The Prevalence of Uncommon Fractures on Skeletal Surveys Performed to Evaluate for Suspected Abuse in 930 Children: Should Practice Guidelines Change?

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OBJECTIVE. The objective of our study was to evaluate the prevalence and site of fractures detected on skeletal surveys performed for suspected child abuse at a tertiary children's hospital and to determine whether any survey images may be eliminated without affecting clinical care or the ability to make a diagnosis.

MATERIALS AND METHODS. We identified all skeletal surveys performed for suspected abuse from 2003 to 2009 of children younger than 2 years. Repeated studies were excluded, as were studies not performed to evaluate for suspected abuse. From the reports, we documented the sites of all the fractures.

RESULTS. Nine hundred thirty children (515 boys and 415 girls) with a median age of 6 months met the entry criteria for the study. Fractures were detected in 317 children (34%), of whom 166 (18%) had multiple fractures. The most common sites for fractures were the long bones (21%), ribs (10%), skull (7%), and clavicle (2%). Ten children (1%) had fractures in the spine (n = 3), pelvis (n = 1), hands (n = 6), and feet (n = 2). All 10 children had other signs of physical abuse.

CONCLUSION. In skeletal surveys performed for suspected child abuse, fractures limited to sites other than the long bones, ribs, skull, and clavicles are rare. The additional radiation exposure and cost of obtaining radiographs of the spine, pelvis, hands, and feet may outweigh their potential benefit. Given the rarity of fractures of the spine, pelvis, hands, and feet, consideration may be given to eliminating those views from routine skeletal surveys performed to evaluate for suspected child abuse.

Keywords: child abuse, fractures, guidelines, pediatric imaging, skeletal surveys

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Fractures are second only to soft-tissue injuries as the most common presentation of child abuse and are often critical in the documentation of inflicted injury [1]. Failure to document a fracture may result in the child's return to a hostile environment. Repeated injuries have an increased likelihood to be more severe, occasionally resulting in death [2]. Certain types of fractures have been found to be highly specific for child abuse including rib, spinous process, and sternal fractures and classic metaphyseal lesions [1, 3]. The presence of multiple fractures, especially fractures of differing ages, is also commonly associated with child abuse [1, 3, 4].

Because radiologic evidence of trauma is some of the most important tangible evidence in establishing a diagnosis of child abuse, a skeletal survey to evaluate children for signs of physical abuse has been developed as a screening tool [1–4]. Over the past 50 years, the skeletal survey has evolved from a "babygram" (i.e., one or two images of an infant's entire skeleton) to a very specific series of radiographs [5]. The American College of Radiology (ACR) [6] and the American Academy of Pediatrics [3] have outlined the details and use of skeletal surveys in their practice guidelines, and similar guidelines exist in Great Britain [7]. The ACR guidelines recommend a single frontal view of each region of the appendicular skeleton, including the arms, forearms, thighs, legs, hands, and feet. The ACR also recommends frontal and lateral views of the axial skeleton (skull, cervical spine, lumbosacral spine, and thorax) and a frontal view of the pelvis [6]. The ACR skeletal survey guidelines comprise a minimum of 20 radiographs [6].

Most fractures reported in abused children are in the long bones, skull, and ribs [1, 3–5], whereas fractures at other sites, such as the spine, pelvis, hands, and feet, appear to be uncommon [5]. Fractures at these other sites have been reported only as case reports or small case series. To our knowledge, their true prevalence among all children who undergo skeletal surveys for suspected abuse is unknown.

Because our facility is the primary evaluation center for suspected child abuse for a large population, we perform numerous skeletal surveys annually and thus may be able to document the prevalence and site of fractures detected on skeletal surveys performed for suspected child abuse, including these uncommon sites. The purpose of our study was to evaluate the prevalence and site of fractures detected on skeletal surveys performed at a tertiary children's hospital to evaluate for suspected child abuse and to determine whether any survey images may be eliminated without affecting clinical care or the ability to make a diagnosis.

TABLE 1: Fractures in the Long Bones, Ribs, and Skull Identified on 930 Skeletal Surveys in Children Younger Than 2 Years

Site of Fracture	Fracture Detected on Survey		Equivocal Fracture Detected on Survey			
	Children	Fractures	Children	Equivocal Fractures	Follow-Up Imaging	Fractures Confirmed[a]
Long bones	202	375	50	82	79	19
Ribs	97	423	14	27	23	7
Clavicle	20	21	0	0	0	0
Scapula	3	3	2	1	1	0
Skull	67	75	2	2	2	1
Mandible	1	1	0	0	0	0
Nose	1	1	0	0	0	0
Total	309[b]	899	56[b]	112	105	27

[a]Fractures confirmed after follow-up imaging was performed.
[b]Some children had more than one fracture in more than one site.

Materials and Methods

This study was approved by our institutional review board and a consent waiver was granted. From the radiology information system at a tertiary children's hospital, we identified all skeletal surveys performed for suspected child abuse from January 1, 2003, through December 31, 2009. We included only children younger than 2 years because this age cutoff follows the ACR guidelines that a full skeletal survey is recommended in children younger than 2 years [8]. We excluded surveys not performed for suspected child abuse, incomplete, repeat, and follow-up surveys, and those performed postmortem.

All skeletal surveys were performed using high-resolution digital radiography (either Philips Healthcare DigitalDiagnost or Canon DR cassette CXDI-31). Throughout the 7-year study period, skeletal surveys performed for suspected child abuse routinely included 31 radiographs: anteroposterior (AP) and Towne views of the skull, lateral views of the skull and cervical spine, AP and lateral tightly collimated views of the appendicular skeleton, AP and two oblique views of the ribs, an AP view of the thoracic spine, a lateral view of the thorax (including thoracic spine and sternum), AP and lateral views of the lumbar spine, an AP view of the pelvis, and AP views of the hands and feet.

A radiologist reviewed the original radiology reports of the skeletal surveys and documented the presence and site of fractures. Sites equivocal for fracture were noted and analyzed separately. Reports of follow-up imaging performed to better elucidate equivocal findings were reviewed. When a spine, pelvis, hand, or foot fracture was documented, both the skeletal survey and relevant follow-up imaging studies were reviewed by a fellowship-trained pediatric radiologist with 13 years of experience. Discrepancies between the original report and the review of images were documented.

The indication for each skeletal survey and the prior imaging results were also reviewed to determine whether the skeletal survey showed a new finding that was not known from prior imaging.

Results

Nine hundred thirty children met the entry criteria for this study: 515 boys (55%) and 415 girls (45%). The study group ranged in age from 3 days to 2 years (median age, 6 months). In 317 children (34%), 923 definite fractures were documented (Tables 1 and 2). Multiple fractures were seen in 166 children (18%). Skeletal surveys discovered new fractures not shown on prior imaging in 124 of the children (13%).

Fractures Detected in the Long Bones, Ribs, Skull, and Clavicles

Table 1 summarizes the fractures detected on radiographs of the long bones, ribs, and skull. Long bone fractures were the most

TABLE 2: Fractures in the Hands, Feet, Spine, and Pelvis Identified on Skeletal Surveys of 930 Children Younger Than 2 Years

Site of Fracture	Reported Fractures			Equivocal Fractures			Sum of All Fractures Confirmed[a]	
	Children	Fractures	Fractures Confirmed[a]	Children	Equivocal Fractures	Fractures Confirmed[a]	Children	Fractures
Hands								
Metacarpal	4	6	6	1	1	1	4	7
Proximal phalange	0	0	0	1	1	1	1	1
Feet								
Metatarsal	2	4	4	1	1	0	2	4
Spine	5	13	4	1	1	0	3	4
Pelvis	1	1	1	0	0	0	1	1
Total	12	24	15	3[b]	4	2	10[b]	17

[a]Confirmation of the fractures was based on review of the radiographs and follow-up imaging. Spinal fractures were excluded, based on negative follow-up CT scan or MRI.
[b]One child had fractures at two sites.

TABLE 3: Summary of Imaging and Clinical Findings in Patients With Fractures in the Spine, Pelvis, Hands, or Feet

Patient No.	Fractures of the Spine, Pelvis, Hands, or Feet		Other Fractures	Classic Metaphyseal Lesions	Posterior Rib Fractures	Intracranial Injury	Retinal Hemorrhage	Skin Markings
	Location (No. of Fractures)	Signs of Injury						
1	T11 (1)	Bruises	Yes	Yes	Yes	No	No	Bruises and bite
2	L1, T12 (2)	Swelling	Yes	Yes	Yes	Yes	No	Bruises
3	L2 (1)	No	Yes	No	No	Yes	No	Bruises
4	Pelvis (1)	No	Yes	No	No	No	No	Bruises
5	Metacarpal (1)	Pain and bruises	Yes	Yes	No	No	No	Bruises
6	Metacarpal (3) and proximal phalange (1)	Bruises	Yes	Yes	No	No	No	Bruises
7	Metacarpal fractures (2)	Bruises	No	No	No	No	No	Bruises
8	Metacarpal (1)	No	Yes	No	Yes	No	No	Burn injuries
9	Metatarsal (1)	—	Yes	No	Yes	No	—	—
10	Metatarsal (3)	Bruises	Yes	Yes	No	No	No	Bruises

Note—Dash (—) indicates that no medical records were available.

commonly identified fractures in the 930 children (n = 202, 22%), although other common sites of fracture included the ribs (n = 97, 10%) and skull (n = 67, 7%). Clavicular fractures were identified in 20 of 930 children (2%), and scapular fractures were seen in three children (0.3%).

Equivocal Findings

One hundred sixteen equivocal fractures (long bones, n = 82; ribs, n = 27; skull, n = 2; scapula, n = 1; metacarpal, n = 1; proximal phalange, n = 1; metatarsal, n = 1; spine, n = 1) were documented in 58 children (Tables 1 and 2).

Follow-up imaging was performed for 109 of the 116 equivocal fractures. Imaging included radiography only (n = 43), bone scanning and radiography (n = 35), bone scanning only (n = 25), radiography and CT (n = 4), CT only (n = 1), and bone scanning and CT (n = 1). Follow-up imaging showed definite fractures in 29 of the 116 equivocal fractures (25%) (Tables 1 and 2).

Fractures in the Spine, Pelvis, Hands, and Feet

Definite fractures in the spine, pelvis, hands, and feet were rare and seen in only 12 of the 930 skeletal surveys (1%). Of those 12 children, two also had equivocal fractures as follows: One child with definite metacarpal fractures also had equivocal fractures in the metacarpal and proximal phalange and one child had three definite metatarsal fractures and one equivocal metatarsal fracture. Another child had an equivocal spinal fracture. All 13 surveys (12 children with definite fractures and one child with an equivocal fracture) were reviewed including follow-up studies (Table 2). The fracture sites including equivocal fractures were seen in the spine (14 fractures in six children), metacarpals (seven fractures in four children), proximal phalange of the hand (one fracture), metatarsals (five fractures in two children), and pelvis (one fracture). Follow-up imaging of the six children with definite or equivocal spine fractures revealed that three children with reported fractures in the spinal processes had no fracture on follow-up CT or MRI. The other three children had compression fractures. Three of the 930 children (0.3%) had compression fractures involving one to two vertebral bodies at the levels of T11–L2. None of the children with spinal fractures had neurologic signs. All fractures and equivocal fractures in the hands and feet (except one equivocal fracture in the metatarsal of patient 10) were confirmed on review of the radiographs and follow-up studies (Table 3). Overall, fractures in the spine, pelvis, hands, and feet were confirmed in 10 children (1%).

Medical records were available for nine of the 10 children with confirmed fractures in the spine, pelvis, hands, or feet (Table 3). Signs of injury (pain, swelling, or bruising) at the site of fracture were seen on six of the nine children. Physical examination of these nine children revealed skin bruises on eight. In addition to the bruising, one child had a bite skin marking, one child had signs of an old burn injury, and another child had a torn frenulum (patient 10). In nine of the 10 children, there were multiple other fractures: Seven had fractures highly specific for child abuse and two had an intracranial injury (patient 2, subarachnoid hemorrhage; and patient 3, epidural and subdural hematomas). One child who had only metacarpal fractures had multiple bruises on the hands and feet (patient 7). Thus, all fractures in this group were associated with clinical findings at the site of fracture or with multiple additional fractures elsewhere.

Discussion

Our study represents the largest series to date of children younger than 2 years who underwent a skeletal survey to evaluate for suspected child abuse. The prevalence of fractures (34%) in our series is in the range of previous reports of fracture frequencies (from 11% to 55%) [1–5]. We found that 13% of the skeletal surveys added value because they revealed fractures not shown in the initial radiographs of the child's injuries. The fracture distribution found in our study is also similar to other studies that found the most common sites of fractures were in the long bones, ribs, and skull [1, 3–5].

Our skeletal survey technique includes 31 radiographs. A review of the skeletal survey practices for child abuse showed that 11.2% of children's hospitals and related institutions obtain more than the ACR-recommended protocol of 20 radiographs [9].

Thus, our skeletal survey technique is more detailed than the skeletal surveys performed in most other facilities. The additional images that we obtain relate to the appendicular skeleton, ribs, and skull.

We found that fractures of the long bones, ribs, and skull constituted most fractures on skeletal surveys performed for suspected child abuse and that fractures of the spine, pelvis, hands, and feet were very uncommon. Only 10 of 930 children (1%) had fractures at the latter sites that were confirmed on review of the skeletal survey and with follow-up imaging. Furthermore, in all 10 children, there were other signs of physical abuse including skin bruises, burns, bites, and torn frenulum ($n = 9$); classic metaphyseal lesions or posterior ribs fractures ($n = 7$); and intracranial injuries ($n = 2$). Six children had pain, swelling, or bruising at these sites indicating injury.

Spinal fractures are thought to be uncommon in child abuse and have been reported mainly in small case series [10–13]. In a larger series of 189 children with a total of 429 fractures, King et al. [14] found that 3% of all fractures were of the spine. This finding is difficult to interpret because the number of children with spinal fractures was not reported in the King et al. study and also relied on only the written reports and not the actual radiographs. The advantage of our study is that we reviewed the skeletal surveys, follow-up imaging, and medical records. We found that three of six children with a suspected spinal fracture on skeletal survey actually had normal spines with no fractures seen on follow-up CT or MRI studies. This is only a 0.3% incidence of spinal fractures. A similarly low incidence of spinal fractures is supported by Merten et al. [15] who did not find any spinal fractures in the largest published study to date of 563 skeletal surveys for child abuse. Kleinman et al. [16] also found that only one of 165 fractures in 31 abused infant fatalities was of the spine. Kemp et al. [17] performed a systemic review of the international literature from 1950 to 2009 and found only 25 children with a documented spinal injury resulting from abuse.

From their review, Kemp et al. [17] found that neurologic signs were rare and reported in only two of 25 children with spinal injuries. A visible deformity was detected in 14 of the children. In our series, none of the three children with spinal fractures had neurologic signs related to the spine injury or a visible deformity. However, two of the three children had skin markings (swelling and bruising) suggesting injury to the back and possible inflicted injury to the spine.

Fractures in the hands and feet appear to be rare in cases of child abuse and have been reported mainly in the metacarpal and metatarsal bones [16, 18]. They were reported in small case series. Our study confirms that these fractures are rare given that these fractures were seen in only six of the skeletal surveys (0.6%) performed for suspected abuse. In four of the six children, there were clinical signs indicating injury in those sites.

Pelvic fractures have been reported only in case reports or small case series [19–21] and almost all children with pelvic fractures also had fractures at other sites. In our series, only one child had a pelvic fracture. This child also had a skull fracture and skin bruises indicating abuse.

The pattern of fracture distribution seen in our study raises the possibility that some of the radiographs routinely obtained in the skeletal survey for suspected abuse might be eliminated. Only 10 of the 930 children (1%) had fractures in the spine, pelvis, hands, or feet, and all 10 showed other signs indicating child abuse. The ACR guidelines recommend a skeletal survey that includes nine radiographs to evaluate for these fractures including views of the hands ($n = 2$), feet ($n = 2$), an AP view of the pelvis and lower lumbar spine ($n = 1$), AP and lateral views of the cervical spine ($n = 2$), and lateral views of the thoracic ($n = 1$) and lumbar ($n = 1$) spine. Elimination of these radiographs would decrease by 45% the number of radiographs in the initial skeletal survey and, therefore, decrease cost, time, and radiation exposure associated with skeletal surveys for suspected abuse. In their recent study of 101 children, Harlan et al. [22] found that, on follow-up skeletal surveys, these radiographs did not provide additional diagnostic information and could thus be eliminated. Elimination of these nine radiographs must be balanced by the very rare possibility of missing occult fractures and cases of abuse and leaving a child at risk.

The limitations of this study include those associated with a retrospective review. We only reviewed clinical records and images of the children with reported fractures of the spine, pelvis, hands, and feet. Review of all images including follow-up studies may have altered the prevalence and distribution of fractures. It is possible that some of these fractures were missed and could have been diagnosed on retrospective evaluation of the study.

In summary, most fractures in children who have been physically abused occur in the long bones, ribs, skull, and clavicles. Fractures of the spine, pelvis, hands, and feet are rare, and children with these injuries usually have other findings that indicate physical abuse. Confirmation of our results by other investigators may allow one to eliminate radiography of the spine, pelvis, hands, and feet from routine screening, thus decreasing the cost, time, and radiation exposure associated with skeletal surveys performed to evaluate for suspected child abuse.

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