Yield of Radiographic Skeletal Surveys for Detection of Hand, Foot, and Spine Fractures in Suspected Child Abuse

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OBJECTIVE. Previous studies have found that fractures involving the spine, hands, and feet are rare on skeletal surveys in cases of suspected child abuse, leading some authors to suggest eliminating these regions from the initial skeletal survey protocol. We assessed this recommendation by performing a historical review of these injuries in a pediatric population undergoing film screen–based radiographic skeletal surveys for suspected child abuse.

MATERIALS AND METHODS. This cross-sectional retrospective study reviewed reports of initial skeletal surveys of all children younger than 2 years with suspected abuse imaged between April 1988 and December 2001. Radiographic skeletal survey imaging was performed according to American College of Radiology standards. Sixty-two percent (225/365) of all skeletal surveys had positive findings, and 44% (98/225) showed more than one fracture. Surveys with fractures involving the spine, hands, or feet were identified, and the data were tabulated and analyzed.

RESULTS. Twenty of 365 studies (5.5%) yielded fractures involving the spine, hands, or feet. Of all positive skeletal surveys, 8.9% (20/225) had fractures involving the spine, hands, or feet. Of all patients with more than one fracture on skeletal survey, 20.4% (20/98) had fractures involving these regions.

CONCLUSION. These data, acquired during the film-screen era, suggest that fractures of the spine, hands, and feet may not be rare in infants and toddlers in cases of suspected child abuse. The benefits of eliminating views of these regions from the initial skeletal survey should be carefully weighed against the cost of missing these potentially important injuries in at-risk pediatric populations.

Keywords: bones, child abuse, diagnostic imaging, fractures, radiography

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Current American College of Radiology (ACR) practice guidelines specify frontal views of the hands and feet, a lateral view of the cervical spine, and individual frontal and lateral views of the thoracic and lumbar spine to optimize fracture detection [1]. A national survey of U.S. pediatric centers suggests that lateral views of the spine have become common practice and that dedicated views of the hands and feet are likely to be obtained [2]. Published studies assessing fracture prevalence in cases of suspected abuse indicate that fractures involving the hands, feet, and spine are uncommon [2–5].

These findings are supported by the largest study to date, by Karmazyn et al. [3], who reviewed the results of digitally acquired skeletal surveys performed for suspected abuse in 930 children younger than 2 years. They found that fewer than 1% of surveys were positive for fractures in the spine, hands, or feet and that these injuries were accompanied by other indications of abuse. They therefore advised that consideration be given to the elimination of dedicated views of these regions on routine skeletal surveys for suspected abuse and that further research was warranted. Exclusion of these regions from the initial evaluation of suspected abuse could have forensic implications, with respect to the care and protection of abused children, as well as to the outcome of criminal proceedings. The purpose of this study is to assess the prevalence of fractures of the spine, hands, and feet in cases of suspected child abuse on ACR-standardized skeletal surveys acquired near the end of the film-screen era.

Materials and Methods

This cross-sectional retrospective study was approved by the institutional review boards of the two participating institutions. Data were collected from the image files of one of the participating

TABLE 1: Skeletal Surveys With Fractures of the Spine, Hands, or Feet

Body Region	All Initial Skeletal Surveys (n = 365)	Positive Skeletal Surveys (n = 225)	Skeletal Surveys With > 1 Fracture (n = 98)
Spine	2.7 (10)	4.4 (10)	10.2 (10)
Hands	1.4 (5)	2.2 (5)	5.1 (5)
Feet	1.6 (6)	2.7 (6)	6.1 (6)

Note—Data are percentage of surveys (no. of fractures). One of the 20 patients had both hand and spine fractures; all other patients had fractures isolated to one of the three body regions.

institutions between April 27, 1988, and December 31, 2001 on 441 consecutive pediatric patients who had undergone a radiographic skeletal survey examination for suspected abuse. Seventeen percent (76/441) of patients were 2 years old and older, and 83% (365/441) were younger than 2 years. This study reviewed the initial skeletal survey reports on patients younger than 2 years (range, 0.194 months to 1.96 years).

The skeletal survey protocol recommended by the ACR during that period was followed [4]. It included carefully collimated frontal views of each region of the upper and lower extremities and anteroposterior and lateral views collimated to each region of the axial skeleton. In infants, images were acquired with a high-contrast slow-speed mammographic film-screen system with more than 12lp/mm of resolution. For toddlers, a medium-speed system with six lp/mm of resolution was used.

Of the 365 cases reviewed, 38% (140/365) were determined to have a negative initial skeletal survey, and 62% (225/365) showed positive findings. Fifty-six percent (127/225) of the positive examinations were determined to have only a single fracture, and 44% (98/225) had more than one fracture. We then determined the number of patients with "definite" fractures of the spine, hand (finger or metacarpal), or foot (toe or metatarsal) identified on the initial skeletal survey. In addition, if a fracture in these regions was considered "possible" on an initial survey, the reports of additional images or follow-up skeletal surveys were reviewed, and, if the finding was confirmed, it was included in the data analysis. The percentages of surveys with fractures of the spine, hands, or feet were calculated for all surveys, positive surveys, and surveys positive for more than fracture. All other fractures outside these regions of interest were noted and tabulated.

When available, the medical records of children with fractures of the spine, hands, or feet were reviewed to identify the indication for the skeletal survey. If a fracture in these regions initiated the request for the skeletal survey, it was not included in the data analysis. This was the case with an unexplained metacarpal fracture that prompted a skeletal survey examination, which revealed an unsuspected skull fracture. In one case, a skeletal survey had been performed earlier at another institution, but the results of that study were not available. When the available records indicated that a report was made to the Department of Social Services, the state agency responsible for investigating allegations of child abuse and neglect, any information regarding outcome of the report was recorded.

Results

The breakdown of skeletal surveys with fractures involving the spine, hands, or feet are detailed in Table 1. Of all 365 studies, 5.5% (20) had fractures involving the spine, hands, or feet (mean patient age, 9.2 months; range, 1.3–22.4 months). Of all positive skeletal surveys, 8.9% (20/225) had fractures involving these regions, and 20.4% (20/98) of all patients with more than one fracture on skeletal survey had fractures involving these areas. One patient had both spine and hand fractures. All others had fractures isolated to one of the three body regions.

TABLE 2: Distribution of Spine Fractures

Spine Region, Vertebra	No. of Fractures
Cervical, C2	1
Thoracic	
T2	2
T3	3
T4	2
T8	1
T9	2
T10	3
T11	3
T12	3
Lumbar	
L1	1
L2	1
Sacral	
S4	1
S5	2

Spine Fractures

There were a total of 25 spine fractures noted on the 10 surveys positive for this region, with a mean of 2.5 fractures per patient (range, 1–3 fractures per patient). The mean patient age was 10.9 months (range, 2.5–22.4 months). The distribution of spine fractures is detailed in Table 2.

With the exception of one patient with an isolated hangman's fracture at C2 and a child with two isolated sacral fractures, all patients had two or three vertebral compression deformities in the thoracic and lumbar regions. One of the patients also had a sacral fracture. The two patients with lumbar fractures also had lower thoracic compression deformities. There were no posterior element injuries or fracture-dislocations. All but one of the patients had associated nonspinal injuries, typically involving the long bones. Two patients had one nonspinal fracture, three had two nonspinal fractures, two had three nonspinal fractures, and two had more than three nonspinal fractures. High-specificity abusive injuries were noted in three cases; classic metaphyseal lesions were found in three cases, with rib fractures in one of the cases.

Hands

There were a total of 10 hand fractures noted on the five surveys positive for this region (mean number of fractures, 2.0; range, 1–4 fractures). The mean age of the patients was 14.1 months (range, 5.6–22.4 months). The distribution of hand fractures is detailed in Table 3. There were a total of three metacarpal fractures in three patients (mean age, 19.6 months; range, 14.5–22.4 months). Two involved the fifth and one involved the third digit. A 5.6-month-old and a 5.9-month-old infant both had bilateral finger fractures. One child had adjacent forearm fractures along with two spine fractures; another had a Salter-Harris group II epiphyseal separation, a long bone buckle fracture, and two classic metaphyseal lesions. The two patients with phalangeal fractures each had one other fracture, both classic metaphyseal lesions.

Feet

There were a total of nine foot fractures noted on the six surveys positive for this region (mean, 1.5 fractures; range, 1–3 fractures). The mean patient age was 10 months (range, 1.3–13.6 months). The distribution of foot fractures is detailed in Table 4. There were a total of eight metatarsal fractures in five patients (mean age, 6.3 months; range, 1.3–13.6 months). One pa-

TABLE 3: Distribution of Hand Fractures

Hand Region, Digit	No. of Fractures
Phalanx	
2	1
3	3
4	3
Metacarpal	
3	1
5	2

tient had three fractures, one had two fractures, and three patients had solitary fractures. A single toe fracture was noted involving the fifth digit. Four of the five children with metatarsal fractures had multiple rib fractures (total, 23 fractures; mean, 7.7 fractures; range, 4–15 fractures) or classic metaphyseal lesions (total, 4 lesions; mean, 1.7 lesions; range, 1–2 lesions). One patient had only a long bone shaft and a skull fracture. The patient with the solitary phalangeal fracture also had 10 rib fractures, three classic metaphyseal lesions, two skull fractures, a long bone shaft fracture, and a clavicle fracture.

Clinical Results

The available clinical records indicated that a mandated report was made to the Department of Social Services in 17 of 20 cases. In the one fatality, no record of a report to Department of Social Services was found in the chart. In the remaining two cases, the clinical records were not accessible. When information regarding the outcome of the Department of Social Services investigation was available (13/17 cases), the mandated report of abuse was supported in all cases.

Discussion

Although Caffey [6] recommended routine views of the long bones when he drew attention to skeletal injuries associated with subdural hematomas in 1946, there continued to be wide variation in the approach to skeletal imaging for suspected child abuse for most of the 20th century. Despite the recognized subtlety of digital fractures and most spinal injuries on the frontal projection, early excellent and comprehensive discussions of abusive skeletal injuries in texts and important journal articles paid little attention to imaging of these regions [7–11]. At most, they recommended that the hands and feet be included on full views of the extremities and did not specify lateral views of the entire spine [11].

In 1997, an important step was taken with the publication of ACR standards for skeletal surveys obtained for suspected child abuse [4]. These recommendations acknowledged that the skeletal survey is "frequently critical to diagnosis and is often presented as evidence in care and protection cases, criminal proceedings and other types of litigation" [4]. The guidelines and standards committee specified dedicated frontal views of the hands and feet and separate frontal and lateral views of the cervical, thoracic, and lumbosacral spine for all studies. Similar recommendations then followed from the British Society of Paediatric Radiology [12] and the American Academy of Pediatrics [13]. Although compliance with these recommendations in the United States is quite variable, it is customary to separately image the hands and feet and to include lateral views of the spine in skeletal surveys for suspected abuse [2]. A 2003 report by Offiah and Hall [5] suggests that compliance with the published standards in England is less encouraging.

Fractures of the spine, hands, or feet are detected on 0–3% of skeletal surveys done for suspected abuse [2, 3, 8, 14]. Comprehensive reviews have found that 1%–3% of abusive fractures involved the vertebrae and that 1% of children who suffer abusive head trauma have coexisting spinal trauma [7, 8, 15, 16]. Few data are available with respect to the hands and feet, but limited reports suggest that these injuries are also very uncommonly noted on skeletal surveys [3, 14, 17]. The apparent rarity of these injuries has led some authors to suggest that lateral views of the spine and dedicated frontal views of the hands and feet should be eliminated from the initial standard skeletal survey protocol [3]. Others have provided data that overall fracture detection is not significantly affected if lateral views of the spine are omitted from the follow-up survey when the initial views are negative [14]. The present study supports the view that these fractures are relatively uncommon among all skeletal surveys performed for suspected abuse in children younger than 2 years. We found that only 2.7% of children had spine fractures, 1.4% had hand fractures, and 1.6% had fractures of the feet. However, the combined prevalence of 5.5% is considerably higher than the 1% figure reported by Karmazyn et al. [3]. Importantly, the prevalence of these injuries among all positive skeletal surveys was 8.9%; this figure increased to 20.4% when only surveys with more than one fracture were considered.

There are few data to determine the effect, if any, that documented fractures of the spine, hands, or feet might have had in influencing a determination of abuse in cases reported in the literature, as well as those in the current study. Karmazyn et al. [3] found that all but one of their patients with fractures in these regions had other fractures and suggested that these fractures, as well as other indicators of trauma in their cohort, including bruising and bite marks, might permit exclusion of these regions from the skeletal survey protocol. Similarly, we found that most patients with fractures of the hands and feet had multiple rib fractures or classic metaphyseal lesions. It is possible that the exclusion of hand and foot injuries in these studies might have had little impact on outcome, but this is by no means certain; therefore, the costs must be weighed against the potential benefits. The radiation exposure from views of the hands and feet constitutes less than 5% of the total exposure of the study [18], these image acquisitions add little time to the examination, and their exclusion would not affect the global charge of a skeletal survey. Thus, there would appear to be little benefit in eliminating these views from the standard protocol.

In contrast, six of the 10 patients with spinal injuries in our study had fewer than three nonspinal fractures, and only three patients had high-specificity injuries. Spinal injuries, even potentially devastating fracture-dislocations, generally manifest as anatomic alterations that are subtle or absent on frontal projections, despite gross displacement and malalignment on the lateral view. The presence of specific clinical indicators of spinal injury is variable, and a delay in diagnosis may risk the development of severe and permanent neurologic impairment [16, 19–21]. The potential loss of important diagnostic information by failing to identify spinal injuries is of significant concern, and, in our view, outweighs the dose reduction achievable by excluding the lateral views of the spine.

TABLE 4: Distribution of Foot Fractures

Foot Region, Digit	No. of Fractures
Phalanx, 5	1
Metatarsal	
1	4
2	1
3	2
4	1

The determination of abuse in infants and toddlers is based on an array of complex issues that includes the number and type of fractures viewed in clinical context. Importantly, the burden of proof of abuse varies depending on the type of legal proceeding. For example, "beyond a reasonable doubt" may be the standard of proof in most criminal trials, whereas no more than "clear and convincing" evidence will be required in most juvenile court or dependency and neglect proceedings [22]. It is difficult to anticipate how many and what type of fractures will be sufficient to support a diagnosis of maltreatment. In the courtroom setting, it is impossible to determine whether a fracture of the hand, foot, or spine carries a different weight than other fractures in the mind of a lay person. It could be argued that these fractures might facilitate a more graphic understanding of the injury mechanism by a judge or jury than some higher-specificity injuries, including classic metaphyseal lesions and acromial fractures. The use of skeletal surveys as forensic evidence requires that the data be acquired in a systematic and thorough fashion that provides child protection teams, investigators, and finders-of-fact with complete and reliable information, at radiation doses that are as low as reasonably achievable. If there is the perception that the assessment is incomplete and that all alternative explanations for the findings have not been excluded, the evidence may carry insufficient weight to meet the required legal burden of proof.

This study entailed a review of skeletal surveys performed on a high-resolution mammographic film-screen imaging system, and the results may not be generalizable to the current digital environment. Although the resolution of current digital imaging equipment is substantially lower, the diagnostic performance of these systems with demanding skeletal applications appears to be comparable to that of traditional high-resolution film-screen imaging techniques [23, 24]. Therefore, at least equivalent performance to the standard of quality set in the film-screen era can be expected if the technical parameters of digital imaging systems are optimized for a high signal-to-noise ratio. Our study may also be limited because our available clinical information might not have always provided the actual indication for the skeletal surveys. Follow-up data were limited, particularly with respect to Department of Social Services documents not accessible at the time of this review. For this reason, we did not attempt to classify our cases with respect to certainty of maltreatment.

Our findings suggest that, although injuries of the spine, hands, and feet are uncommonly detected on high-resolution skeletal surveys for child abuse, they are not rare, particularly in cases where other fractures are present. On the basis of the available data, we recommend that all children younger than 2 years with suspected physical abuse continue to undergo radiographic skeletal surveys that include dedicated views of the hands and feet and lateral projections of the spine, in keeping with current recommendations [1, 12, 13].

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