ASSESSING THE USE OF FOLLOW-UP SKELETAL SURVEYS IN CHILDREN WITH SUSPECTED PHYSICAL ABUSE

by

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Background: A follow-up SS (FSS) can provide additional clinical data in a subset of children that undergo an initial skeletal survey (ISS) for the evaluation of physical abuse. Three studies suggested that 33-57% of FSS identify additional fractures, but the study populations were small and highly selective.

Objective: To assess a consecutive study sample of children who underwent an ISS and FSS, to evaluate the results of the ISS and FSS, and to calculate the proportion in whom clinical diagnosis depended on the FSS results.

Methods: This was a retrospective, descriptive study of children who had an ISS and FSS at Children's Hospital of Pittsburgh of UPMC from 4/1/02 to 3/31/09. Data were collected about demographics, reason for and results of ISS and FSS, the interval in days between ISS and FSS, and whether the FSS affected clinical diagnosis.

Results: During the 7-yr study period, 1470 children underwent an ISS. Eleven percent (169/1470) of these children also underwent a FSS. These 169 children made up the subjects of the study. The FSS identified 39 fractures in 16% (27/169) of the study subjects. All 39 fractures were rib, metaphyseal or metacarpal. The identification of new fractures on FSS led a definite diagnosis of abuse in 7.6% (7/92) of the subjects who did not have a previous diagnosis. These 7 subjects were all less than a year of age. The ISS identified no fractures in 43% (3/7) of these subjects. A total of 29 fractures that were felt to be equivocal of ISS were confirmed as normal

variants on FSS.

Conclusions: This is the largest study to evaluate the use of FSS. The proportion of subjects with additional fractures identified on FSS was lower than in previous studies. The FSS made a definite diagnosis of abuse in ~8% of subjects. A large number of equivocal fractures on ISS were felt to be normal variants on FSS. Future studies will compare children who only receive an ISS with those who receive an ISS and FSS to identify characteristics that, when present in a child undergoing an ISS, also warrant a FSS.

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INTRODUCTION

In 2007, 794,000 children were victims of child maltreatment. Physical abuse was the third leading cause of maltreatment, accounting for over 85,000 of the victims.[1] While physical abuse only accounted for 10.8% of the total cases of maltreatment, it was responsible for at-least 26.4% of the fatalities (Table 1). Since physical abuse was a part of multiple maltreatments, it is possible that physical abuse was a contributor in over 62% of the fatalities.

Table 1: Fatalities due to child maltreatment (2007)

Maltreatment Type	Number	Percent
Medical Neglect	15	1.2
Multiple Maltreatment Types	**451**	**35.2**
Neglect	437	34.1
Other	26	2.0
Physical Abuse	**338**	**26.4**
Psychological Abuse	1	0.1
Sexual Abuse	3	0.2
Unknown	9	0.7
Total	**1,280**	**-**
Percent	-	99.9

ABUSIVE FRACTURES

Fractures are a common manifestation of child physical abuse.[2] Leventhal and colleagues showed that in children less than a year of age, over 60% of rib and radius/ulna fractures were attributable to abuse.[3] While all unsuspected skeletal injuries in infants and young children without underlying genetic or endocrine abnormalities should prompt concern, certain fractures are more specific for abuse than others (Table 2).[4] Several previous studies have described the distribution of fractures in physically abused children.[5-8] In infants, rib and metaphyseal fractures predominate. In children older than a year, long bone fractures are the most common of skeletal injuries due to abuse.

Table 2: Specificity of fractures for physical abuse

High specificity
Classic metaphyseal lesion
Rib fractures, especially bilateral
Scapular fractures
Spinous process fractures
Sternal fractures
Moderate specificity
Multiple fractures, especially bilateral
Fractures of different ages
Epiphyseal separation
Vertebral body fractures and subluxations
Digital fractures
Complex skull fractures
Common but low specificity
Subperiosteal new bone formation
Clavicular fractures
Long bone shaft fractures
Linear skull fractures

Diagnosing fractures in infants and young children can be challenging. Infants are non-verbal and therefore cannot provide a history of the injury. Infants are also non-ambulatory so injury cannot be detected from impaired motor movement. While abusive fractures are rarely fatal, the early recognition of child abuse cannot be overemphasized. If abusive fractures are not identified, a child may unknowingly be discharged to a violent environment and placed at a significantly increased risk of repeated injury. Previous studies have reported acute and/or healing fractures on postmortem evaluation in abused children. In a study by King and colleagues, 24% (9/37) of children who died from abuse had healing fractures.[5] Oral and colleagues found that 7.5% (3/38) children with fatal abusive head trauma had previous sign of physical abuse which were missed by medical staff.[9]

THE SKELETAL SURVEY

The skeletal survey (SS) is an important screening tool for identifying unsuspected fractures in infants and young children.[6, 10] A SS is a series of x-ray images of all bones in the body in one, often two, anatomical views. The American Academy of Pediatrics (AAP) recommends the following views for the SS (Table 3):[11]

Table 3: Complete skeletal survey

Skeleton	Views
Appendicular	Arms (AP)
	Forearms (AP)
	Hands (PA)
	Thighs (AP)
	Legs (AP)
	Feet (PA or AP)
Axial	Thorax (AP and lateral), to include thoracic spine and ribs
	AP abdomen, lumbosacral spine, and bony pelvis
	Lumbar spine (lateral)
	Cervical spine (AP and lateral)
	Skull (frontal and lateral)

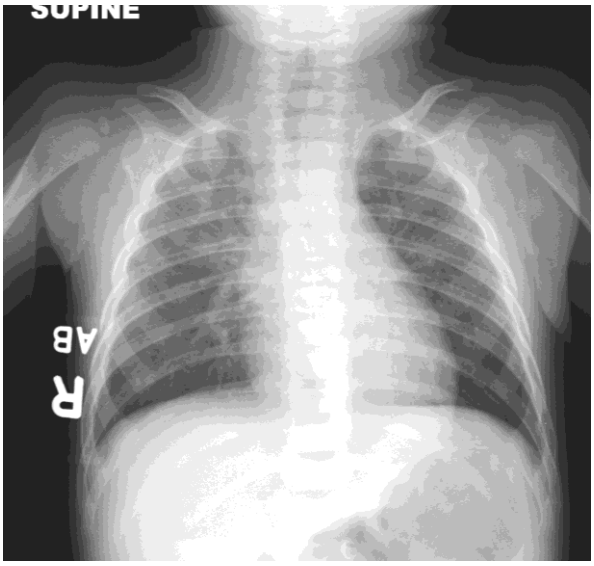
AP indicated anteroposterior; PA, posteroanterior

Previous studies have demonstrated that the SS is an important tool in recognizing unsuspected fractures in the evaluation of child abuse. In a study by Merten and colleagues, the SS identified unsuspected fractures in 33% (186/563) of abused infants and children.[12] In a similar study, Belfer and colleagues reported that 26% (25/96) of children suspected of physical abuse had a SS which recognized unsuspected fractures.[13] Day and colleagues showed similar findings: 24% (17/76) of children suspected of physical abuse had a SS which identified new fractures.[14]

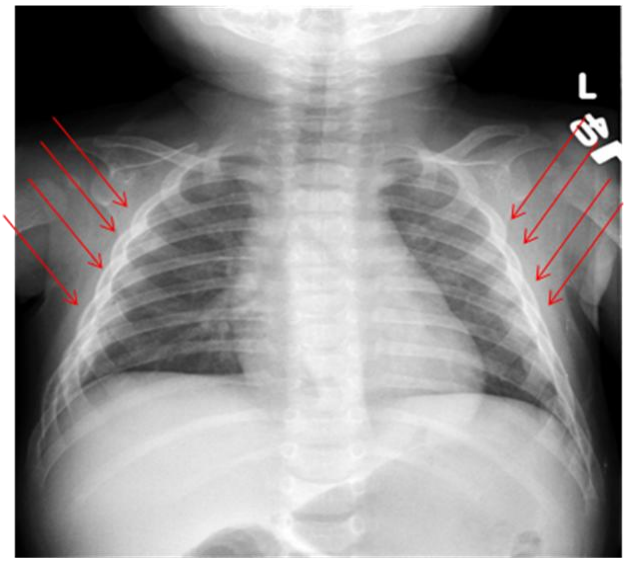
In support of these studies, the 2009 AAP policy statement recommends that, "A [SS] is mandatory in all cases of suspected physical abuse in children younger than 2 years…the screening [SS] or bone scan has little value in children older than 5 years. Decisions about which types of imaging to perform in the 2-to 5-year-old age group must be made individually on the basis of the specific clinical indicators of abuse."[11]

While previous studies confirm the importance of the SS in recognizing unsuspected fractures,[12-14] some fracture are not consistently identified on the SS. Rib (Figure 1) and metaphyseal (Figure 2) fractures, both which are highly specific for physical abuse,[4] are difficult to detect when acute and can be missed on an initial SS (ISS).[13, 15-16]

Figure 1: Rib fractures

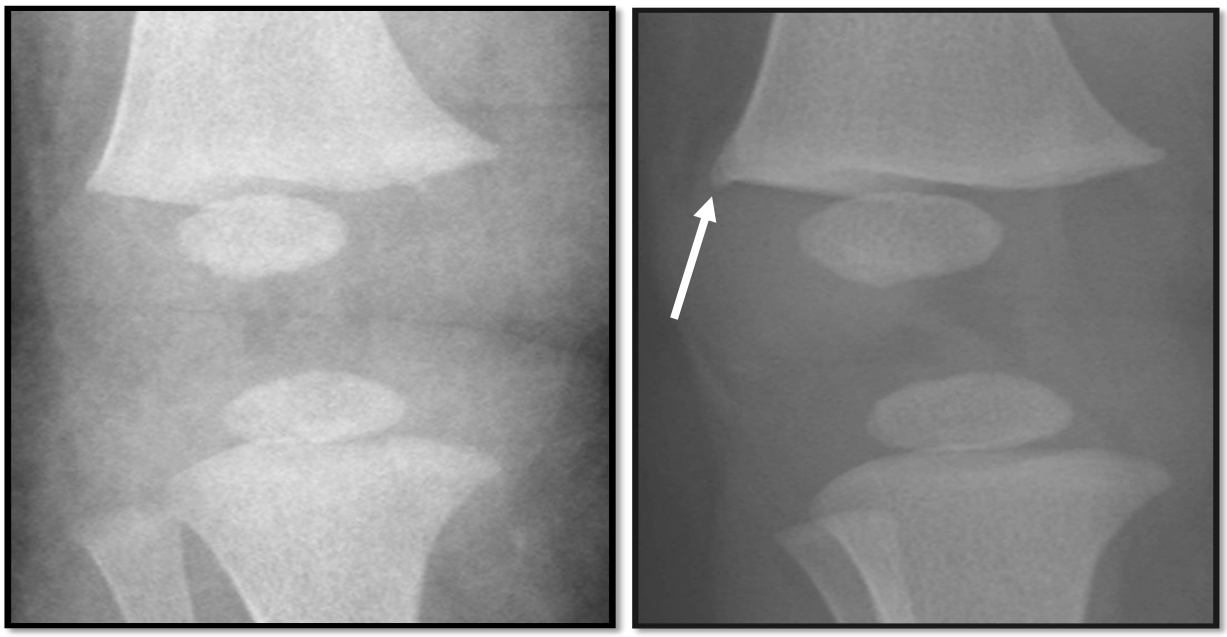


The acute rib fractures are not visible



In the same film obtained 2 weeks after the ISS, the rib fractures are clearly visualized (see arrows)

Figure 2: Metaphyseal fracture



No evidence of a metaphyseal fracture

In the same film obtained 2 weeks after the ISS, the metaphyseal fracture of the femur is clearly visible (see arrow)

THE FOLLOW-UP SKELETAL SURVEY

Because of this limitation of the ISS, three notable studies have assessed the use of the follow-up SS (FSS) in child physical abuse evaluation. In a small study involving 23 children, Kleinman and colleagues prospectively obtained a FSS in children in whom the diagnosis of physical abuse was strongly suspected.[17] The mean age (range) of their subjects was 9 months (1 week – 35 months). In all these subjects, the ISS identified at least one fracture. The FSS identified fractures in 57% (13/23) of the subjects. Nineteen fractures were identified: 8 ribs, 8

metaphyseal, 1 vertebra, 1 sacrum and 1 metacarpal. From these data, the authors concluded that, "A [FSS] performed approximately 2 weeks after the [ISS] appears to provide additional information regarding the number, character and age of injuries inflicted on infants and toddlers." [17]

In support of the findings of Kleinman and colleagues, the APP for the first time included a recommendation for a FSS in their 2000 policy statement: "Recent evidence suggests that a [FSS] approximately 2 weeks after the [ISS] increases the diagnostic yield, and this procedure should be considered when abuse is strongly suspected."[18]

In the second study to evaluate the use of the FSS, Zimmerman and colleagues used the same inclusion criteria as the Kleinman study and had a similar study population. [19] The FSS identified fractures in 33% (16/48) of subjects. Thirty-five fractures were identified: 18 ribs, 4 metaphyseal, 4 scapular, 1 tibular, 2 fibular, 1 ulnar, 3 vertebrae and 2 clavicular. In addition, there were 21 equivocal fractures on ISS which were later determined to be normal variants on FSS. The findings of the FSS led to a definite diagnosis of abuse in 4.2% (2/48) of subjects. Zimmerman and colleagues concluded by recommending that, "a [FSS] should be completed on all patients who have an [ISS] performed for suspected physical abuse and for whom child abuse is still a concern." The recommendation by Zimmerman and colleagues was broader than the recommendation by Kleinman and colleagues, encompassing all children that underwent an ISS. Also, the data did not support the recommendation because Zimmerman and colleagues used a strong enrollment bias, only including children in whom abuse was strongly suspected. An accompanying editorial supplemented the conclusion of the Zimmerman study by stating: "I

agree with the authors that any child who warrants an [ISS] should also have a [FSS] completed." [20]

In the largest study to assess the use of FSS, Harlan and colleagues included all children less than 3 years of age who underwent an ISS and FSS between 10-21 days of one another. A total of 101 children met the inclusion criteria. In this study, 38% (38/101) of the subjects had FSS that identified a total 60 new fractures. From these fractures, there were 40 rib fractures, 3 upper extremity fractures, 12 lower extremity fractures, 4 metatarsal fractures and 1 vertebra fracture. These new findings modified the diagnosis of abuse in 8.9% (9/101) of subjects; the authors did not explain whether this meant that the diagnosis of abuse was made after FSS or that the concern for abuse was decreased. In addition, there were 14 fractures which were felt to be equivocal on ISS but were later determined to be normal variants on FSS. Harlan and colleagues concluded that, "…the [FSS] is an important part of the medical evaluation of suspected child abuse."[21]

Previous studies that have assessed the use of the FSS were limited and strongly selective. These studies usually only included children in whom there were abnormal findings on the ISS and/or children in whom the diagnosis of physical abuse was strongly suspected. These studies also generally failed to mention the total number of children who received an ISS without a FSS. Not surprisingly, in all these studies, a high proportion of children had FSS that identified fractures (Table 4).

Table 4: Summary of previous studies

	Kleinman et al (1996)	Zimmerman et al (2005)	Harlan et al (2009)
Sample size	23	48	101
Proportion with new fractures on FSS	57%	33%	38%
Number of fractures identified on FSS	19	35	60
Description of new fractures	Majority rib and metaphyseal	Majority rib and metaphyseal	Majority rib
Effect of FSS result on the assessment of abuse	Did not look at this outcome	FSS made diagnosis of abuse in 2/48 (4.2%)	Diagnosis of abuse modified in 9/101 (8.9%)

In 2009, the AAP modified its 2000 FSS recommendation to support the findings of Zimmerman and colleagues. The 2009 AAP policy recommended that a FSS should be performed approximately two weeks after the ISS in cases "when abnormal or equivocal findings are found on [ISS] and when abuse is suspected on clinical grounds."[11] The 2009 AAP policy made the FSS an important component of the clinical practice of evaluating children in whom abuse is suspected.

While the 2009 policy statement expands the use of the FSS, one problem with the recommendation is that it is vague on what is meant by "…when abuse is suspected on clinical grounds." 'Suspected abuse' may vary significantly and is often based on a clinician's individual experiences and background. Not surprisingly, studies show that two clinicians taking care of patients with identical histories and physical exams may reach completely different conclusions on whether they 'suspect' abuse on clinical grounds[22-24] and therefore whether a FSS is warranted.

CURRENT STUDY: GOALS, OBJECTIVES AND HYPOTHESES

The goals of the current study were to expand on previous literature and assess the use of the FSS by evaluating a large consecutive sample of children who underwent both ISS and FSS at Children's Hospital of Pittsburgh (CHP) of UPMC. The objectives of the study were: (1) to calculate the proportion of children who underwent both an ISS and FSS; (2) to determine the results of ISS and FSS in children who had both; (3) to evaluate the proportion and characteristics of patients in whom the clinical diagnosis was changed by the results of the FSS. We hypothesized that (1) there would be a subset of children with no fractures on ISS in whom the FSS would reveal fractures and a diagnosis of abuse would be dependent on the FSS, and that (2) a significant proportion of children with equivocal fractures on ISS would be recognized as having normal variants on FSS and in these children, the concern for abuse would be decreased as a result of the FSS.

MATERIALS AND METHODS

STUDY DESIGN AND SUBJECTS

This was a retrospective, descriptive study approved by the Institutional Review Board at the University of Pittsburgh with a waiver of informed consent. Children were eligible for the study if they had an ISS billed to their medical record between 4/1/02-3/31/09. The electronic medical record of each eligible child was reviewed to determine whether the ISS was for the evaluation of trauma and whether the patient also had a FSS. Children with an ISS not performed for the evaluation of trauma were excluded. Children with only an ISS performed for trauma were included to determine the proportion of all children that underwent both ISS and FSS. No information was collected about these children except for the fact that they only had an ISS.

The ISS performed routinely at CHP complies with the American College of Radiology (ACR) and AAP recommendations.[11, 25] The FSS performed at CHP is identical to the ISS, except that views of the skull and spine are excluded. Skull and spine views are excluded because recent studies show that views of the chest, lower extremities and upper extremities are equally as sensitive as a full FSS in identifying fractures.[21, 26] The FSS also routinely excludes oblique views of the ribs.

DEFINITIONS

A ‘previously recognized fracture’ was defined as a fracture that was diagnosed prior to the ISS. A ‘positive ISS’ was defined as a SS that identified any fractures, including those that were previously recognized. A ‘positive FSS’ was defined as a SS that identified new fractures or confirmed equivocal fracture from ISS as definite fractures. A ‘negative FSS’ was defined as a SS that identified no new fractures or confirmed equivocal fractures from ISS as normal variants. Clinical diagnosis of abuse was defined as (1) definite (2) probable (3) possible and (4) not abuse, as assessed by the Child Protection Team (CPT) at CHP, a commonly used gold-standard for defining and assessing abuse.[27-29]

DATA COLLECTION

The following data was collected on each subject using electronic medical records: age at time of ISS in months, gender, ‘reason for ISS,’ number of days between ISS and FSS, results of ISS and FSS and assessment of the clinical diagnosis of abuse after ISS and after FSS. Race and insurance information was unavailable.

Possible ‘reason for ISS’ was: (1) ‘previously recognized fractures’ (2) features of child abuse (e.g. bruising) (3) suspected abusive head injury (AHT) (4) signs or symptoms of injury (e.g. swelling) (5) non-specific symptoms (e.g. fussiness) (6) social concerns (e.g. abused sibling) (7) acute life threatening event (ALTE) (8) death (9) other. These categories were derived through an iterative process as part of a related study at CHP.[30] The ‘reason for ISS’ was determined by

two data extractors by referencing the emergency department notes and CPT notes. In children with more than one 'reason for ISS,' the reason which prompted the most concern for abuse (e.g. multiple bruises in an infant with vomiting) was documented. Suspected AHT was documented as the 'reason for ISS' only if an abnormal result on neuroimaging was obtained prior to the ISS.

The assessment of abuse made by the CPT was used to determine the clinical diagnosis of abuse after the ISS and after the FSS. These two diagnoses were compared to determine whether the results of the FSS influenced and/or altered the initial clinical diagnosis of abuse. Consult notes by the CPT that detailed the assessment of abuse after ISS were available on all subjects. In most cases, these notes also contained addendums which explained the CPT assessment of abuse after FSS. In the very few cases where the assessment of abuse after FSS was not detailed by the CPT, senior author, Rachel Berger MD, MPH, made the assessment in subjects with a positive FSS. This was subjective, though, limited to only a few cases.

Result of ISS and FSS were documented by assessing the location, type and age of each fracture. Possible locations of fractures were: (1) rib (2) skull (3) humerus (4) radius/ulna (5) femur (6) tibia/fibula or (7) other (e.g. hand, foot, spine and clavicle). Multiple rib fractures were considered a single fracture. Types of fractures were: (1) transverse/greenstick (2) spiral/oblique (3) subperiosteal elevation (4) metaphyseal (5) buckle, (6) rib or (7) unknown. Skull fractures were classified as unknown because we did not collect specific information on their various types (e.g. linear, depressed, diastatic, basilar, etc). Ages of fractures were either (1) acute (2) healing (3) acute and healing or (4) unknown. The age of skull fractures was always classified as unknown. Fractures were also either definite or equivocal based on the radiologist's reading. If

the radiologist did not mention whether the fracture(s) was definite or equivocal, it was assumed that the fracture was definite. Original radiographs were not reinterpreted. When additional radiological films were obtained within 48 hours of the ISS and/or FSS, these films were counted as part of the ISS and/or FSS.

DATA ANALYSIS

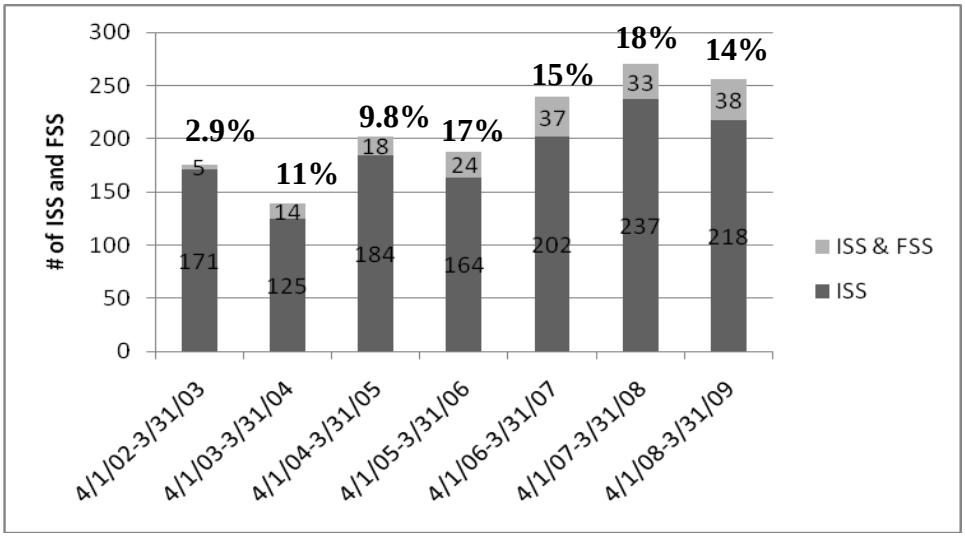
SPSS 17.0 (SPSS Inc., Chicago, IL) was used for analyses. Descriptive statistics were used to describe the study population; chi-square was used to compare proportions.

RESULTS

DEMOGRAPHICS

Between 4/1/02 and 3/31/09, 1470 children underwent an ISS for the evaluation of suspected physical abuse. Of these, 11% (169/1470) also received a FSS. These 169 patients made up the subjects of the study. The median (range) age of the study subjects was 2 (0-33) months. Eighty-eight percent (148/169) of the subjects were less than 12 months of age. The mean time (SD) in days between ISS and FSS was 19 (11). The mean (SD) number of FSS performed each year during the study period was 24 (13). There was a significant increase ($p < 0.00$) in the proportion of FSS performed in the last four years of the study (4/1/05-3/31/09) as compared to the first three years (4/1/02-3/31/05) (Figure 3).

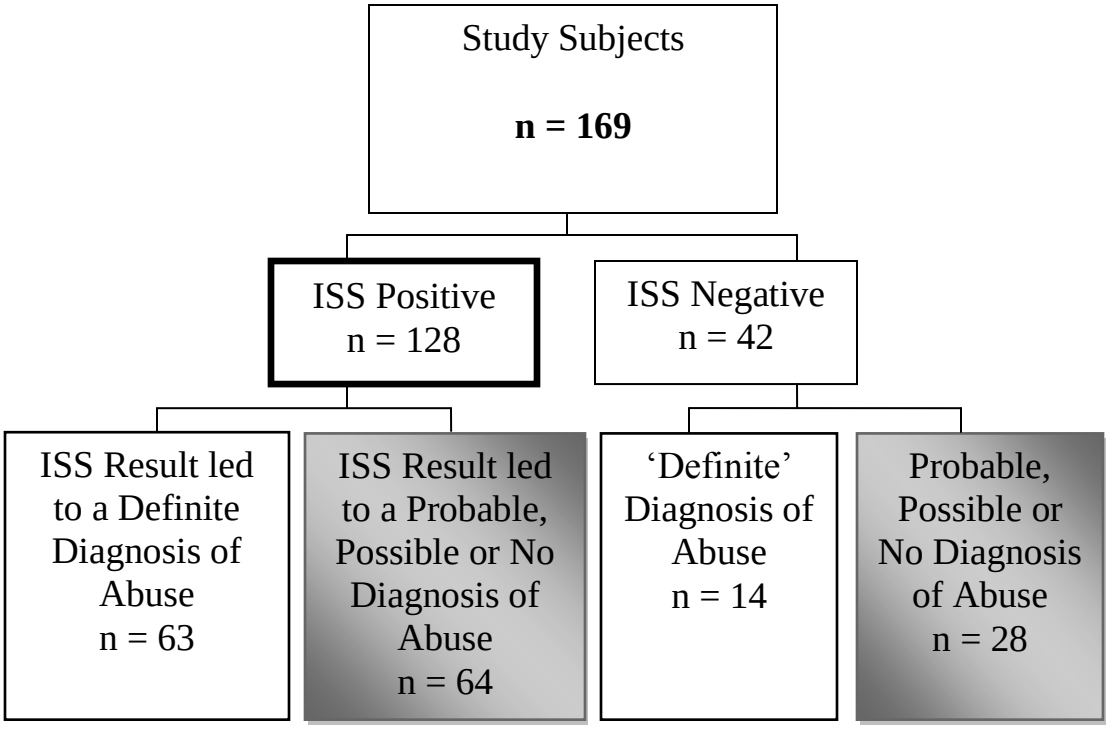
Figure 3: Proportion of children who had an initial skeletal survey and follow-up skeletal survey



RESULT OF INITIAL SKELETAL SURVEY AND ASSESSMENT OF ABUSE

The most common reason for ISS among the 169 study subjects were 'previously recognized fracture(s)' (44%) and suspected AHT (29%). The ISS was positive in 76% (128/169) of subjects, leading to a definite diagnosis of abuse in 37% (63/169) of subjects. For subjects with a negative ISS, a definite diagnosis of abuse was made in 8.3% (14/169) based on clinical findings other than fractures (e.g. AHT, bruising) (Figure 4).

Figure 4: Assessment of abuse after initial skeletal survey



RESULT OF FOLLOW-UP SKELETAL SURVEY

The FSS was positive in 16% (27/169) of the study subjects. The median (range) age of these 27 subjects was 2 (1-33) months. Fifty-two percent (14/27) were females. Thirty-nine healing fractures were identified in these 27 subjects. Ninety two percent (36/39) of these fractures were not noted on ISS; the remaining 8% (3/39) were felt to be equivocal on ISS but determined to be definite fractures on FSS. Forty-four percent (17/39) of these fractures were in the ribs. Fifty-four percent (21/39) were extremity fractures; the majority of these extremity findings were metaphyseal fractures or subperiosteal elevation. The FSS was negative in 84% (142/169) of the subjects. The median age (range) of these 141 subjects was identical to the 27 subjects with positive FSS. Forty-six percent (65/142) were female.

EQUIVOCAL FRACTURES ON INITIAL SKELETAL SURVEY

There were a total of 32 equivocal fractures on ISS. Nine percent (3/32) of these equivocal fractures were later determined to be definite fractures; 91% (29/32) were determined to be normal variants. Seventy-nine percent (23/29) of the equivocal fractures confirmed as normal variants were in the extremities (Table 5); the type for the majority of equivocal fractures later confirmed as normal variants was metaphyseal (Table 6).

Table 5: Location of fractures on follow-up skeletal survey

Location	New Fractures	Confirmed Fractures	Normal Variants
Ribs	15	2	3
Skull	0	0	2*
Humerus	2	0	2
Radius/Ulna	6	0	6
Femur	4	0	4
Tibia/Fibula	8	0	9
Clavicle	0	0	1
Hand	1	1	2
Total	**36**	**3**	**29**

*One patient did have views of the skull on FSS

Table 6: Type of fractures on follow-up skeletal survey

Type	New Fractures	Confirmed Fractures	Normal Variants
Transverse/ Greenstick	0	0	0
Spiral/Oblique	0	0	0
Subperiosteal Elevation	6	0	0
Metaphyseal	12	0	12
Buckle	0	0	3
Rib	15	2	3
Unknown	3	1	11

Prior to the FSS, 92 subjects did not have a definite diagnosis of abuse. Among these subjects, the FSS was positive and led to a definite diagnosis of abuse in 7.6% (7/92) (Figure 5). In the 7 cases in which the FSS was critical in making a diagnosis of abuse, the FSS identified definite fractures (Table 7). In one subject with a positive FSS and without a definite diagnosis of abuse prior to FSS, the findings on FSS were equivocal and therefore did not change the diagnosis of abuse. Among the 84 patients with a negative FSS, the concern for abuse was lowered in one 16 month old male from 'probable' to 'possible' when rib fractures from ISS were interpreted as adrenal calcifications on FSS.

Figure 5: Assessment of abuse after follow-up skeletal survey

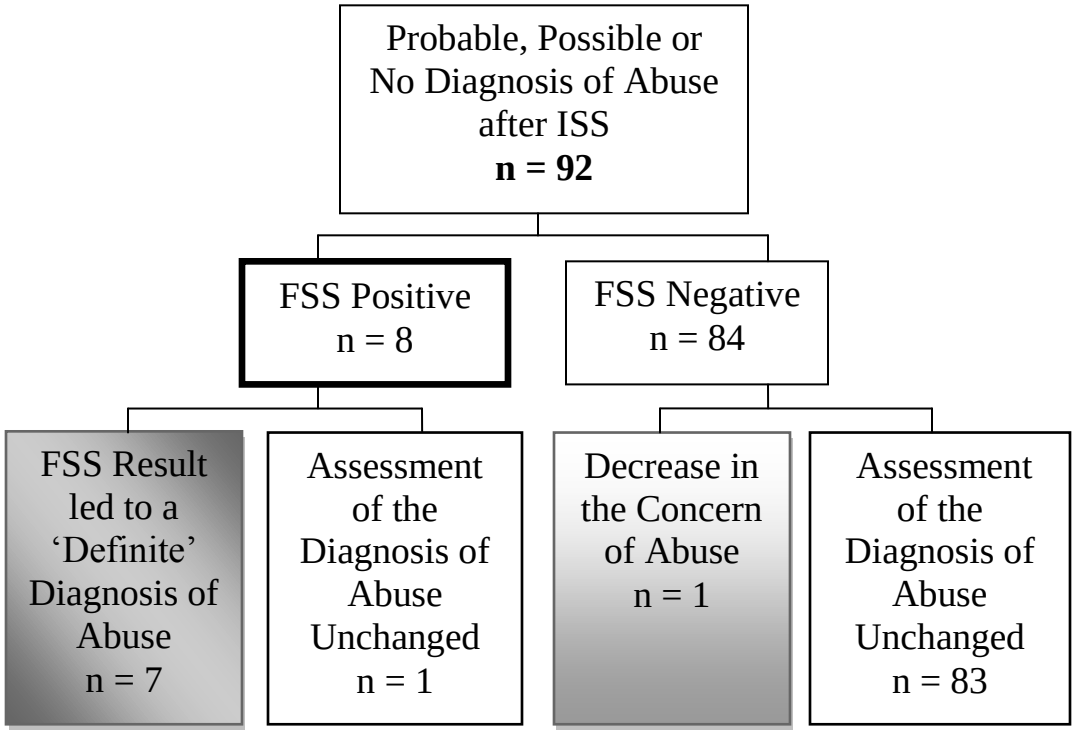


Table 7: Subjects in whom the findings of follow-up skeletal survey led to a definite diagnosis of physical abuse

#	Age(mo)	Gender	Reason for ISS	Fx on ISS	Abuse after ISS	#days ISS→FSS	FSS (new fractures)
1	3	Female	Bruises	No	Possible	21	12 fxs (6 ribs*, 3 metaphyseal tibia, 1 subperiosteal elevation humerus, 1 femur
2	2	Female	Bruises	No	Probable	21	7 rib fxs*
3	4	Female	Skull fx	No new fxs	Possible	18	8 fxs (7 ribs*, 1 metaphyseal femur)
4	7	Female	Skull fx	No new fxs	Probable	18	1 rib fx
5	2	Male	Skull fx	No new fxs	Possible	24	5 fxs (4 ribs*, 1 subperiosteal elevation femur)
6	10	Female	Femur fx	No new fxs	Probable	16	3 subperiosteal elevation fxs (2 radius, 1 ulna)
7	1	Female	Abused sibling	No	Not abuse	18	7 ribs fxs*

fx(s) = fracture(s)

No new fxs = ISS only identified previously recognized fractures, which are listed under the 'reason for the ISS'

*The number of rib fractures has been specified in this table to show the extent of injuries identified on the FSS in these 8 subjects. In the remaining data collection for this study, multiple rib fractures counted as a single fracture.

DISCUSSION

This is the largest study to date to assess the use of the FSS in children with suspected physical abuse. Unlike previous studies which only included patients in whom the diagnosis of abuse was strongly suspected before the FSS and/or patients who already had one or more fractures identified on ISS, our study included all patients who underwent both an ISS and FSS. Therefore, the lower proportion of positive FSS in our sample is likely more representative of the true rate than rates observed in previous studies.[17, 19, 21]

The Zimmerman and colleagues' recommendation that all patients who undergo an ISS should also get an FSS was published in late 2005. We therefore expected to see and did see an increase in the proportion of children who underwent both ISS and FSS after this time.

USE OF FOLLOW-UP SKELETAL SURVEY IN DIAGNOSIS OF CHILD PHYSICAL ABUSE

Children with a definite diagnosis of abuse after ISS routinely undergo FSS for reasons other than to identify new fractures (e.g. to make sure injuries are healing properly, to delineate the age of injuries). The major point of this study was to evaluate how the FSS influenced the diagnosis of abuse in children who did not have a previous definite diagnosis. In these children, a clinician, when deciding to obtain a FSS, had to compare the risks and benefits of a FSS. The primary risk of obtaining a FSS is radiation. However, there are also logistical barriers to obtaining a FSS

which should be considered. Arranging for a child to return to the hospital for a FSS can be difficult if the patient is in foster care or in the care of the parent being investigated as the possible perpetrator. The benefits of obtaining a FSS are (1) being able to make a definite diagnosis of abuse and (2) preventing repeated injury in select cases. In the current study, the findings of the FSS were critical in making a definite diagnosis of abuse in 7.6% of the subjects without a previous diagnosis. Whether this proportion justifies the benefits over the risks of obtaining a FSS is a matter for future studies.

The 7 subjects in whom the FSS led to a definite diagnosis of abuse were all less than 12 months of age and the time interval between when the subjects underwent ISS and FSS was greater than 14 days in each case. These data suggest that clinicians should obtain a FSS in children who do not have a previous definite diagnosis of abuse even if the time interval between ISS and FSS is greater than the two week AAP recommendation. Among these 7 subjects, 3 had a negative ISS. Two of the 3 subjects had multiple bruises, which were the reason for ISS. One of the 3 subjects had no physical findings; she received an ISS because she was a contact child (she was in contact with her abused twin).

EVALUATION OF EQUIVOCAL FRACTURES ON FOLLOW-UP SKELETAL SURVEY

An important role of the FSS is to evaluate equivocal fractures and to confirm them as either normal variants or definite fractures. In our study, neither of these situations had a significant influence on the clinical diagnosis of abuse. There were a total of 32 equivocal fractures on ISS. A small portion of these equivocal findings were confirmed as definite fractures on FSS.

However, a much larger portion was confirmed to be normal variants. Since fractures are common in physical abuse cases, radiologists are likely to be more sensitive to unusual findings and are more likely to interpret them as equivocal fractures when evaluating children with suspected abuse. Our results demonstrate that the type of fracture which was most likely to be 'over-read' was a metaphyseal fracture, which is highly specific for abuse.[4-8] This presents an unusual problem for clinicians and radiologists that have to read the ISS in children suspected of physical abuse: missing a metaphyseal fracture could lead to mistakenly discharging a child into a dangerous environment. 'Over-reading' an unusual finding in the extremities as a metaphyseal fracture is a safeguard against this problem. An 'over-read' of the ISS in children suspected of physical abuse will encourage clinicians to obtain a FSS, upon which the equivocal findings can be reassessed.

THE POTENTIAL USE OF FOLLOW-UP SKELETAL SURVEY IN CONTACT CHILDREN

In our study, there was a single contact child with a negative ISS and no stigmata of abuse in whom the FSS demonstrated multiple rib fractures and led to a definite diagnosis of abuse. Previous literature suggests that contact children are at an increased risk of abuse.[31-37] In a related study at CHP that retrospectively assessed the use of the ISS in children with suspected physical abuse, 2 of 32 contact children who underwent an ISS had a positive ISS. The contact child in the current study was also part of the cohort of 32 contact children in the related study.[30] Thus, 9.4% (3/32) of contact children had either a positive ISS or a positive FSS. These data suggest that an FSS may be warranted in contact children even when the ISS is negative.

LIMITATIONS

This study had several limitations. Most importantly, although we evaluated all patients who underwent both ISS and FSS, there was still selection bias. The only patients who undergo FSS at CHP are those evaluated by the CPT. Thus children who have a negative ISS who do not obtain a consultation from the CPT do not get a FSS. Thus only patients in whom the treating physician obtains a CPT consult have the possibility of undergoing a FSS. The one exception is contact children who are evaluated by the CPT even if they have no stigmata of abuse. As a result, it is not possible to know the true rate of positive FSS. The fact that this study was retrospective is also a limitation, although performing this type of study prospectively would require parental consent and therefore would likely introduce a significant enrollment bias.

FUTURE RESEARCH

Future studies should compare children who only receive an ISS with those who receive an ISS and FSS. This type of comparison could help identify certain clinical characteristics that, when present in a child undergoing an ISS, should warrant a FSS. Future studies should assess the use of the FSS in contact children. The findings of such a study could be useful in establishing clinical practices to assess contact children by encouraging the use of the ISS and FSS in these select cases. There currently exists no national policy detailing the evaluation and medical management of contact children.[37]

CONCLUSION

The FSS is an important part of the clinical evaluation of suspected child physical abuse. The FSS identified new fractures which led to a definite diagnosis of abuse in ~8% of subjects without a previous diagnosis of abuse. Future research should attempt to identify clinical characteristics that, when present in a child undergoing an ISS, suggest that the child should also undergo a FSS.

APPENDIX A

DEMOGRAPHICS AND INITIAL SKELETAL SURVEY DATA COLLECTION FORM

First Name:_____ Last Name: _____

MRN:_____ DOB: __ __/__ __/__ __ __ __ DOSS1: __ __/__ __/__ __ __ __

SEX	1	Male
	2	Female
REASSKEL	1	recognized fracture – looking for others (i.e. single fx diagnosed first)
	2	features of child abuse noted (e.g. head injury, bruises)
	3	looking for fractures – symptomatic: sx or signs of trauma
	4	looking for fractures – non-specific symptoms
	5	asymptomatic/ social concerns (sibs, report of adult, CYF request, etc)
	6	Other
	7	ALTE
	8	death

MOREINFO (select only 1 response)

If # 1	If # 2	If #3	If #4	If #5
1 rib	1 bruise/bruises	1↓ use/moving	1 fussiness	1 sib/contact
2 skull	2 head injury	2 swelling	2 ↓ sleep	2 danger envir
3 upper ext (not hand)	3 burns, other skin	3 bruising	3 ↓ activity	3 CPS request
4 lower ext (not feet)	4 FTT	4 other	4 GI(vomit)	4 Family reques
5 femur	5 sexual abuse	5 pain	5 other	5 other
6 hand/feet/spine	6 other ____			6 assault witnessed
7 other _____	7 ^ OFC			7 neglect/abandonment
	8 abnormal eye exam			

SS1RESULT	0	suspected fx only
	1	no fx

	2	no fx, other than initial fx dx pre-survey (use only if #1 in REASSKEL)
	3	fracture(s) possible
	4	fracture(s) definite
	5	some definite, some possible
SS1ABNORM1	1	rib (s) (ribs count as 1fracture if likely to be caused by single event; > 2 fxs if different ages)
	2	single fracture: skull
	3	single fracture: upper extremity (not incl hands)
	4	single fracture: lower extremity (not incl feet)
	5	single fracture: other (e.g. hand, foot, spine)
	6	two separate fractures
	7	three fractures
	8	four fractures
	9	more than 4 fractures
	10	single fracture: clavicle
SS1ABNORMSTATUS	1	acute
	2	healing/not acute (skull fractures without STS go here)
	3	both acute and healing
	4	unknown/ can't tell
REPEATSS	1	Not done
Abuse ED	1	No
	2	Yes – definite
	3	Significant concern
	4	Slight concern
	5	Unknown – not enough info
	6	No findings, but social concerns

Variables Defines

Variable	Label
STUDYID	Study ID
MRN	MRN
DOB	Date of Birth
DOSS	Date of SS
year	<none>
AGE	Age in months at time of SS
SEX	Sex
ARRIVAL	Mode of arrival at CHP

REASHOSP	Initial reason for seeking medical attention
REASSKEL	Primary Reason for SS
MOREINFO	more information about reason for SS
SS1RESULT	Result of initial SS
SS1ABNORM	Abnormalities on initial SS (only if 3,4,5 above)
SS1ABNORMSTATUS	Status of abnormalities on initial skeletal survey:
HBVALUE	Hb
PLATELETVALUE	Platelet
ALKPHOSVALUE	alk phos
CPK	CPK
HEADCTRESUL	Head CT
MRI	MRI
repeatss	Repeat skeletal survey
SS2ABNORMSTATUS	Location of new abnormalities on repeat skeletal survey - only fill out if #3 above
abuseed	abuse or not: assessment at the time
location	Location
ID2	Study ID
researchassistant	research person filling in data
NOTES	Notes

APPENDIX B

FRACTURES ON ISS AND FSS DATA COLLECTION FORM

First Name:_____ Last Name:_____

MRN:_____ DOSS1: __ __ / __ __ / __ __ __ __

Was the reason for initial SS a previously recognized fracture? 1 No 2 Yes

	PREVFXLOC	PREVFXTYPE	Acute(1)	Healing(2)	Unknown(3)
1	_____	_____	☐	☐	☐
2	_____	_____	☐	☐	☐

ISSFX	3	Normal (*no fracture(s) on initial SS*)
	4	Only fracture(s) identified were those already recognized/suspected (*see above*)
	5	Single rib: posterior/PL
	6	Single rib: anterior/AL
	7	Multiple ribs
	8	Single fracture: skull
	9	Single fracture: humerus
	10	Single fracture: radius/ulna
	11	Single fracture: femur
	12	Single fracture: tibia/fibula
	13	Single fracture: other (*e.g. hand, foot, spine, clavicle*)
	14	More than one fracture
	15	More than six fractures
FXTYPE	1	Transverse/greenstick
	2	Spiral/oblique
	3	Subperiosteal elevation
	4	Metaphyseal
	5	Buckle

6 Unknown/other

SEPERATEFXS		SEPFXLOC	SEPFXTYPE	Definite(1)	Possible(2)	Acute(1)	Healing(2)	Unknown(3)
16	(1)	_____	_____	☐	☐	☐	☐	☐
17	(2)	_____	_____	☐	☐	☐	☐	☐
18	(3)	_____	_____	☐	☐	☐	☐	☐
19	(4)	_____	_____	☐	☐	☐	☐	☐
20	(5)	_____	_____	☐	☐	☐	☐	☐
21	(6)	_____	_____	☐	☐	☐	☐	☐

DOFSS: __ __ / __ __ / __ __ __ __ TIMEAFTERISS: _____

FSS

1 No new fx(s) seen—confirms definite fractures from SS1
2 No new fx(s) seen—confirms possible fractures from SS1
3 No new fx(s) seen—confirms definite and possible fractures from SS1
4 Conflict with original SS—fracture(s) from SS1 no longer appear to be fracture(s) on repeat SS *(applicable for both possible and definite fxs from SS1)*
5 New fx(s) seen *(takes precedence over 1, 2 and 3 if applicable)*
6 No new fx(s) seen (*no fx(s) on SS1)*
7 Other (*when 4&5, pick 7: explain other in notes at the end*)

SS2CONFLICT

1 Specific fracture(s) no longer visible, list below (*use #1-21 from INITIALSSABNORML and MULTIPLESEPERATEFXS)*:
(1) ___ (2) ___ (3) ___ (4) ___ (5) ___
2 ALL skeletal findings from initial SS are no longer visible on repeat SS

SS2NFX

		Definite(1)	Possible(2)	Acute(1)	Healing(2)	Unknown(3)
1	Single rib: posterior/PL	☐	☐	☐	☐	☐
2	Single rib: anterior/AL	☐	☐	☐	☐	☐
3	Multiple ribs	☐	☐	☐	☐	☐
4	Single fracture: skull	☐	☐	☐	☐	☐
5	Single fracture: humerus	☐	☐	☐	☐	☐
6	Single fracture: radius/ulna	☐	☐	☐	☐	☐
7	Single fracture: femur	☐	☐	☐	☐	☐
8	Single fracture: tibia/fibula	☐	☐	☐	☐	☐
9	Single fracture: other	☐	☐	☐	☐	☐
10	More than one fracture					
11	More than six fractures					

NFXTYPE

1 Transverse/greenstick
2 Spiral/oblique
3 Subperiosteal elevation
4 Metaphyseal
5 Buckle
6 Unknown/other

NSEPERATEFXS		NSEPFXLOC	NSEPFXTYPE	Definite(1)	Possible(2)	Acute(1)	Healing(2)	Unknown(3)
12	(1)	_____	_____	☐	☐	☐	☐	☐
13	(2)	_____	_____	☐	☐	☐	☐	☐
14	(3)	_____	_____	☐	☐	☐	☐	☐

15 (4)_____ _____ ☐ ☐ ☐ ☐ ☐
16 (5)_____ _____ ☐ ☐ ☐ ☐ ☐
17 (6)_____ _____ ☐ ☐ ☐ ☐ ☐

What additional information did the f/up SS provide about the diagnosis of abuse?

1 None. Level of concern about abuse unchanged by f/up SS
2 Newly recognized fractures contributed to ability to make abuse dx
3 Some fractures no longer visible. As a result, level of concern for abuse lower
4 Other, describe:
_____

NOTES: _____

Variables Defines

Variable	Label
STUDYID	Study ID
MRN	Medical Record Number
DOB	Date of Birth
DOSS1	Date of Initial SS
YEAR	<none>
AGE	Age in months at time of SS1
SEX	Sex
REASSKEL	Reason for Initial SS
MOREINFO	more information about reason for SS
PREVFX	Was there a previously recognized fracture?
PREVFX1LOC	Previously recognized fx 1 location
PREVFX1TYPE	Previously recognized fx 1 type
PREVFX1STATUS	Previously recognized fx 1 status
PREVFX2LOC	Previously recognized fx 2 location
PREVFX2TYPE	Previously recognized fx 2 type
PREVFX2STATUS	Previously recognized fx 2 status
SS1RESULT	Result of Initial SS (definite and possible)
SS1FXVISIBLE	Visiblity of single or multiple fxs on intial SS
SS1ABNORMSTATUS	Status of abnormalities on initial skeletal survey
FXTYPE	Long bone fracture type
SEPFX1LOC	Multiple separate fx 1 location

SEPFX1TYPE	Multiple separate fx 1 type
SEPFX1VISIBLE	Multiple separate fx 1 visibility
SEPFX1STATUS	Multiple separate fx 1 status
SEPFX2LOC	Multiple separate fx 2 location
SEPFX2TYPE	Multiple separate fx 2 type
SEPFX2VISIBLE	Multiple separate fx 2 visibility
SEPFX2STATUS	Multiple separate fx 2 status
SEPFX3LOC	Multiple separate fx 3 location
SEPFX3TYPE	Multiple separate fx 3 type
SEPFX3VISIBLE	Multiple separate fx 3 visibility
SEPFX3STATUS	Multiple separate fx 3 status
SEPFX4LOC	Multiple separate fx 4 location
SEPFX4TYPE	Multiple separate fx 4 type
SEPFX4VISIBLE	Multiple separate fx 4 visibility
SEPFX4STATUS	Multiple separate fx 4 status
SEPFX5LOC	Multiple separate fx 5 location
SEPFX5TYPE	Multiple separate fx 5 type
SEPFX5VISIBLE	Multiple separate fx 5 visible
SEPFX5STATUS	Multiple separate fx 5 status
SEPFX6LOC	Multiple separate fx 6 location
SEPFX6TYPE	Multiple separate fx 6 type
SEPFX6VISIBLE	Multiple separate fx 6 visible
SEPFX6STATUS	Multiple separate fx 6 status
AbuseED	Assessment of abuse at time of SS1
DOSS2	Date of repeat SS
TIMEAFTERSS1	Time (in days) between SS1 and SS2
SS2	Result of repeat SS
SS2CONFLICT	Old fracture (s) no longer visible on repeat SS
CONFLICTFX1	Fracture 1 no longer visible (1-21)
CONFLICTFX2	Fracture 2 no longer visible (1-21)
CONFLICTFX3	Fracture 3 no longer visible (1-21)
CONFLICTFX4	Fracture 4 no longer visible (1-21)
SS2NFX	New recognized fracture(s)
NFXVISIBLE	New fracture visibility
NFXSTATUS	New fracture status
NFXTYPE	New fracture type
NSEPFX1LOC	New multiple separate fx 1 location
NSEPFX1TYPE	New multiple separate fx 1 type

NSEPFX1VISIBLE	New multiple separate fx 1 visibility
NSEPFX1STATUS	New multiple separate fx 1 status
NSEPFX2LOC	New multiple separate fx 2 location
NSEPFX2TYPE	New multiple separate fx 2 type
NSEPFX2VISIBLE	New multiple separate fx 2 visiblity
NSEPFX2STATUS	New multiple separate fx 2 status
NSEPFX3LOC	New multiple separate fx 3 location
NSEPFX3TYPE	New multiple separate fx 3 type
NSEPFX3VISIBLE	New multiple separate fx 3 visibility
NSEPFX3STATUS	New multiple separate fx 3 status
NSEPFX4LOC	New multiple separate fx 4 location
NSEPFX4TYPE	New multiple separate fx 4 type
NSEPFX4VISIBLE	New multiple separate fx 4 visiblity
NSEPFX4STATUS	New multiple separate fx 4 status
NSEPFX5LOC	New multiple separate fx 5 location
NSEPFX5TYPE	New multiple separate fx 5 type
NSEPFX5VISIBLE	New multiple separate fx 5 visiblity
NSEPFX5STATUS	New multiple separate fx 5 status
NSEPFX6LOC	New multiple separate fx 6 location
NSEPFX6TYPE	New multiple separate fx 6 type
NSEPFX6VISIBLE	New multiple separate fx 6 visibility
NSEPFX6STATUS	New multiple separate fx 6 status
NFXVISIBLEHS	Were new skeletal findings visible in hindsight
FXVISIBLEHS1	New fx 1 visible in hindsight
FXVISIBLEHS2	New fx 2 visible in hindsight
FXVISIBLEHS3	New fx 3 visible in hindsight
ADDINFOSS2	What additional info. did the follow-up SS provide
NOTES	Describe "other" from ADDITIONALINFOSS2

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