; the terms "high risk", "suspected", and "strongly suspected" are not further defined (American College of Radiology, 2012; Christian et al., 2015; Flaherty, Perez-Rossello, Levine, Hennrikus, & American Academy of Pediatrics and Society for Pediatric Radiology, 2014; Kleinman et al., 2009). Two series have demonstrated that FUSS can identify additional fractures and change the perceived likelihood of abuse, even when the initial SS is negative, or when the perceived likelihood of abuse is moderate (Bennett, Chua, Care, Kachelmeyer, & Mahabee-Gittens, 2011; Harper et al., 2013). Even in cases in which there are likely to be occult fractures, child abuse pediatricians (CAPs) may omit FUSS based on the child's clinical condition or if the recognition of additional fractures is unlikely to affect the ultimate diagnosis or management.

Completing recommended FUSS may require substantial effort by child protective services workers and primary pediatricians in the face of reluctance from families or caregivers. This absence of clear, objective guidelines may lead to variability in FUSS recommendations, which could, in turn, decrease compliance. Our objective was to measure the variability in FUSS recommendation, completion, and injury identification for children who underwent subspecialty evaluation with concern for physical abuse at centers with child protection teams.

## Methods

This was a prospectively planned, secondary analysis of the Examining Siblings To Recognize Abuse (ExSTRA) research network. The methods and results of the parent study have been published previously (Lindberg et al., 2012). Briefly, the ExSTRA research network was a prospective, observational study of 20 United States child abuse teams that included all children less than ten years of age who underwent subspecialty evaluation for concerns of physical abuse between January 15, 2010 and April 30, 2011. One center was excluded from this analysis because none of its nine participants received an initial SS. Each participating center included at least one member of the Ray E. Helfer Society, an honorary society for physicians who evaluate children who may have been victims of child abuse and neglect. The number of physical abuse consultations performed by each center during the data enrollment period ranged from 28 to 396.

While the parent study involved household contacts such as siblings or children who shared a daycare with the index child, this analysis includes data only from index children. All participating centers and the data coordinating center obtained approval for the parent study with waiver of informed consent from their local institutional review board. Each IRB also determined that secondary analyses of previously collected data that had been purged of all identifiers did not constitute human subjects research and were exempt from further review.

CAPs recorded whether an initial SS was obtained, whether a FUSS was recommended and ultimately completed, and any results. The perceived likelihood of abuse for each case was recorded both before and after FUSS results were available. Physicians recorded initial level of concern on a seven-point scale (1 – Definitely Not Inflicted Injury; 7 – Definitely Inflicted Injury). Data were entered prospectively into a secure, web-based data entry form (Quickbase, Intuit, Waltham, MA). Participating centers conducted skeletal surveys according to published guidelines from the AAP and/or American College of Radiology (Kleinman et al., 2009). Views of the skull are routinely excluded from FUSS because the membranous bones of the skull do not exhibit callus in the healing process and fractures do not become more apparent over time (Kleinman, 1998). In addition, six participating centers routinely excluded views of the spine and five of these centers also excluded views of the pelvis based on prior data suggesting that these views are unlikely to identify additional fractures (Harlan, Nixon, Campbell, Hansen, & Prince, 2009). 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 attending 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.

For these analyses, we report the proportion of participants with an initial SS in which FUSS was recommended, completed, and the proportion that identified a new fracture. Next, we conducted logistic regression analysis to assess whether demographic or clinical information predicted whether a FUSS was (a) recommended, (b) completed, and (c) associated

**Table 1**
Characteristics of study subjects.

| | All subjects with SS $n = 2,049$ | Subjects with FUSS recommended $n = 1,038$ | Subjects with FUSS completed $n = 796$ | Subjects with new fractures identified by FUSS $n = 124$ |
|---|---|---|---|---|
| Age in months – median (IQR) | 11 (4–31) | 6 (3–12) | 6 (3–11) | 3 (2–7) |
| Male – *n* (%) | 1,212 (59) | 613 (59) | 464 (58) | 66 (53) |
| White, Non-Hispanic – *n* (%) | 1,169 (57) | 600 (58) | 459 (58) | 59 (48) |
| Initial Level of Concern – *n* (%) | | | | |
| 1 | 78 (4) | 6 (1) | 3 (0) | 0 (0) |
| 2 | 345 (17) | 39 (4) | 25 (3) | 0 (0) |
| 3 | 306 (15) | 113 (11) | 82 (10) | 6 (5) |
| 4 | 270 (13) | 157 (15) | 118 (15) | 7 (6) |
| 5 | 312 (15) | 200 (19) | 164 (21) | 17 (14) |
| 6 | 321 (16) | 238 (23) | 181 (23) | 41 (33) |
| 7 | 417 (20) | 285 (27) | 223 (28) | 53 (43) |
| Insurance – *n* (%) | | | | |
| Private | 350 (17) | 149 (14) | 116 (15) | 13 (10) |
| Public | 1,578 (77) | 837 (81) | 638 (80) | 109 (88) |
| None/Self-Pay | 121 (6) | 52 (5) | 42 (5) | 2 (2) |
| Fracture(s) known prior to FUSS (%) | 1,072 (52) | 657 (63) | 522 (66) | 102 (72) |
| Traumatic brain injury (%) | 477 (23) | 254 (24) | 190 (24) | 23 (19) |
| Intra-abdominal injury (%) | 76 (4) | 45 (4) | 35 (4) | 5 (4) |
| Cutaneous injury (%) | 1,097 (54) | 535 (52) | 398 (50) | 79 (64) |

**Table 2**
Relationship between subject characteristics and FUSS outcomes OR (95%CI).

| | FUSS recommended by CAP | FUSS completed | FUSS identifies new injury |
|---|---|---|---|
| Age (in months) | **0.96 (0.95–0.97)** | **0.97 (0.96–0.97)** | **0.95 (0.92–0.98)** |
| Gender (male vs. female) | 1.05 (0.85–1.29) | 0.98 (0.80–1.20) | 0.72 (0.48–1.09) |
| Race/ethnicity[a] | **1.31 (1.06–1.62)** | 1.21 (0.98–1.48) | **0.61 (0.41–0.93)** |
| Initial level of concern | **1.79 (1.68–1.90)** | **1.59 (1.50–1.69)** | **1.59 (1.35–1.88)** |
| Insurance[b] | 0.79 (0.61–1.04) | 0.84 (0.64–1.09) | 0.69 (0.37–1.28) |
| Fracture(s) (known prior to FUSS) | **1.90 (1.54–2.36)** | **1.88 (1.52–2.32)** | **2.49 (1.50–4.13)** |
| Traumatic brain injury | 0.98 (0.77–1.26) | 0.89 (0.70–1.13) | 0.68 (0.40–1.14) |
| Intra-abdominal injury | 1.61 (0.94–2.73) | 1.54 (0.92–2.55) | 0.99 (0.35–2.77) |
| Cutaneous injury | **0.81 (0.66–1.00)** | **0.76 (0.62–0.93)** | **2.04 (1.33–3.11)** |

For clarity, significant ($p < 0.05$) estimates are bold.
[a] White and Non-Hispanic subjects against all others.
[b] Private Insurance against Public and Self-Pay.

with new fracture identification. Specifically, we examined whether race (White/Non-White), child gender, child age (in months), insurance (private or not), initial level of concern, and identification of the following: TBI, cutaneous injury, intra-abdominal/thoracic, and fracture identified prior to FUSS. Statistical analyses were completed using SAS 9.3.

## Results

As reported previously, the 2,890 participants enrolled in the parent study for the ExSTRA research network included 2,049 (71%) with initial SS and of these, 1,038 (51%) had FUSS recommended and 796 (39%) had FUSS completed. New fractures were identified in 124 (16%; Harper et al., 2013). Characteristics of study participants are shown in Table 1. Participants primarily held public insurance and our population had a slight male predominance, consistent with other studies of children evaluated for physical abuse (Lindberg et al., 2009; US Department of Health and Human Services Administration for Children and Families, 2013).

### *Variability*

Rates of FUSS recommendation, completion and results are shown for each center in Fig. 1. Among children with an initial SS, rates of FUSS recommendation ranged from 20% to 97% and completion rates ranged from 10% to 100%. After excluding centers with fewer than 10 completed FUSS (to avoid instability of the data), at least one additional fracture was identified in 8% to 28% of FUSS across centers. We were unable to identify a relationship between the fraction of FUSS that identified new fractures and the fraction of participants with FUSS recommended or completed.

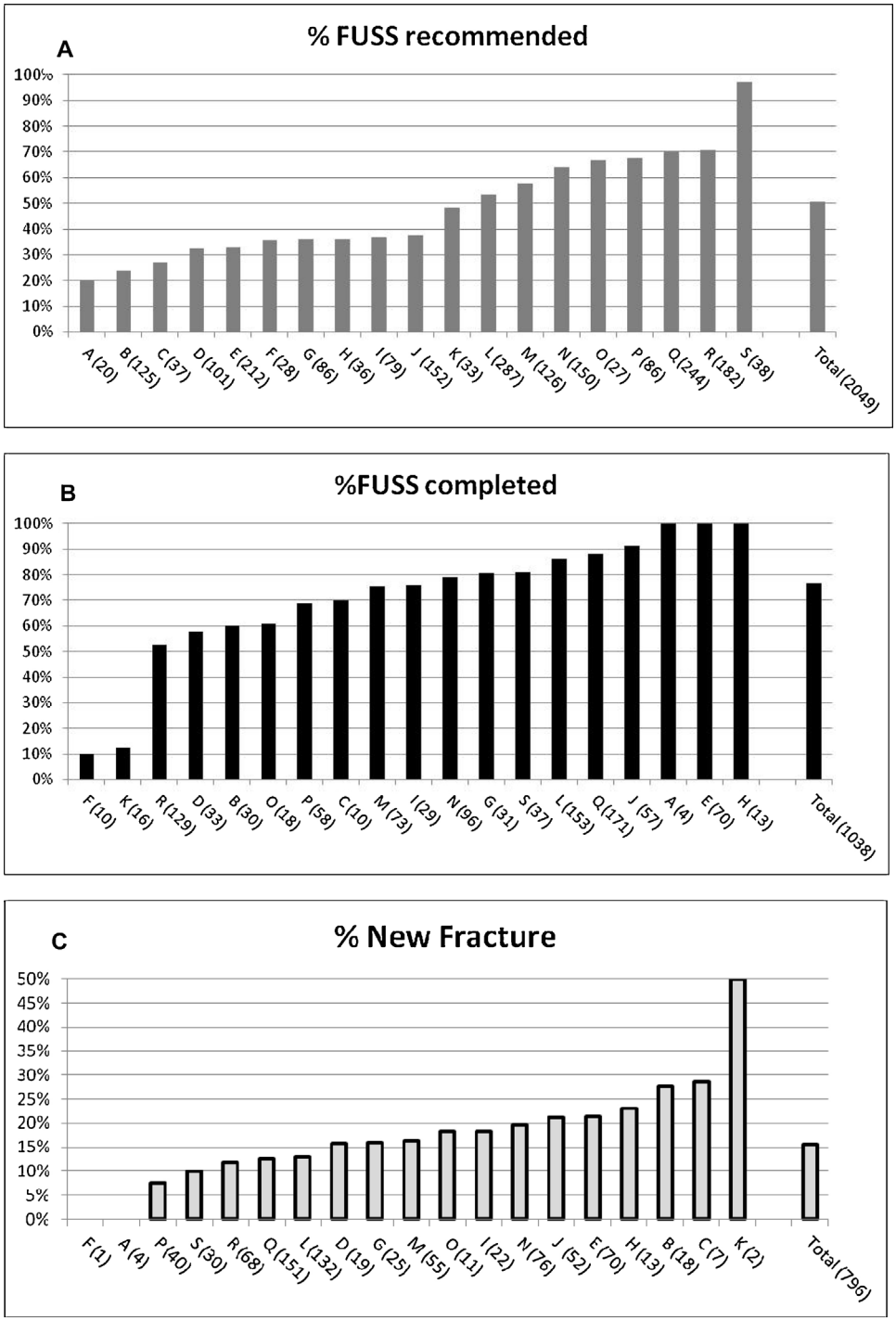


**Fig. 1.** Variation in FUSS recommendation, completion and results by center. Each center is labeled on the *X*-axis with an assigned letter that remains consistent in each panel. A. Proportion of subjects with initial SS in which FUSS was recommended. Numbers in parentheses indicate the number of initial SS obtained at each center. B. Proportion of subjects with FUSS recommended in which FUSS was completed (FUSS compliance). Numbers in parentheses indicate the number of subjects at each center in whom FUSS was recommended. C. Proportion of subjects in whom FUSS was obtained where FUSS identified at least one additional fracture. Numbers in parentheses indicate the number of subjects at each center with completed FUSS.

*Predictors of FUSS Recommendation, Completion and Results*

Results of the logistic regression models are shown in Table 2. FUSS was more likely to be recommended for younger children, for children who were White and not Hispanic, for children with higher initial levels of concern for abuse and for children with fractures identified on the initial evaluation (before the FUSS was obtained). Children with cutaneous injuries were less likely to have FUSS recommended.

For participants with FUSS recommended, FUSS was more likely to be completed for younger children, for those with a higher initial level of concern for abuse, with known fractures, and without cutaneous injury. Among those with FUSS completed, additional fractures were more likely to be identified among younger children, children with non-White race or Hispanic ethnicity, and for children with higher initial level of concern for abuse, fractures or cutaneous injury.

## Discussion

These data demonstrate broad variability among CAPs in the decision to recommend FUSS, and equally broad variability in their ability to ensure compliance with recommended testing. In general, FUSS was more commonly recommended and obtained in children who had characteristics associated with higher risk of abuse (younger age, higher perceived likelihood of abuse and fractures). Yet at the level of the center, neither FUSS recommendation nor completion rates clearly correlated with the center's rate of new fracture identification. Centers with lower rates of FUSS recommendation or completion did not demonstrate higher rates of injury identification, which suggests that they were not preferentially omitting FUSS in low-risk participants.

CAPs were more likely to recommend FUSS, and FUSS was more likely to be completed, for younger children, for those with higher initial level of concern, and for those with at least one fracture identified before the FUSS was obtained. These practices were validated by the increased likelihood of additional fractures being identified in children with these characteristics. Notably, rates of fracture identification were relatively increased in children with cutaneous injury, although CAPs seemed less likely to recommend or complete FUSS in these children. One possibility is that FUSS was more likely to be ordered and completed in those children with cutaneous injuries that are especially concerning for abuse such as patterned bruises, bite marks or bruising in very young children or in atypical locations (Pierce, Kaczor, Aldridge, O'Flynn, & Lorenz, 2010).

We suggest that there is an urgent need for research to support more objective guidelines for FUSS use in children with concern for physical abuse (American College of Radiology, 2012; Christian et al., 2015; Offiah, van Rijn, Perez-Rossello, & Kleinman, 2009). While FUSS has the potential to improve abuse recognition, it is also associated with significant cost and small but important exposure to ionizing radiation for young children. Furthermore, because FUSS is performed at least 10–14 days after the initial presentation, it requires significant coordination and effort to ensure completion for discharged patients.

In contrast to other studies of other tests for abusive injuries (Lane & Dubowitz, 2007; Wood et al., 2010), we did not identify disproportionate FUSS completion on the basis of race and ethnicity. Other possible explanations for the variation in practice we identified include factors such as physician training and the center's relationship with child protective services.

We do not feel that the use of bone scans contributed significantly to the variability we identified. The use of $^{99}$Tc bone scans has decreased substantially in recent years and few centers have begun using newer $^{18}$F PET scans for potentially abused children (Drubach et al., 2010). In the ExSTRA dataset, radionuclide bone scanning was undertaken in 17 subjects at 11 centers (one scan completed by each of nine centers and two centers each completed three). Bone scans identified additional fractures in three subjects, confirmed previously suspected fractures in seven cases, and excluded fractures in two cases.

This study is the first to systematically examine the rate of recommended and completed FUSS, and incidence of new fracture identification in a large multi-site cohort of children with subspecialty evaluation of child physical abuse. Nevertheless, our work is subject to a number of limitations. First, we did not measure the interval between the initial SS and FUSS. However, we think it is unlikely that the percentage of additional fractures identified on FUSS would change if we had used a uniform protocol to determine FUSS timing. The standard interval of at least 10–14 days between initial SS and FUSS is well-known to CAPs and all participating centers included a child protection team. Furthermore, radiographic signs of fractures persist for several weeks or months.

Second, while these data imply that occult fractures were likely to have been missed in several participants who did not have FUSS, it is not possible to measure this directly. We are not able to identify from these data the reasons that FUSS was or was not recommended or obtained. Therefore, we cannot exclude the possibility that CAPs recommended and completed FUSS on all participants with additional occult fractures. It is possible that CAPs used unmeasured factors to identify all children who would benefit from FUSS. However, we think this is unlikely. Occult fractures are occult specifically because there are no "soft signs" that allow their identification. Furthermore, for this hypothesis to be true the rates of occult fractures would have to be as broadly variable as the rates of FUSS utilization.

Finally, our data were taken from a cohort of children who were all evaluated by a CAP. Because the specialty of child abuse pediatrics is relatively new (Block & Palusci, 2006), many children with concern for abuse are evaluated by physicians without dedicated training in abuse. Our data may over or under-estimate the rate and variability of FUSS utilization by these providers.

We believe that several steps have the potential to decrease the variability in FUSS recommendations and completion. Recommendations based on more specific or objective classifications of abuse likelihood, on the potential of FUSS to impact the secondary prevention interventions, or on a patient characteristics such as age or identified injuries could add clarity to current recommendations. Further data, including data about the outcomes that occur after hospital discharge is likely necessary before changes are made to the current guidelines. In addition, quality improvement methodologies targeted to clinicians, CPS and families could improve completion of FUSS once recommended.

In conclusion, there is currently broad variability in the recommendation and completion of FUSS by child abuse pediatricians. This variability is not explained by the likelihood that FUSS identifies additional fractures. Further evidence is needed to develop more objective guidelines for FUSS for both CAP and non-specialist providers who evaluate potentially abused children.

## Author Contributions

Dr. Harper drafted the initial version of the manuscript and participated in study design, data collection and analysis and review and approval of the final manuscript. Dr. Lewis participated in data analysis and revision and approval of the final manuscript. Ms. Eddleman participated in study design and data collection and review and approval of the final manuscript. Dr. Lindberg led the parent study and participated in study design, data analysis and substantial revision of the initial draft of the manuscript and approval of the final manuscript. Dr. Lindberg takes responsibility for the final manuscript as a whole.

## Conflicts of Interest

Drs. Harper, Eddleman and Lindberg have provided paid expert testimony for prosecution and defense in cases of alleged child maltreatment. Dr. Lewis declares that she has no conflicts.

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