Sensitivity of the Limited View Follow-up Skeletal Survey

WHAT'S KNOWN ON THIS SUBJECT: A previous study suggested that spine and pelvis views may be omitted from the follow-up skeletal survey protocol for suspected child abuse, when these views are normal on the initial skeletal survey, without limiting the sensitivity of the study.

WHAT THIS STUDY ADDS: This multicenter study provides estimates of the risk of missing occult fractures in the evaluation of suspected child abuse with omission of spine and pelvis views from the follow-up skeletal survey protocol. Results may be used to update practice recommendations.

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KEY WORDS
abuse, fractures, radiation, skeletal survey

ABBREVIATIONS
AAP—American Academy of Pediatrics
ACR—American College of Radiology
ALARA—as low as reasonably achievable
CI—confidence interval
CT—computed tomography
IQR—interquartile range
SS1—initial skeletal survey
SS2—follow-up skeletal survey

Dr Hansen participated in the initial conceptualization and design of the study, planned and participated in data collection, participated in analysis and interpretation of data, drafted the initial manuscript, reviewed and revised the initial manuscript, and finalized the final manuscript as submitted; Dr Keeshin participated in the initial conceptualization and design of the study, planned data collection, designed the data collection instrument and participated in data collection, participated in analysis and interpretation of data, and assisted with the drafting of and critical revision of the initial manuscript; Drs Flaherty, Newton, Passmore, and Prince participated in the concept and design of the study, collected data, and assisted with critical revision of the initial manuscript; and Dr Campbell directed the initial conceptualization and design of the study, directed the analysis and interpreted the data, and assisted with the drafting of and critical revision of the initial manuscript. All authors approved the final manuscript as submitted.

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abstract

BACKGROUND AND OBJECTIVE: Reducing radiation exposure to minimize risk has been emphasized in recent years. In child abuse, the risk of missing occult injuries is often believed to outweigh radiation risk associated with skeletal surveys. Our hypothesis was that there would be no clinically significant difference in results from a limited view, follow-up skeletal survey (SS2) protocol, which omits spine and pelvis views unless these views have findings on the initial skeletal survey (SS1), compared with a traditional SS2 protocol for radiographic evaluation of suspected physical abuse.

METHODS: This study was a retrospective record review involving 5 child protection teams. Consultations for suspected physical abuse were reviewed to identify subjects <24 months of age who had an SS1 and a traditional SS2. The results of these studies were compared to identify subjects in which newly identified spine and pelvis fractures (fractures seen only on SS2 and not on SS1) would have been missed by using a limited view SS2 protocol.

RESULTS: We identified 534 study subjects. Five subjects had newly identified spine fractures, and no subjects had newly identified pelvis fractures on traditional SS2 studies. Only 1 subject with a newly identified spine fracture would have been missed with the limited view SS2 protocol used in this study (0.2% [95% confidence interval: <0.005–1.0]). None of the newly identified fractures changed the abuse-related diagnosis.

CONCLUSIONS: We found no clinically significant difference in the results of a limited view SS2 protocol versus a traditional SS2 protocol for radiographic evaluation of suspected abuse. *Pediatrics* 2014;134:242–248

Skeletal trauma is common in abuse.[1] Both the initial skeletal survey (SS1) and the follow-up skeletal survey (SS2) are recognized as essential elements in the medical evaluation of abuse in young children. The American Academy of Pediatrics (AAP) and the American College of Radiology (ACR) consider SS1 the standard of care for the medical evaluation of suspected physical abuse in children <24 months of age. SS2 is recommended ~2 weeks after SS1when abnormal or equivocal findings are present on SS1 and when abuse is suspected on clinical grounds.[2,3] SS2 may identify occult fractures present at the time of the initial evaluation but not visible until some callus has formed. SS2 may also clarify equivocal findings on the initial study and help with approximate dating of fractures.[4,5]

The yield of SS2 may be defined as the rate at which SS2 adds information to that available from SS1. Different authors may consider added information as newly identified fractures, clarification of questioned fractures on SS1 as fractures or not fractures, information about fracture age, or some combination of these factors. Previous research suggests that the yield of SS2 ranges between 14% and 61%.[4–9] When SS2 has a positive yield, the new information affects the abuse-related diagnosis by increasing certainty, decreasing certainty, or reversing the diagnosis in 14% to 41% of cases.[5–8] These features make SS2 important in the accurate medical evaluation and diagnosis of abuse. They also make SS2 important in the complete documentation of all injuries when the diagnosis of abuse has been made. The complete documentation of injuries has been shown to be helpful in better establishing the medical diagnosis of child abuse, the protection of children, and the legal prosecution of child abuse cases.[10]

Although imaging studies are central to the evaluation of child abuse, concern about the use of radiation in children has increased in the past several years. The Society for Pediatric Radiology supports a linear, no-threshold model as the best way to estimate the risk of radiation exposure. This model states that no level of radiation exposure is without consequence.[11] The ALARA concept (as low as reasonably achievable) addresses these concerns as a philosophy of radiation–dose management.[12]

In 2009, our center published a study that suggested that the spine and pelvis views could be omitted from SS2 without loss of information when no spine or pelvis findings (fractures or questioned fractures) were present on SS1.[6] Removing routine spine and pelvis views from SS2 not only eliminates the highest single radiation dose views from the study but also decreases radiation to the thymus, thyroid, and gonads, which are particularly sensitive to radiation. This is in keeping with the ALARA concept while maintaining the goals of accurate diagnosis and complete documentation of injuries.

Our objective in the present study was to determine if a large multicenter study would support the results of our previous single-center study.[6] Our hypothesis was that there would be no clinically significant difference in results from a limited view SS2 protocol that omits the spine and pelvis views (when no spine or pelvis fractures or questioned fractures are present on SS1) compared with a traditional SS2 protocol for radiographic evaluation of suspected physical abuse.

METHODS

This study was a retrospective trial based on record review involving 5 child protection teams. Each center obtained approval from their respective institutional review board. Consecutive child protection team consultations for possible physical abuse were reviewed to identify subjects <24 months of age (eligible subjects). Study subjects were those eligible subjects with both an SS1 and a traditional SS2 performed from 10 to 42 days later at the same institution.

The study included cases that were evaluated from 1999 through 2009. All centers performed SS1 and traditional SS2 according to published ACR standards during the study period. The studies were interpreted by pediatric radiologists at each institution. The total study population included 97 cases from the 2009 study.[6] The data from that study were recollected based on the present study's protocol.

We defined the limited view follow-up skeletal survey protocol as an SS2 with the same views as the traditional SS2,[13] without spine and pelvis views, unless there are definite or questioned spine or pelvis fractures on the SS1. The spine or pelvis views are included in the limited view SS2 in that situation (Table 1).

Definite fractures were those findings on SS1 about which the radiologist could make a definitive diagnosis of fracture. Questioned fractures were those findings on SS1 about which the radiologist raised the possibility that the finding was a fracture but could not make a definitive diagnosis. Newly identified fractures were findings seen only on SS2. By definition, these newly identified fractures were not referenced in the radiology report for SS1, including as a questioned fracture. If a new questioned spine or pelvis fracture was identified only on SS2, it was included as a newly identified fracture in this study to be as conservative as possible with regard to the study question.

Investigators at each institution reviewed radiology reports for each study subject. Definite fractures and questioned fractures were listed for each SS1. Newly identified factures and the follow-up information about questioned

TABLE 1 Individual Radiographs Obtained in the Follow-up Skeletal Survey

Traditional Follow-up SS2 of 19 Individual Radiographs	Limited View Follow-up SS2 of 15 Individual Radiographs[a]
Humeri (AP)	Humeri (AP)
Forearms (AP)	Forearms (AP)
Hands (PA)	Hands (PA)
Femurs (AP)	Femurs (AP)
Lower legs (AP)	Lower legs (AP)
Feet (PA) or (AP)	Feet (PA) or (AP)
Thorax (AP, left and right obliques[b])	Thorax (AP, left and right obliques[b])
Cervical spine (lateral)	
Thoracic and upper lumbar spine (lateral)	
Lumbosacral spine (lateral)	
Pelvis (AP), to include mid lumbar spine	

AP, anterioposterior; PA, posterior-anterior.

[a] Lateral spine and pelvis views are performed when fractures or questioned fractures of the spine or pelvis are noted on the SS1.

[b] The ACR and Society for Pediatric Radiology include left and right oblique chest views as part of the initial skeletal survey protocol.[13] They are part of the limited view follow-up skeletal survey protocol.

fractures on SS1 were listed for each SS2. This information was used to determine when SS2 added information to that obtained on SS1. Added information for SS2 was defined as: (1) newly identified fractures; (2) questioned fractures on SS1 confirmed as fractures; or (3) questioned fractures on SS1 determined not to be an injury.

When newly identified spine or pelvis fractures were present on SS2, the SS1 radiology report was reviewed to determine if there had been any spine or pelvis findings on SS1. In addition, radiographs were reviewed with pediatric radiologists at each center to determine on which views of SS2 the newly identified fractures could be seen, and if the newly identified fractures could be seen in retrospect on SS1. Notes from child protection team consultations were reviewed for all cases with newly identified spine or pelvis fractures on SS2 to determine if the newly identified fractures had changed the abuse-related diagnosis in any way. This determination was made by the child abuse pediatrician involved in the study at each site.

The outcome of interest was any newly identified spine or pelvis fractures seen on the traditional SS2 that would have been missed with the limited view SS2 protocol. "Missed" newly identified fractures could not be accompanied by any other definite spine or pelvis fractures or questioned fractures on SS1 and could not be seen on any of the views routinely included in the limited view SS2. Secondary outcomes included changes in abuse-related diagnoses associated with findings that would have been missed with the limited view SS2 protocol.

Due to the ethical and clinical significance of missing a diagnosis of child abuse based on a more limited medical evaluation, we sought a sample size of 598 study subjects to establish a 95% confidence interval (CI) of 99.5% to 100.0% (1-sided) based on the hypothesis that we would identify no failures of the limited view SS2. Stata version 12 (Stata Corp, College Station, TX) was used for descriptive analysis of all data.

RESULTS

The 5 centers involved in this study identified 1963 eligible subjects. Of these, 534 study subjects (27.2%) were identified (Fig 1). Although smaller than initially planned, the study sample would provide a 95% CI that was >99.4% if no protocol failures were identified. The mean age of the study subjects was 5.4 months, and the median age was 4 months. The SS2 added information in 207 (38.8%) of 534 cases.

The number of subjects with spine fractures was 14 (2.6% [95% CI: 1.4–4.4]) of 534, for a total of 26 spine fractures. For the purposes of this count, "spine fracture" was defined as definite spine fractures on SS1, questioned spine fractures on SS1 confirmed as fractures on SS2, and newly identified spine fractures on SS2. In 5 of the 14 subjects with spine fractures (5 of 534 [0.9%]; 95% CI: 0.3–2.2), these were newly identified spine fractures, seen only on SS2, for a total of 8 fractures. The 14 subjects with spine fractures had a median of 3 other fractures (interquartile range [IQR]: 3–15). Subjects without spine fractures had a median of 1 fracture (IQR: 0–4).

In 2 of the 5 subjects with newly identified spine fractures on SS2 (Table 2), there were also other spine findings on SS1 (spine fractures or questioned spine fractures in other locations). In 2 of the remaining 3 subjects, the newly identified spine fractures were seen on the anterioposterior chest view of SS2. The final subject did not meet either of these 2 conditions (1 of 534 [0.2%]; 95% CI: <0.005–1.0) (Table 2, subject 5). The newly identified spine fractures did not change the abuse-related diagnosis in any of the 5 subjects.

Pelvis fractures were identified in 2 (0.4%) of 534 subjects (95% CI: 0.05–1.3), for a total of 2 fractures. These were both identified on SS1. No pelvis fractures were identified on SS2 that were not identified on SS1 (95% CI: 0–0.7). Subjects with pelvis fractures had a median of 7.5 other fractures (IQR: 2–13). Subjects without pelvis fractures had a median of 1 fracture (IQR: 0–4).

DISCUSSION

In this study, 5 subjects had newly identified spine fractures seen only on

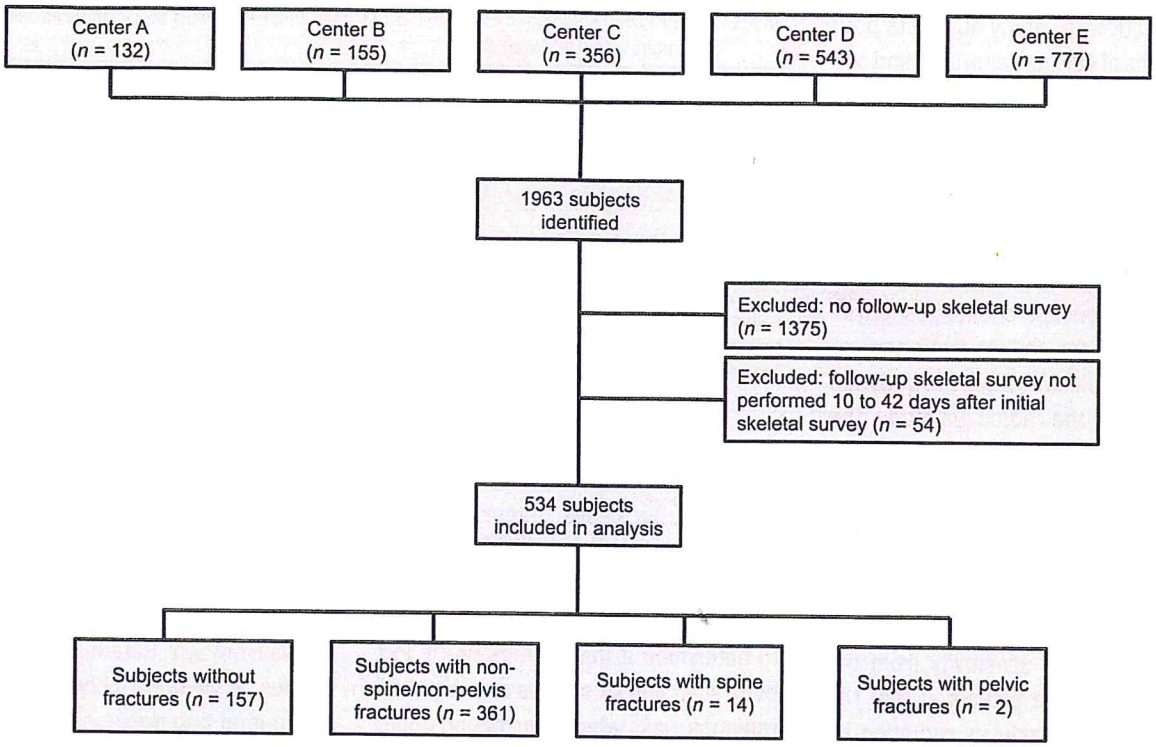

FIGURE 1
Study subjects. "Fractures" include definite fractures on SS1, findings questioned as fractures on SS1 and confirmed as fractures on SS2, newly identified fractures on SS2, and findings questioned as fractures on SS2.

TABLE 2 Subjects With Newly Identified Spine Fractures on Traditional Follow-up SS2

Subject	SS1 Spine Findings[a]	Traditional Follow-up SS2 Newly Identified Spine Fractures	Traditional Follow-up SS2 Non-Spine Views Showing Newly Identified Spine Fractures[b]	Other Injuries Identified
1	1 questioned compression fracture	1 compression fracture (at another site than the 1 questioned on the initial skeletal survey)	None	Multiple fractures; humerus, radius, ulna, tibia, fibula
2	2 compression fractures at thoracic vertebrae T7 and T8	1 compression fracture at thoracic vertebrae T6	None	Subdural hematoma
3	None	3 compression fractures at thoracic vertebrae T9, T10, and T11	AP chest	Subdural hematoma, tibia fracture
4	None	2 compression fractures, thoracic vertebrae	AP chest	Classic metaphyseal lesion of femur
5	None	1 fracture at lumbar vertebrae L2	None	Subdural hematoma

AP, anterioposterior.
[a] When spine findings (fractures or questioned fractures) are present on SS1, spine films are added back into the limited view follow-up SS2 per protocol; thus, the limited view follow-up SS2 identifies any new spine fractures that may be present.
[b] The limited view follow-up SS2 always has an AP chest view, per protocol; thus, if a spine fracture is identified on the AP chest view of a traditional follow-up SS2, the limited view SS2 will also identify it.

SS2. The limited view SS2 protocol would identify these fractures in 4 of these subjects. Two subjects had other spine findings on SS1, and the spine views would therefore have been included in the limited view SS2. In the 2 other subjects, the newly identified spine fractures were visible on the anterioposterior chest view, which is always included in the limited view SS2. One newly identified spine fracture in 1 subject (Table 2, subject 5) would have been missed by using the limited view SS2 protocol, without changing the abuse-related diagnosis. This finding was a questioned spine fracture included in the data to be as conservative as possible in addressing the study question, and the area in question was seen on SS1 in retrospect. This subject had other clear evidence of abuse and also had multiple congenital spine anomalies.

These data demonstrate that the limited view SS2 will rarely miss spine and pelvis fractures that would have been identified on a traditional view SS2. This

large multicenter study supports both the results of our earlier study[6] and our hypothesis that there is no clinically significant difference in results from a limited view SS2 protocol versus a traditional view SS2 protocol for radiographic evaluation of suspected physical abuse.

The ALARA concept challenges physicians to use the lowest radiation exposure possible to answer the question addressed by the radiologic study. The limited view SS2 protocol is compelling and of clinical significance because it meets this challenge via elimination of routine spine and pelvis views, thus decreasing radiation to organs that are particularly radiosensitive, without significant change in sensitivity from the traditional SS2. We estimated that the limited view SS2 reduces radiation by ~90%, compared with the traditional SS2 (Table 3).[14] The benefits of less discomfort, less time spent in the radiology department for the child, and potential cost savings must also be considered.

Although spine and pelvis fractures are not common in abuse cases, and are rarely missed by the limited view SS2, they do have the potential to enhance child abuse cases as additional injuries, with mechanisms different from other fractures. Centers must balance the advantages to patients offered by the limited view SS2 with this potential impact on the overall outcome of cases.

Our results suggest a need for thoughtful discussion and research surrounding the role of newer modes of radiographic imaging in selected cases. ^{18}F PET bone scan and computed tomography (CT) scans are not the standard of care for fracture identification in child abuse, and both studies involve more radiation exposure than the skeletal survey. One subject in our study had a pelvis fracture not identified on either SS1 or SS2, but identified on ^{18}F PET bone scan and CT scan. In 2 of our subjects with newly identified spine fractures on SS2, these fractures were identified after ^{18}F PET bone scan had already identified them. Our cases suggest that SS2 may not be the radiographic study of choice for identifying spine and pelvis fractures. Further research is needed to determine if the benefits of ^{18}F PET bone scan and CT studies outweigh the radiation risks when information about spine and pelvis fractures is deemed critical to case outcome or to explain persistent clinical signs or symptoms.

SS2 is performed primarily to identify callus. The skull, which is primarily membranous bone, is not expected to show new findings in the time frame in which SS2 is performed,[3,5] and skull films are not part of the recommended traditional SS2 protocol.[3] Similar reasoning can be applied to the pelvis and spine. The pelvis is a membranous, noncallus-forming bone. The spine is an endochondral bone, but radiologists have long noted that the vertebrae do not develop callus in the manner of other endochondral bones.

The small number of subjects with spine and pelvis fractures in this study is comparable to that found in previous studies.[15–28] The small number of these fractures, and their frequent association with other evidence allowing the diagnosis of abuse, has triggered a suggestion that spine and pelvis views be omitted from SS1.[24,26] Others have opposed this viewpoint for spine fractures,[25,27,28] making the argument that there is high specificity for abuse when occult spine fractures are discovered, and that spine fractures, while uncommon, are not rare. The low initial prevalence of spine and pelvis fractures on both SS1 and SS2 supports decreasing repeated exposure by eliminating these views from SS2. Retaining them on SS1 allows a balance between complete evaluation and documentation and the ALARA concept.

Others have suggested eliminating hand views from SS2 when these views are normal on SS1.[9] Hand and foot fractures are anatomically and mechanistically similar and may be considered together. Our study found 10 (1.9%) of 534 subjects had these fractures. Despite this low yield, the inclusion of these views in SS2 may achieve the best balance between the ALARA concept and the need for complete injury documentation, given the high specificity for abuse of these fractures and their relatively low required radiation dose.

At the time of this writing, 7 studies have been published with regard to SS2.[4–9,29] Although of different design, and occurring in different time periods (some involving screen-film and others computed or digital radiography), all have supported the utility of SS2 in the evaluation of child abuse. Our study also demonstrates this utility, and our yield of 38.8% is comparable to the yield demonstrated in previous studies (14%–61%).[4–9] The variation in yield between studies is explained in part by the authors' different consideration of

TABLE 3 Approximate Radiation Exposure in the Traditional Follow-up SS2 Compared With the Limited View Follow-up SS2

Skeletal Survey Dose Estimates (Based on Average Dose for 1-Year-Old Child)	Exposure per Radiograph (mSv)[a]	SS1	Traditional SS2	Limited View Follow-up SS2
Skull	0.008	0.016	0	0
Thorax	0.016	0.048	0.048	0.048
Pelvis	0.015	0.015	0.015	0
Spine	0.17	0.51	0.51	0
Extremity[b]	0.0005	0.006	0.006	0.006
Total		0.595	0.579	0.054

[a] Adapted from Ahmed BA, Connolly BL, Shroff P, et al. Cumulative effective doses from radiologic procedures for pediatric oncology patients. *Pediatrics*. 2010;126(4): e853.[14]

[b] Includes hand and foot views.

added information. For example, the study by Singh et al,[8] with an SS2 yield of 14%, did not consider added information to include subjects in which fractures questioned on SS1 were excluded as fractures on SS2. We included these as added information in our study because these data may affect the abuse-related diagnosis.[5,7] The AAP guidelines for obtaining SS2 leave some room for interpretation, and child abuse pediatricians may vary in their practice as to which cases receive an SS2 and in the effort made in each case to ensure that the study is obtained. These variations in practice could contribute to the variation in SS2 yield among studies.

In this study, SS2 was obtained in 27.2% of eligible subjects. This finding is comparable to the rate found in other studies (11.5%–65%).[4–8] Subjects may not have had an SS2 available for study purposes due to loss to follow-up, obtaining the study at another hospital or in another state, death before the time when SS2 should be obtained, identification of a medical cause that explains the physical findings, or due to practice variations as described earlier.

The present study had limitations. It was observational and retrospective. Child abuse centers may interpret guidelines for obtaining SS2 differently. This study was based on record review and did not include independent review of radiographs except when there were newly identified spine or pelvis fractures on SS2. Although this procedure does not allow assessment of interrater agreement, it does reflect the reality of actual practice. The determination of whether new spine and pelvis fractures changed the abuse-related diagnosis was left up to the child abuse pediatrician involved in the study at each center. A structured method for this determination might have yielded different results. This study was limited to children <24 months old. A recent study of SS1 found a higher incidence of spine fractures in children >24 months old than in children <24 months old[28]; thus, our results may not be freely generalized as to age. Finally, SS2 were obtained in only 27.2% of our eligible subjects. This low rate of follow-up could potentially create a selection bias in either direction. We see this as a theoretical limitation because we can think of no clear reason why or find any data to indicate that subjects would be more or less likely to be lost to follow-up based on spine and pelvis fractures.

CONCLUSIONS

This study confirmed our hypothesis that there is no clinically significant difference in the results of a limited view SS2 protocol versus a traditional SS2 protocol for radiographic evaluation of suspected physical abuse. It also confirms the utility of SS2 as a routine part of the evaluation of possible physical abuse in children. We recommend that the AAP and the ACR review the available data and consider revising their recommendations for SS2 in the direction of the limited view SS2 protocol. This approach seems advantageous given the radiation-sensitive areas included in the spine and pelvis views of the skeletal survey, and supportive of attainment of both thorough and complete medical evaluation, documentation of all injuries, and the ALARA concept.

REFERENCES

1. Leventhal JM, Martin KD, Asnes AG. Incidence of fractures attributable to abuse in young hospitalized children: results from analysis of a United States database. *Pediatrics*. 2008;122(3):599–604
2. Section on Radiology; American Academy of Pediatrics. Diagnostic imaging of child abuse. *Pediatrics*. 2009;123(5):1430–1435
3. Meyer JS, Gunderman R, Coley BD, et al; American College of Radiology. ACR Appropriateness Criteria(®) on suspected physical abuse-child. *J Am Coll Radiol*. 2011;8(2):87–94
4. Kleinman PK, Nimkin K, Spevak MR, et al. Follow-up skeletal surveys in suspected child abuse. *AJR Am J Roentgenol*. 1996;167(4):893–896
5. Zimmerman S, Makoroff K, Care M, Thomas A, Shapiro R. Utility of follow-up skeletal surveys in suspected child physical abuse evaluations. *Child Abuse Negl*. 2005;29(10):1075–1083
6. Harlan SR, Nixon GW, Campbell KA, Hansen K, Prince JS. Follow-up skeletal surveys for nonaccidental trauma: can a more limited survey be performed? *Pediatr Radiol*. 2009;39(9):962–968
7. Harper NS, Eddleman S, Lindberg DM; ExSTRA Investigators. The utility of follow-up skeletal surveys in child abuse. *Pediatrics*. 2013;131(3). Available at: www.pediatrics.org/cgi/content/full/131/3/e672
8. Singh R, Squires J, Fromkin JB, Berger RP, Berger RP. Assessing the use of follow-up skeletal surveys in children with suspected physical abuse. *J Trauma Acute Care Surg*. 2012;73(4):972–976
9. Sonik A, Stein-Wexler R, Rogers KK, Coulter KP, Wootton-Gorges SL. Follow-up skeletal surveys for suspected non-accidental trauma: can a more limited survey be performed without compromising diagnostic information? *Child Abuse Negl*. 2010;34(10):804–806
10. Kleinman PK, Blackbourne BD, Marks SC, Karellas A, Belanger PL. Radiologic contributions to the investigation and prosecution of cases of fatal infant abuse. *N Engl J Med*. 1989;320(8):507–511
11. Willis CE, Slovis TL. The ALARA concept in pediatric CR and DR: dose reduction in pediatric radiographic exams—a white paper conference executive summary. *Pediatr Radiol*. 2004;34(suppl 3):S162–S164
12. Willis CE, Slovis TL. The ALARA concept in radiographic dose reduction. *Radiol Technol*. 2004;76(2):150–152
13. ACR–SPR practice guideline for skeletal surveys in children. Available at: www.acr.org/~/media/ACR/Documents/PGTS/guidelines/

Skeletal_Surveys.pdf. Accessed November 26, 2013

14. Ahmed BA, Connolly BL, Shroff P, et al. Cumulative effective doses from radiologic procedures for pediatric oncology patients. *Pediatrics*. 2010;126(4). Available at: www.pediatrics.org/cgi/content/full/126/4/e851
15. Akbarnia B, Torg JS, Kirkpatrick J, Sussman S. Manifestations of the battered-child syndrome. *J Bone Joint Surg Am*. 1974;56(6):1159–1166
16. Kogutt MS, Swischuk LE, Fagan CJ. Patterns of injury and significance of uncommon fractures in the battered child syndrome. *Am J Roentgenol Radium Ther Nucl Med*. 1974;121(1):143–149
17. Ablin DS, Greenspan A, Reinhart MA. Pelvic injuries in child abuse. *Pediatr Radiol*. 1992;22(6):454–457
18. Merten DF, Radkowski MA, Leonidas JC. The abused child: a radiological reappraisal. *Radiology*. 1983;146(2):377–381
19. King J, Diefendorf D, Apthorp J, Negrete VF, Carlson M. Analysis of 429 fractures in 189 battered children. *J Pediatr Orthop*. 1988;8(5):585–589
20. Kleinman PK, Marks SC Jr, Richmond JM, Blackbourne BD. Inflicted skeletal injury: a postmortem radiologic-histopathologic study in 31 infants. *AJR Am J Roentgenol*. 1995;165(3):647–650
21. Offiah AC, Hall CM. Observational study of skeletal surveys in suspected non-accidental injury. *Clin Radiol*. 2003;58(9):702–705
22. Belfer RA, Klein BL, Orr L. Use of the skeletal survey in the evaluation of child maltreatment. *Am J Emerg Med*. 2001;19(2):122–124
23. Day F, Clegg S, McPhillips M, Mok J. A retrospective case series of skeletal surveys in children with suspected non-accidental injury. *J Clin Forensic Med*. 2006;13(2):55–59
24. Karmazyn B, Lewis ME, Jennings SG, Hibbard RA, Hicks RA. The prevalence of uncommon fractures on skeletal surveys performed to evaluate for suspected abuse in 930 children: should practice guidelines change? *AJR Am J Roentgenol*. 2011;197(1):W159–W163
25. Lindberg DM, Harper NS, Laskey AL, Berger RP; ExSTRA Investigators. Prevalence of abusive fractures of the hands, feet, spine, or pelvis on skeletal survey: perhaps "uncommon" is more common than suggested. *Pediatr Emerg Care*. 2013;29(1):26–29
26. Jha P, Stein-Wexler R, Coulter K, Seibert A, Li CS, Wootton-Gorges SL. Optimizing bone surveys performed for suspected non-accidental trauma with attention to maximizing diagnostic yield while minimizing radiation exposure: utility of pelvic and lateral radiographs. *Pediatr Radiol*. 2013;43(6):668–672
27. Kleinman PK, Morris NB, Makris J, Moles RL, Kleinman PL. Yield of radiographic skeletal surveys for detection of hand, foot, and spine fractures in suspected child abuse. *AJR Am J Roentgenol*. 2013;200(3):641–644
28. Barber I, Perez-Rossello JM, Wilson CR, Silvera MV, Kleinman PK. Prevalence and relevance of pediatric spinal fractures in suspected child abuse. *Pediatr Radiol*. 2013;43(11):1507–1515
29. Bennett BL, Chua MS, Care M, Kachelmeyer A, Mahabee-Gittens M. Retrospective review to determine the utility of follow-up skeletal surveys in child abuse evaluations when the initial skeletal survey is normal. *BMC Res Notes*. 2011;4:354–357

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