



## Utility of follow-up skeletal surveys in suspected child physical abuse evaluations

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### Abstract

**Objective:** To evaluate the utility of a follow-up skeletal survey in suspected child physical abuse evaluations.

**Methods:** In this prospective study, follow-up skeletal surveys were recommended for 74 children who, after an initial skeletal survey and evaluation by the Child Abuse Team, were suspected victims of physical abuse. The number and location of the fractures were recorded for the initial skeletal survey and for the follow-up skeletal survey in each case.

**Results:** Forty-eight of the 74 (65%) children returned for a follow-up skeletal survey. The follow-up skeletal survey yielded additional information in 22 of 48 patients (46%). In three patients (6%) the additional information changed the outcome of cases; child abuse was ruled out in one of these patients and abuse was confirmed in two cases. In three other patients, the follow-up skeletal survey refuted tentative skeletal findings, but did not change the outcome because of other physical findings.

**Conclusion:** A follow-up skeletal survey identified additional fractures or clarified tentative findings in children who were suspected victims of physical child abuse. The follow-up skeletal survey should be completed on all

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patients who have an initial skeletal survey performed for suspected physical child abuse and for whom child abuse is still a concern.

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**Keywords:** Child physical abuse; Fractures; Skeletal survey; Outcomes

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## Introduction

Data from the United States Department of Health and Human Services showed that there were an estimated 896,000 victims of child abuse and neglect in 2002, with an incidence of 12.3 per 1,000 children (US Department of Health and Human Services, 2004). Physical abuse was the second most common form of child abuse, accounting for almost 20% of victims. In 2002 an estimated 1,400 children died from child abuse or neglect (US Department of Health and Human Services, 2004).

After Kempe's landmark article that linked skeletal fractures and inflicted injury (Kempe, Silverman, Steele, Droegemueller, & Silver, 1962), physicians became aware of the challenges involved in recognizing and diagnosing child abuse (O'Neill, Meacham, & Griffin, 1973; Silverman, 1972). Given that significant skeletal, abdominal, and head injuries can be present in abuse victims even when symptoms or external signs of trauma are absent, a high level of clinical suspicion is warranted (Kleinman, 1998). Diagnostic imaging studies have become required tools in the assessment of suspected abuse and the results of these studies often confirm or rule out the diagnosis (Cadzow & Armstrong, 2000; Kleinman, 1990).

The finding of occult fractures or the presence of certain specific fractures can be a strong indicator of abuse (Cadzow & Armstrong, 2000; Kleinman, 1998). The radiographic skeletal survey is the method of choice for initial imaging in cases of suspected abuse in children less than 3 years of age (Cadzow & Armstrong, 2000; Kleinman, 1990; Kleinman, Marks, Richmond, & Blackbourne, 1995; Kleinman, Marks, Spevak, & Richmond, 1992; Merten, Radkowski, & Leonidas, 1983; Nimkin, Spevak, & Kleinman, 1997; Sane et al., 2000). The skeletal survey must image the entire skeleton, each body region should be imaged with a separate radiographic exposure, and a suitable high-detail imaging system should be used (Thorwarth et al., 1999). Even when done properly the skeletal survey may fail to reveal acute rib and metaphyseal fractures, injuries which have a high specificity for abuse (Belfer, Klein, & Orr, 2001; Kleinman, Blackbourne, Marks, Karellas, & Belanger, 1989; Kleinman, Marks, Richmond, & Blackbourne, 1995; Merten, Radkowski, & Leonidas, 1983; Sane et al., 2000; Spevak, Kleinman, Belanger, Primack, & Richmond, 1994). Therefore, a follow-up skeletal survey performed 10 or more days after the initial skeletal survey may reveal fractures that were not visible or may clarify uncertain findings.

Kleinman et al. (1996) evaluated the follow-up skeletal survey's additional yield in identifying fractures for cases in which child abuse was strongly suspected. A follow-up skeletal survey performed in 23 patients approximately 2 weeks after the initial examination increased the total number of definite fractures detected in those patients and provided information about the age of their injuries. This study concluded that although child abuse can be suggested on the basis of findings from the initial skeletal survey, a follow-up skeletal survey provides a more thorough assessment of these injuries (Kleinman et al., 1996). Our study is the second to evaluate and define the utility of a follow-up skeletal survey in suspected child

physical abuse evaluations. We hypothesized that a follow-up skeletal survey would yield additional information regarding skeletal trauma in suspected child physical abuse evaluations.

## Materials and methods

A prospective study, approved by the Institutional Review Board at Cincinnati Children's Hospital Medical Center, was conducted between September 1998 and December 2000. After evaluation by the hospital Child Abuse Team, follow-up skeletal surveys were considered for all infants and toddlers who were suspected to be victims of physical abuse based upon their history, physical examination, initial skeletal survey and other available imaging studies such as head computed tomography scans and radionuclide bone scans. Information from the county children's services agency and law enforcement was considered as well. Factors that led to a recommendation for a follow-up skeletal survey are listed in Table 1. Any patient with a family history or physical signs suggestive of a bony dysplasia such as osteogenesis imperfecta was referred to genetics for a consultation and skin biopsy. These patients were excluded from the study.

The initial skeletal survey at Cincinnati Children's consists of a minimum of 19 images including anteroposterior and lateral views of the axial skeleton and tightly collimated anteroposterior views of the appendicular skeleton. If an abnormality is suspected on the standard views, additional views are obtained at that time. The follow-up skeletal survey is done 10 or more days after the initial survey and is identical to the initial survey except that skull radiographs are omitted since no new findings are expected from the skull films. Any patient who had a follow-up skeletal survey performed more than 6 weeks after the initial survey was excluded from the study since some fractures may have completely healed during this interval making comparison between the two sets of films inaccurate. A single pediatric radiologist (MC), who is a member of the Child Abuse Team, read all of the initial and follow-up skeletal surveys in this study. She was not blinded to the history, physical examination findings, or assessment by the child abuse team. In the time interval between the initial and follow-up skeletal surveys, all children were reported to the county children's services agency as suspected child abuse victims.

During Child Abuse Team meetings the number and location of fractures were recorded for the initial skeletal survey and for the follow-up skeletal survey in each case. At the time of the initial skeletal survey, fractures were classified as "definite" or "tentative." At a later team meeting after the follow-up skeletal survey had been obtained, differences between the initial and follow-up skeletal surveys were identified and recorded. The case was then re-reviewed by the Child Abuse Team to determine if the abuse diagnosis should be modified.

Table 1  
Factors that led to a recommendation of a follow-up skeletal survey

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Multiple fractures
Fractures of varying ages
Fracture type or appearance inconsistent with the history
Radiographic finding on initial skeletal survey that was concerning but not diagnostic for injury
Physical examination findings consistent with physical abuse
Any radiological study consistent with physical abuse

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## Results

Follow-up skeletal surveys were recommended for 74 children. Forty-eight of the 74 children returned for a complete follow-up skeletal survey (65%) and were enrolled in the study. The mean age of these children was 7.4 ( $\pm 10.6$ ) months, and the mean time between the initial and follow-up skeletal surveys was 21.4 ( $\pm 9.7$ ) days.

There were 26 children for whom we recommended follow-up imaging but who were not enrolled. These 26 children included 13 children who had only a partial follow-up skeletal survey (not all films were obtained), 6 children who had radionucleotide bone scans instead of follow-up radiographs, 3 children whose parents failed to return for the follow-up films, 1 child who had the initial skeletal survey done at another hospital, 1 child who had the follow-up study done at another hospital, and 2 children who returned  $2\frac{1}{2}$  and  $3\frac{1}{2}$  months, respectively after the initial skeletal survey, which made comparison with the original skeletal survey inaccurate.

The follow-up skeletal survey yielded additional information regarding skeletal trauma in 22 of 48 patients (46%). Twenty-seven previously undetected fractures were seen on the follow-up studies of 11 patients, and the initial skeletal surveys of 15 patients with “tentative” findings were clarified (see [Table 2](#)). None of the newly diagnosed fractures required medical intervention.

In the 11 patients with additional fractures detected on follow-up films, 18 rib fractures, 4 scapular fractures, 1 tibia metaphyseal fracture, 1 femur metaphyseal fracture, 1 clavicular fracture, 1 fibular fracture, and 1 ulnar fracture were discovered. After the follow-up skeletal survey, the diagnosis of suspected abuse was modified in two of these patients. One patient was a 4-month-old with a skull fracture on initial skeletal survey; the follow-up skeletal survey revealed seven additional rib fractures. The diagnosis of suspected abuse was changed to definite abuse. The second patient was a 6-month-old with a tentative humerus metaphyseal fracture for whom the follow-up skeletal survey confirmed the humerus metaphyseal fracture and revealed a previously unidentified femur metaphyseal fracture. A diagnosis of possible abuse was changed to abuse in this patient after review of the follow-up skeletal survey. The diagnosis was unchanged in the nine other patients after review of the follow-up skeletal survey.

There were 29 tentative findings in 15 patients clarified on the follow-up skeletal survey. The most common tentative findings were rib (6/29) and metaphyseal (6/29). Eight tentative findings in 6 patients were confirmed as fractures and 21 tentative findings were determined not to indicate injury in 13 patients. After the follow-up skeletal survey, child abuse was ruled out in one patient in whom abuse had been suspected. This patient was a 2-month-old with three tentative metatarsal fractures. The follow-up skeletal survey did not confirm these fractures. The abuse diagnosis was unchanged in the other 13 patients. In one patient, abuse was established after a tentative metaphyseal fracture was confirmed and another metaphyseal fracture was discovered (patient discussed in paragraph above).

## Discussion

Child abuse can be difficult to recognize and diagnose. Commonly, a history of abuse is not offered because the child is afraid to disclose or is too young to provide a history, and the perpetrator fails to disclose or lies about the history. Furthermore, many of the injuries seen in abused children are

Table 2

Significant changes found in 22 of 48 follow-up skeletal surveys

Child abuse diagnosis change	Patient age in months	Initial findings	Follow-up skeletal survey		
			New fractures	Tentative findings confirmed	Tentative findings negative
No	3	3 ribs	1 additional rib		
No	9	Clavicle humerus, B tibia/fibula	B scapula, clavicle		
No	2	Metatarsal	B scapula		
No	2	3 ribs, B skull	3 additional ribs		
Yes	4	Skull	7 ribs		
No	1	Skull, femur metaphyseal	Tibia metaphyseal		
No	1	3 ribs, clavicle	2 additional ribs		
No	10	Skull, B clavicle, ulna/radius, humerus, ? scapula, ? T7 vertebral body	3 ribs	T7 vertebra	Scapula
Yes	6	? humerus metaphyseal	Femur metaphyseal	Humerus metaphyseal	
No	41	B scapula, humerus metaphyseal, ? metatarsal	Fibula, ulna		Metatarsal
No	1	Tibia metaphyseal, ? femur metaphyseal	2 ribs		Femur metaphyseal
No	1	Ulna, ? femur metaphyseal		Femur metaphyseal	
No	9	T6–T8 vertebral body, ? tibia/fibula, ? four ribs, ? femur metaphyseal		Tibia/fibula	4 ribs, femur metaphyseal
No	2	Humerus, radius/ulna, two rib, ? T9, T12, L2 vertebral body		T12, L2 vertebral body	T9 vertebral body
No	18	? ulna, ? clavicle		Clavicle	Ulna
No <sup>a</sup>	4	? femur metaphyseal			Femur metaphyseal
No	7	7th rib, ? 7th rib			7th rib
Yes	2	? 3 metatarsal			3 metatarsal
No <sup>a</sup>	1	? B humerus, ? femur			B humerus, femur
No	3	Phalanx 11th rib, ? 9th rib			9th rib
No	10	B tibia metaphyseal, femur metaphyseal, ? humerus metaphyseal			Humerus metaphyseal
No <sup>a</sup>	3	? rib			Rib

Abbreviations: ?—tentative finding; B—bilateral.

<sup>a</sup> The child abuse diagnosis was not changed in these patients because of the presence of head imaging findings consistent with abusive head trauma.

not specific for abuse and might also be seen with accidental trauma. If child abuse is unrecognized, the child will likely return to the violent environment, and the abuse may continue. Physicians, therefore, need to be alert for possible abuse and need tools which can help to identify abuse victims. It is equally important that physicians have methods to avoid the over diagnosis of abuse and to prevent the unwarranted removal of children from safe homes. We have shown that the follow-up skeletal survey is a valuable diagnostic tool which helps the clinician differentiate between accidental and abusive trauma.

In this study, the follow-up skeletal survey provided additional information regarding skeletal trauma in 46% of patients, and improved the diagnostic accuracy for child abuse. The follow-up skeletal survey not only detected new fractures, but also confirmed or refuted tentative findings. In two children, a suspicious case became much stronger when additional fractures were discovered on the follow-up skeletal survey. In another case, the initial impression of child abuse was reversed based on the findings of a normal follow-up skeletal survey. The patient was a 2-month-old with fussiness and tentative initial skeletal survey findings of three metatarsal fractures. The additional medical and social evaluations failed to reveal any suspicions of child abuse. In three other cases, although the follow-up skeletal survey refuted tentative skeletal findings, the child abuse diagnosis was not changed because the three patients also had head imaging findings consistent with abusive head trauma.

Rib fractures accounted for 51%, and metaphyseal fractures accounted for 11% of the additional fractures detected or tentative findings confirmed as fractures on the follow-up skeletal survey. These percentages are slightly lower than what was found by Kleinman in his 1996 study, in which 84% of the additional injuries were rib fractures or classic metaphyseal lesions (Kleinman et al., 1996). Both of these fracture types have a high specificity for child abuse in young infants, and, when acute, both are difficult to detect radiographically (Kleinman, 1990; Kleinman & Marks, 1995, 1996; Kleinman, Marks, & Blackbourne, 1986). Other fractures which also have an increased specificity for child abuse include scapular fractures, vertebral fractures, and sternal fractures (Kleinman, 1998). In our series, the follow-up skeletal survey identified four scapular fractures and three vertebral fractures as additional fractures or confirmed tentative findings.

Skeletal scintigraphy (bone scan) is an adjunct tool in the initial evaluation of fractures in suspected child physical abuse (Mandelstam, Cook, Fitzgerald, & Ditchfield, 2003). Skeletal scintigraphy uses technetium-99m methylene diphosphonate ( $^{99m}\text{Tc}$  MDP) compounds to identify areas of increased bone activity secondary to fracture healing or other causes. Skeletal scintigraphy can suggest fractures that cannot be detected on initial radiographs, such as acute rib fractures, and scintigraphy should be obtained in cases of suspected child abuse when findings may influence the immediate safety plan for the child. Skeletal scintigraphy should not be performed in place of the follow-up skeletal survey since the normal increased uptake of  $^{99m}\text{Tc}$  MDP by the growth plate makes metaphyseal fractures difficult to recognize.

While we acknowledge certain limitations to this study, we do not believe that they diminish our findings. Thirty five percent of patients for whom a follow-up skeletal survey was recommended either had an incomplete series, did not return for follow-up films, or received a bone scan but no follow-up skeletal survey. Therefore, we had incomplete data from many patients. In addition, a single pediatric radiologist who reviewed all of the films was also aware of the clinical history in each case, and we did not perform any multi-observer analysis of the radiographic findings. To the extent that this protocol may have introduced bias, it also reflects clinical routine. In clinical practice, radiological interpretation of suspected child abuse is made with accompanying clinical history, and often the initial and follow-up

skeletal surveys are in fact read by the same radiologist. Therefore, we believe that our study design reflects the typical clinical environment in which these tests are used.

This study validates the utility of a follow-up skeletal survey in specific situations. Although the follow-up skeletal survey requires additional time and effort for the family and/or county social service agency, additional radiation exposure to the child, and added expense, our findings together with those of Kleinman's, demonstrate that the follow-up skeletal survey yields valuable new information regarding skeletal trauma in almost half of the cases in which such a study is recommended. For some cases in our study, the findings from the follow-up skeletal survey increased the certainty of child abuse or reversed an initial impression of child abuse.

It is noteworthy that the follow-up skeletal surveys obtained in the 11 patients who had a normal initial skeletal survey yielded no new information. These numbers are not large enough for statistical comparison, but if these findings are reproduced it could support a recommendation only to obtain a follow-up skeletal survey for patients who have fractures or tentative findings on the initial skeletal survey. All fractures determined to be "definite" by the radiologist on the initial skeletal survey were also recognized on the follow-up skeletal survey; in many of these cases, however, new fractures were diagnosed, as well.

## Conclusions

A follow-up skeletal survey identified additional fractures or clarified tentative findings in children who were suspected victims of physical child abuse. In one case, the additional information reversed the diagnosis of suspected abuse and in other cases the presumptive diagnosis of child abuse became more certain. Although the follow-up skeletal survey adds time, expense, and radiation exposure to the child abuse evaluation, it should be completed on all patients who have an initial skeletal survey performed for suspected physical child abuse and for whom child abuse is still a concern.

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## Résumé

**Objectif:** Evaluer l'utilité d'un suivi de l'examen squelettique dans les évaluations de suspicions de maltraitance physique infantile.

**Méthodes:** Dans cette étude prospective, des études de suivi squelettique ont été recommandées chez 74 enfants qui, après une étude squelettique initiale et une évaluation par l'Equipe de détection de maltraitance, étaient suspectés d'être victimes de maltraitance physique. Le nombre et la localisation des fractures ont été enregistrés dans l'étude initiale du squelette et dans l'étude du suivi de chaque cas.

**Résultats:** Quarante-huit des 74 enfants (65%) ont eu une étude de suivi d'examen squelettique. Cette étude de suivi a fourni une information complémentaire chez 22 des 48 patients (46%). Chez 3 patients (6%), l'information complémentaire a changé la conclusion: le diagnostic de maltraitance a été éliminé dans un cas et confirmé dans 2 cas. Chez 3 autres patients l'étude de suivi a réfuté les constatations squelettiques initiales, mais n'a pas changé l'issue à cause d'autres constatations physiques.

**Conclusion:** Une étude de suivi de l'examen squelettique a identifié des fractures supplémentaires ou clarifié des constatations provisoires chez des enfants suspectés d'être victimes de maltraitance physique. L'étude du suivi squelettique devrait être réalisée chez tous les patients qui ont eu un examen squelettique initial pour suspicion de maltraitance physique infantile et chez qui la maltraitance est encore une inquiétude.



## Resumen

**Objetivo:** Evaluar la utilidad de una evaluación esquelética de seguimiento en valoraciones de sospecha de maltrato físico infantil.

**Métodos:** En este estudio prospectivo se recomendaron evaluaciones esqueléticas de seguimiento para 74 niños que, después de un examen esquelético inicial y de una evaluación por el Equipo de Protección Infantil, fueron considerados con sospecha de ser víctimas de maltrato físico. El número y localización de las fracturas fueron recopiladas en las valoraciones iniciales y en las valoraciones de seguimiento en todos los casos.

**Resultados:** Un 65% de los 74 niños ( $n = 48$ ) volvieron para la valoración de seguimiento. La evaluación de seguimiento proporcionó información adicional en 22 de los 48 pacientes (46%). En 3 pacientes (6%) la información adicional cambió el resultado del caso: en uno de esos pacientes se eliminó la evidencia de maltrato infantil y en dos casos se confirmó. En otros tres pacientes la valoración esquelética de seguimiento refutó los hallazgos esqueléticos tentativos pero no cambió el resultado porque había otros hallazgos de tipo físico.

**Conclusión:** Una valoración esquelética de seguimiento identificó fracturas adicionales o clarificó los hallazgos tentativos de aquellos casos en que había sospecha de maltrato físico infantil. Este tipo de seguimiento debe ser completado en todos los pacientes en los que se haya hecho una evaluación esquelética por sospecha de maltrato físico y para quienes hay todavía preocupación de maltrato.