Cause and Clinical Characteristics of Rib Fractures in Infants

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ABSTRACT. *Objective.* **Rib fractures are uncommon in infancy and, when diagnosed, often raise the suspicion of child abuse. However, the prevalence of other causes of rib fractures has not been well defined. The purpose of this study was to determine the causes and clinical presentations of rib fractures in infants <12 months old.**

Methods. **Retrospectively, we identified all infants with rib fractures under 12 months old over a 3-year period using computerized databases at the Children's Hospital Medical Center in Cincinnati, Ohio and at the Children's Hospital, Winnipeg, Manitoba, Canada. Data extracted from the individual patient charts included: age, sex, chief complaint, number and location of rib fractures, associated injuries, birth history, history of cardiopulmonary resuscitation, and any evidence of bone dysplasia. After the chart review and a review of the radiographs by a pediatric radiologist, all fractures were determined to be attributable to one of the following causes: child abuse, birth injury, bone fragility, or accidental trauma. A determination of abuse was made when there were other injuries indicative of abuse, there was no clinical or radiographic evidence of bone fragility, there was a confession of abuse, when no reasonable history of trauma was provided, or when the history was not plausible to explain the rib fractures. Standard practice at these hospitals involves obtaining skeletal surveys on all children <2 years old when abuse is suspected. The child abuse team, which consists of physicians, nurses, and social workers, conducts these investigations and works closely with police in evaluating these children.**

Results. **Thirty-nine infants with rib fractures were identified. Thirty-two (82%) were caused by child abuse. Three (7.7%) were attributable to accidental injuries, 1 (2.6%) was secondary to birth trauma, and 3 (7.7%) were attributable to bone fragility. All 3 infants with fractures from accidental injury had sustained notable trauma (a motor vehicle collision, a forceful direct blow, and a fall from a height). Of the 3 infants with fractures secondary to bone fragility, 1 infant had osteogenesis imperfecta, 1 infant had rickets, and 1 infant, who was born at 23 weeks' gestation, had fragile bones attributable to prematurity.**

Conclusions. **Most rib fractures in infants are caused by child abuse. Although much less common, rib fractures can also occur after serious accidental injuries, birth trauma, or secondary to bone fragility. A thorough clinical and imaging evaluation is mandatory.** *Pediatrics* **2000;105(4). URL: http://www.pediatrics.org/cgi/content/full/105/4/e48;** ***infants, child abuse, birth trauma, rib fractures.***

ABBREVIATIONS. CPR, cardiopulmonary resuscitation; OI, osteogenesis imperfecta; VLBW, very low birth weight.

Child abuse has become widely recognized since the 1960s with a national incidence of nearly 1 million confirmed cases each year. Medical personnel must be skilled in recognizing injuries that are often intentionally inflicted. Rib fractures make up between 5% and 27% of all skeletal injuries in abused children.[1] Although rib fractures in infants are relatively uncommon, they are significant when identified because they frequently indicate abuse. Most rib fractures in infants are thought to result from anterior–posterior compression of the chest, often associated with shaking.[2] Because of this mode of injury, rib fractures may be found in association with intracranial injuries leading to increased mortality in these children.

The clinician's ability to differentiate abused from nonabused children is dependent on empirically gathered information. Rib fractures are often uncovered during the assessment of infants who present to health care providers for a variety of complaints. These complaints include respiratory problems unrelated to the fractures, seizures, or other changes in mental status attributable to accompanying intracranial injuries. Knowledge regarding clinical features and imaging findings may help to differentiate abused infants from those who are not abused. In addition, there should be familiarity with the prevalence and presentation of conditions that can be mistaken for abuse.

The objective of this study was to analyze and describe the different causes, radiographic findings, and clinical characteristics in infants with rib fractures <12 months old.

METHODS

We identified all infants <12 months old who had rib fractures identified at 2 hospitals between August 1994 and January 1997. At Children's Hospital Medical Center in Cincinnati, Ohio, identification was made using the computerized database of the division of Pediatric Radiology. At Winnipeg Children's Hospital in Canada, charts of infants with rib fractures were identified from a computerized database using the American College of Radiology index code. All radiograph reports, which included the term rib fracture, were extracted from the databases. The medical charts of the infants identified by these reports were then reviewed. The

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following information was extracted from each chart by the primary investigator: age of the infant, sex, chief complaint, reported mechanism of injury, whether cardiopulmonary resuscitation (CPR) had been performed, the number and location of rib fractures, associated injuries, birth history, and any evidence of bone dysplasia. The charts were also reviewed for history, physical examination findings, child abuse reports, legal documents, radiographic studies (including radiographs performed before and after the diagnosis of the rib fracture), and laboratory studies. Skeletal surveys were obtained in all cases, as this is the standard of care for children <2 years old in whom abuse is suspected.

Each film was then reviewed by a pediatric radiologist. The locations of the rib fractures were described based on the classification by Kleinman.[2] Posterior rib fractures were divided into 2 types. The first group involved fractures of the posterior rib arcs, primarily at the rib head on the costovertebral articulation or at the rib neck near the costotransverse process. On an anterior–posterior chest radiograph, this corresponds to the posterior ribs medial to the midclavicular line. The second group is the midposterior rib fractures and involves fractures near the midclavicular line, which corresponds to the midportions of the posterior arcs. A lateral fracture location was defined as starting at the lateral end of the posterior aspect of the rib and terminating at the edge of the chest. Anterior fractures were defined as starting at the edge of the chest and continuing to the anterior end of the rib.

Social service reports were reviewed because the hospital social workers are members of the child abuse team and are involved in obtaining a history of the events surrounding the injuries. They also act as liaisons between the hospital and the mandated reporting agencies.

Charts were then reviewed by 2 senior investigators (C.J.S. and R.A.S.) to assure that the data extracted were accurate and complete. The cause of each rib fracture was then categorized by the authors to be attributable to child abuse, accidental injury, birth injury, or bone fragility.

Child abuse was diagnosed whenever the infant had additional injuries specific or indicative of abuse. These included injuries attributable to shaken baby syndrome, such as subdural hemorrhages or retinal hemorrhages, unexplained internal injuries, or other fractures considered specific for abuse. Child abuse was also diagnosed whenever there had been a confession by the perpetrator. A presumptive diagnosis of child abuse was made in all remaining cases when the history given by the caretaker was not plausible to explain the injuries and when accidental trauma, bone fragility, and birth trauma had been ruled out.

Accidental injury was diagnosed whenever the history of trauma was plausible and likely to have caused the rib fractures. Plausible histories included falls from heights greater than 6 feet or falls while in the arms of a caregiver. Motor vehicle collisions and direct blows of sufficient force were also considered plausible histories causing accidental fractures depending on associated historical events and whether independent observers witnessed the injuries.

Rib fractures attributable to birth injury were diagnosed when the radiographs that were obtained while the newborn was still hospitalized revealed acute fracture. To further exclude birth trauma, hospital records were reviewed for type of delivery, infant size, and a record of difficult or complicated delivery. Clinical findings, such as tachypnea and irritability during the newborn period, were also used as indications of possible birth trauma.

Bone fragility was then considered a possible cause in all remaining cases. The criteria used for making the diagnosis of bone fragility were: 1) diagnosis by a geneticist, or 2) a clinical picture consistent with a bone dysplasia including additional accidental fractures or bruising when the child was placed in a safe environment. Telephone contact with the child's primary care physician, review of any subsequent radiographs, as well as data from the medical record were used to investigate this second criterion.

RESULTS

A total of 39 infants less than 1 year old were identified during the study from the 2 hospitals (8 from Winnipeg and 31 from Cincinnati). The causes of the fractures are shown in Table 1. Thirteen (33%) were female and 26 (67%) were male. Of the 7 nonabused infants with rib fractures, 5 had fractures of the posterior rib cage. This was not significantly different from the 32 abused infants, 20 of whom had fractures located posteriorly ($P > .05$). Comparison between the total number of posterior fractures in each group rather than the number of patients with posterior fractures also revealed no significant difference ($P > .05$).

TABLE 1. Cause of Rib Fractures in All Infants Less Than One Year of Age

Cause	Total Number of Cases (%) ($n = 39$)
Abuse	32 (82.0%)
Nonintentional	3 (7.7%)
Birth	1 (2.6%)
Fragility*	3 (7.7%)

* Includes infants with OI, rickets, and those born prematurely.

Three infants had rib fractures attributed to accidental trauma. The first infant was injured in a motor vehicle collision. This infant was restrained in a car seat but the car seat was not secured to the vehicle's interior. At the time of collision, the infant was thrown forward and sustained 5 rib fractures (8th left rib in lateral position and 3rd and 6th to 8th in right midposterior position) and a liver laceration. The second infant presented to the emergency department with a chief complaint of wheezing. A chest radiograph was obtained and 5 healing rib fractures were found (4th to 8th ribs on left in midposterior position). When questioned about the chest injuries, the mother retold the history of a 5-year-old who had fallen on the infant while rollerblading 1 month earlier. She had sought medical attention at that time because of the seriousness of the trauma. She had reported to her physician that her infant's chest felt "crackly" and that the infant was very fussy. Her primary care physician confirmed this history. No radiographs had been obtained, however, until the time of the emergency department visit for wheezing. The third infant was injured during a fall down a flight of stairs while in his father's arms. His father stated that he landed on top of the infant. The child was brought directly to the hospital and diagnosed with a fractured anterior 7th rib on the right, a transverse fracture of the left femur, 3 linear skull fractures (right occipital, right temporal, and left parietal-occipital), and a laceration of the spleen. The second and third cases were unwitnessed and raised the concern of abuse; however, the child protection team investigated both cases and the events surrounding the injuries were believed to be plausible.

Our study revealed 1 case attributable to birth trauma. This 3946-g infant was born at 40 weeks' gestation by vacuum extraction, complicated by shoulder dystocia. During the delivery, the right side of the infant's chest was flexed up under the mother's symphysis pubis. The child was admitted to the intermediate care nursery because of grunting respiration and apnea. On day 4 of life, fractures of the posterior arcs of the right 4th, 5th, and 6th ribs and a fractured right clavicle were diagnosed. The infant was evaluated for possible abuse, but a review of the birth history and hospital notes revealed no evidence

to suggest any other mechanism but birth trauma. Follow-up of this infant at 6 months old revealed no additional injuries.

Fractures secondary to bone fragility are summarized in Table 2. One infant had osteogenesis imperfecta (OI), 1 was premature, and 1 had rickets. The infant with OI was born with multiple fractures and died on the first day of life. The premature infant was born at 23 weeks' gestation by caesarian section and weighed 645 g. His hospital course was complicated by severe hyaline membrane disease, bronchopulmonary dysplasia, hydrocephalus, and necrotizing enterocolitis. Rib fractures were diagnosed during his neonatal admission. The patient with rickets was a Native American Indian from northern Canada who was fed nonfortified milk. He presented to the emergency department with the chief complaint of difficulty breathing and rib fractures were noted on a chest radiograph. A skeletal survey revealed generalized bone undermineralization as well as cupping and fraying of the long bones with areas of periosteal reaction. He had been diagnosed previously at a northern nursing station as suffering from rickets and had been started on vitamin D replacement. As such, his lab values had nearly normalized on his arrival in Winnipeg.

Thirty-two (82%) infants were determined to have rib fractures attributable to child abuse. The clinical characteristics of these infants are summarized in Table 3. There were a total of 119 fractures with an average of 3.7 rib fractures per patient (range: 1–12). Posterior arc fractures made up 35% and midposterior fractures 25% of the total. Lateral and anteriorly located fractures made up 34% and 6%, respectively. The majority of the infants presented with nonspecific respiratory complaints, a history of fever, irritability, or diarrhea. None of these infants had a history of trauma sufficient to explain their injuries. However, 3 infants did present with a history of minor trauma. 1) A 4-month-old infant rolled over and hit his head against a plastic chair presenting with a chief complaint of head injury. He had an acute linear skull fracture and a healed lateral rib fracture. 2) A 7-month-old infant fell from a crib 5 weeks earlier and presented with a history of not using his left arm. This infant had an acute fracture of the proximal humerus and 3 anterior rib fractures that were healing. There was no other history of

TABLE 2. Characteristics of Infants With Rib Fractures Secondary to States of Bone Fragility

Age (Days)	Sex	Pathology	Ribs Fractured and Location	Associated Findings
1 d	Female	Osteogenesis imperfecta	Right: posterior arc Left: multiple fractures occurring in most ribs	Blue sclera, abnormal bones radiographically bilateral humeral, and femur fractures
156 d	Male	Prematurity	Right: 7th and 8th midposterior	23 weeks' gestation
147 d	Male	Rickets	Left: 6th–8th lateral	Radiograph revealed cupping and fraying Calcium 2.31 (normal: 2.1–2.6 mmol/L) Phosphate 1.59 (normal: 1.29–2.26 mmol/L) Alkaline phosphatase 369 (normal: 117–352 units/L)

TABLE 3. Fracture Characteristics of Infants Diagnosed With Child Abuse

Group	Number of Cases	Mean Number and Location of Rib Fractures	Rational for Diagnoses of Abuse
1	9	3.5/patient (range: 1–6) Posterior arc: 13 Midposterior: 8 Lateral: 11 Anterior: 0	Subdural hematomas, retinal hemorrhages, multiple fractures indicative of abuse (ie, metaphyseal fractures) in various stages of healing, liver lacerations, and bruising in various combinations
2	5	2.2/patient (range: 1–4) Posterior arc: 3 Midposterior: 0 Lateral: 4 Anterior: 4	Confessions of abuse by perpetrator
3	12	5.2/patient (range: 1–12) Posterior arc: 22 Midposterior: 16 Lateral: 21 Anterior: 3	Multiple fractures, some with various stages of healing. All lacked a history of trauma 2 with negative biopsies for OI
4	6	2.3/patient (range: 1–6) Posterior arc: 4 Midposterior: 6 Lateral: 4 Anterior: 0	No history of trauma. Follow-up with primary care physicians revealed no additional injuries, short stature, or easy bruisability to help exclude OI. Birth injury excluded and/or normal previous radiographs

trauma offered to explain the injuries. 3) A 6-month-old infant had facial bruising caused by an older sibling who admittedly slapped the infant. In addition to acute scratches and bruising, this infant also had 1 healing rib fracture of the posterior arc. None of these reported mechanisms were believed to be of sufficient magnitude to cause rib fractures.

In 9 of the 32 abused infants, there were additional injuries indicative of abuse (Table 3; group 1). In 2 of these 9 cases, as well as in 5 other cases (Table 3; group 2) the police obtained a confession of abuse. Abuse was diagnosed in an additional 12 cases based on other fractures, some with various stages of healing, and all lacked a history of trauma (Table 3; group 3). In the remaining 6 cases, a presumptive diagnosis of abuse was made after bone fragility and birth trauma had been excluded (Table 3; group 4).

Follow-up was obtained in 18 infants who did not sustain other injuries pathognomonic for abuse, or in which there was no confession of abuse (groups 3 and 4 in Table 3). Twelve of the 18 infants had a diagnosis of abuse made based on multiple fractures, some of which were in various stages of healing, and no history of trauma uncovered by the child abuse team. The remaining 6 infants had no history of trauma and 10 of the 14 rib fractures were located posteriorly (Table 3). All 18 of these infants had been placed in a safe environment after abuse was diagnosed. Follow-up with the child's physician demonstrated no additional fractures, easy bruisability, or short stature. The follow-up ranged from 2 months to 2 years (median: 10 months) after the time of diagnosis. Follow-up was not completed in 1 of these 18 infants but there was no indication of bone fragility at the time of diagnosis. Bone fragility was additionally excluded in 2 of the 18 patients after a genetics consultation and negative tissue biopsies were obtained. There was no family history of bone fragility, no hallmarks of bone fragility on physical examination, and no radiographic evidence to indicate bone fragility in any of these infants.

Two infants in our series received CPR. Both infants presented in full cardiac arrest and died. The first infant was found to have a fractured left clavicle, a fractured right zygomatic arch, and 5 healing rib fractures. The second infant had bruising on the face and abdomen, and the police obtained a confession of abuse from the babysitter.

DISCUSSION

Rib fractures are believed to occur by 1 of 2 mechanisms. The first mechanism, described by Kleinman et al,[3,4] involves anterior–posterior compression. When there is sufficient compression, the stress over the ventral cortex of the posterior rib, where the rib tubercle articulates with the transverse process, results in a fracture. This anterior–posterior compression also stresses the lateral aspects of the ribs and can result in lateral rib fractures. In addition to compression, direct trauma of sufficient force to the thorax can result in rib fractures at the site of impact.

Both of these mechanisms require substantial forces to fracture ribs.[5] The infants identified as abused in our study all lacked a history that described a mechanism sufficient to cause rib fractures. In fact, most had no history of trauma at all. Anterior–posterior compression was the likely mechanism in the majority of the abused infants as 94% (112/119) of the fractures were located posteriorly or over the lateral portion of the rib. Posterior rib fractures are believed to be quite specific for abuse; however, it should be noted that rib fractures that occur secondary to birth trauma are often located posteriorly near the costovertebral junction and although less common can be located in this position in states of increased bone fragility. We found no significant difference in this fracture location between abused and nonabused injured infants.

It can be a challenge to ascertain the cause of rib fractures when offered no plausible history to explain the injury. Few studies have addressed this question.[6,7] Schweich and Fleisher[6] reviewed rib fractures in 21 children and differentiated those fractures caused by abuse from those caused by nonintentional trauma. Patients in this study ranged in age from 3 months to 15 years with a median age of 6 years. They found that 16 of the fractures were the result of accidental injury and only 5 were caused by child abuse. All the abused children were less than a year old (mean: 3 months), whereas all the children with nonintentional fractures were greater than 2 years old (mean: 8 years). Similar to our study, none of the abused infants presented with a history of significant trauma. The average number of fractures in the abused group was 11.8 versus 3.3 in the nonintentional group. Our results did not reveal such a discrepancy between the number of fractures in the abused and the nonintentional group. This value (3.3 fractures) does not include the infant with OI because only an anterior–posterior radiograph was obtained making an accurate determination of all fracture sites impossible. Because our study only included children <12 months old, direct comparisons with this study are difficult to make. Our larger sample size did demonstrate, however, that not all fractures in children <1 year old are from abuse.

Our study included 3 infants classified as having fractures secondary to accidental trauma. The first infant clearly sustained the injuries as a result of the motor vehicle collision. The other 2 cases were not as clear. There was no independent witness to the reported incidents (infant whose 5-year-old cousin fell on him and the infant whose father fell while carrying him), which presumably caused the injuries. Blaming the injuries on a sibling is common in cases of abuse and it is not uncommon to seek immediate medical attention when the caretaker believes that the child may have sustained a serious injury. However, the child protection team investigated both cases and believed the events to be plausible explanations for the injuries. As such, accidental trauma was considered the cause for the fractures, although abuse was difficult to exclude.

Thomas[7] studied a series of 25 infants with rib fractures and determined that 6 were caused by abuse. The cause in 5 additional children was considered to be attributable to coughing, secondary to bronchopneumonia. The details of each of these

cases were not fully described, so it was not possible to determine whether other causes could have explained the fractures. The majority of the remaining patients in this study were premature with birth weights <1500 g.

Koo et al[8] demonstrated that rib fractures are common in infants born at 1500 g or less. This study described 78 very low birth weight (VLBW) infants during the first year of life and found radiographic evidence of healing and remodeling of fractures and rickets in 25 of the infants. Similarly, Amir et al[9] diagnosed rib fractures in 2.1% of premature infants who survived beyond 6 months old. In our study, there was 1 VLBW infant with rib fractures and no other circumstances or associated injuries pointed to abuse as the cause.

Reports of rib fractures in healthy full-term infants attributed to birth injuries are uncommon.[7,10,11] In a study by Rubin,[12] 15 435 consecutive deliveries were reviewed and birth injuries were found in 108 newborns. Injuries included fractured clavicles, facial nerve injuries, brachial plexus injuries, intracranial injuries, and assorted other fractures and soft tissue injuries but excluded cephalohematomas. No infants with rib fractures were identified.

A literature search revealed only 3 articles describing rib fractures from birth trauma, affecting 4 infants.[7,10,11] All the cases involved posterior rib fractures that occurred during difficult vaginal deliveries and often involved infants large for gestational age. Direct compression of the infant's chest from the mother's symphysis pubis during the delivery is the purported mechanism. This is consistent with the infant in our study bringing the number of full-term infants reported in the literature with rib fractures caused by birth trauma to a total of 5.

In infants with unexplained fractures, causes of bone fragility such as OI and rickets must be considered. Osteogenesis imperfecta, the most common genetic cause of bone fragility, is a heterogeneous disorder caused by a molecular defect of collagen.[13,14] Clinical findings often associated with OI include blue sclera, recurrent fractures, and dentinogenesis imperfecta, as well as short stature and bowing of the extremities. Radiographs often exhibit excessive wormian bones of the skull, long bone deformities, and osteopenia. This was consistent with the infant in our study. Rickets is manifested clinically by growth retardation, metaphyseal flaring, prominence of the costochondral junctions (rachitic rosary), and frontal bossing.[15] It is usually attributable to a dietary deficiency of vitamin D. Laboratory data generally reveal low to low–normal serum calcium, low serum phosphorus, and elevated alkaline phosphatase activity. Our infant had been diagnosed clinically at a northern nursing station and started on vitamin D replacement. When seen at Children's Hospital, his lab values had nearly normalized.

Other mechanisms, including CPR, have been thought to be the cause of rib fractures. Several studies in children have shown that rib fractures secondary to CPR are extremely rare.[16–18] Only 2 infants in our series received CPR and neither infant sustained the fractures during the resuscitation. One infant had healing rib fractures and in the other case there was a confession of abuse.

This study was retrospective in design and therefore has certain inherent limitations. Because data were collected from chart review, some pertinent information may not have been available on all patients. Cases of type IV OI were difficult to exclude because of a lack of genetic consultation and tissue biopsies on all patients. As well, a short follow-up period for some of the infants may have been inadequate to rule-out additional injuries.

CONCLUSION

Our study is the largest report of rib fractures in infants to date. It revealed that rib fractures in infants are usually caused by abuse. Most abused infants will present without a plausible explanation for the injury. A thorough clinical and radiologic evaluation should be performed to reliably identify those infants with conditions that may mimic child abuse.

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