Child abuse involves grave and disturbing acts of violence that can have lasting physical and emotional consequences for children and their families. The diagnosis of child abuse is emotionally difficult for those involved, and an error in judgment either way can have a detrimental effect on the health and safety of the child. Physicians rely on the skills of the imaging team to produce high-quality images that assist in differentiating inflicted injuries from accidental trauma. This article explores the significance of imaging in child abuse by discussing the types of injuries that occur and the imaging studies that aid in diagnosing physical child abuse.

Child abuse and neglect is a global public health problem that can result in lifelong consequences for children and their families. Physical abuse of children is a critical cause of pediatric morbidity and mortality and is associated with major physical injuries, permanent disabilities, and behavioral problems that can extend into adulthood. Child abuse or maltreatment refers to any act or failure to act on the part of a parent or caregiver that results in death, serious physical or emotional harm, sexual acts, or exploitation. Child neglect is a broad concept that includes failure to meet the physical, medical, educational, or emotional needs of a child. Other forms of maltreatment include abandonment, threatened abuse, and subjecting a child to the parent’s substance abuse. Within the context of this article, the term child abuse, unless otherwise specified, directly relates to any type of bodily injury caused by the actions, or lack of action, on the part of a parent or caregiver. The terms nonaccidental trauma and inflicted injury are used frequently in the scientific literature to describe how an injury occurred. Both terms are used interchangeably throughout this article.

The concept of child abuse has been defined and redefined throughout history. Society has evolved slowly from viewing children as property to recognizing that children have rights of their own. Parents’ opinions about how children should be treated largely depend on their cultural and religious backgrounds and family values. Practices and patterns of childrearing, including discipline and healing practices, vary, and parents’ views on concepts such as corporal punishment in schools are diverse. The United States is one of the few developed countries that still allows physical punishment of children in schools. Many parents support abolishing this practice, while others believe it is an effective discipline option. Research data has demonstrated that corporal punishment is ineffective and more

After completing this article, the reader should be able to:

- List the signs of child abuse.
- Specify types of fractures that are common in child abuse.
- Explain the significance and technical components of a skeletal survey.
- Discuss the role of computed tomography, magnetic resonance imaging, and sonography in diagnosing child abuse.
- Describe the radiologic technologist’s role in the diagnosis of child abuse.

Imaging and Diagnosis of Physical Child Abuse

Marlene M Johnson, MEd, R.T.(R)
likely to cause harm than good.\textsuperscript{4,7} Spanking or other physical discipline generally is not considered abuse as long as it is reasonable and causes no bodily injury.\textsuperscript{3}

Some cultures use alternative and traditional treatment methods, such as coining, cupping, and acupuncture to treat childhood illnesses. These practices can result in injuries that could be mistaken for abuse. Coining, or \textit{cao gio}, is a common Southeast Asian treatment for minor illnesses, such as colds, flu, headaches, or fever. The Vietnamese term \textit{cao gio} translates to “catch the wind.” Some Asians believe that too much “wind” in the blood causes illnesses, and the practice of coining brings the blood to the surface where the bad wind can be released. The skin is rubbed with a coin or spoon until red or purple spots of hemorrhaging tissue appear. The process results in a distinct, symmetrical pattern of bruises, which is characteristic of abuse.\textsuperscript{4}

Virtually every possible act of violence has been documented in child abuse, from beating, kicking, and biting to shaking and aggressively pulling on an extremity. Injuries also can result from a child fending off a violent act or from a fall caused by an adult. Injuries resulting from adult actions are considered abuse regardless of whether the adult intended to hurt the child.\textsuperscript{7}

Nonaccidental trauma is a leading cause of childhood traumatic injury and death in the United States. Children younger than 1 year have the highest incidence of abuse and neglect, and approximately 75% of all abuse-related childhood fatalities occur in children younger than 3 years.\textsuperscript{4}

Child abuse and neglect are on the rise in the United States. In 2015, child protection agencies received an estimated 4 million child abuse referrals that involved approximately 7.2 million children. The majority of these children were neglected (75%), followed by physical abuse (17%) and sexual assault (8%). In 2015, 1670 children died as a result of physical child abuse and neglect in the United States.\textsuperscript{4}

The majority of perpetrators of child abuse are the parents, with most of these parents aged between 18 and 44 years. Approximately 78% of child abuse fatalities involved at least 1 parent. Boys are victims of abuse more than are girls, and women cause abuse more than do men. The 3 largest racial and ethnic groups responsible for abuse are whites (48.7%), blacks (20%), and Hispanics (19.5%). The total amount of child abuse and maltreatment referrals varies by state, with California having the highest number of referrals (see Table 1).\textsuperscript{4}

International studies have shown that 25% of all adults suffered abuse as a child.\textsuperscript{1} Adults who experienced abuse as children are more likely to report chronic physical and mental health conditions than adults who did not experience childhood abuse, and abused adolescents have demonstrated depression, conduct disorders, drug abuse, and cigarette smoking. In addition, childhood victims of abuse have shown evidence of physically aggressive behaviors, depression, low academic performance, and decreased cognitive function. Many abused children suffer permanent disfiguring injuries and have an increased risk of obesity, potentially harmful sexual behaviors, and unintended pregnancy.\textsuperscript{1,2}

Children younger than 4 years are at increased risk of abuse compared with other age groups, and preteens and younger teenagers are more likely to be abused than are older teens. Children who were unwanted or fail to meet their parents’ expectations are more likely to be abused, as well as children who persistently cry, have special needs, or have abnormal physical features.\textsuperscript{4}

Children are the victims of abuse and never should be blamed for maltreatment. The perpetrator could be a parent, legal guardian, caregiver, or other family member. Parental characteristics that increase the risk of child maltreatment include difficulty bonding with a newborn,

<table>
<thead>
<tr>
<th>States With the Most Child Abuse and Maltreatment Referrals in 2015*</th>
<th>Child Abuse Referrals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. California</td>
<td>379 806</td>
</tr>
<tr>
<td>2. Texas</td>
<td>230 467</td>
</tr>
<tr>
<td>3. Florida</td>
<td>217 895</td>
</tr>
<tr>
<td>4. Indiana</td>
<td>176 713</td>
</tr>
<tr>
<td>5. Ohio</td>
<td>172 445</td>
</tr>
<tr>
<td>6. New York</td>
<td>156 994</td>
</tr>
<tr>
<td>7. Michigan</td>
<td>149 114</td>
</tr>
<tr>
<td>8. Georgia</td>
<td>108 718</td>
</tr>
<tr>
<td>9. Tennessee</td>
<td>114 914</td>
</tr>
<tr>
<td>10. Kentucky</td>
<td>101 094</td>
</tr>
</tbody>
</table>
inability to nurture the child, personal history of abuse as a child, lack of knowledge about child development, and unrealistic expectations of the child. Parents who are substance abusers, criminal offenders, and having financial difficulties are all more likely to abuse their children.1

**History**

The discussion of child abuse began in 1860, with Ambroise Tardieu, a French medical lawyer, describing abuse findings.2 Imaging’s involvement in diagnosing child abuse began in 1946 with John Caffey, a radiologist who specialized in pediatrics. He reported 6 cases of otherwise healthy infants with coexisting subdural hematomas and long bone fractures in which the caretakers denied trauma. The long bone fractures appeared to have occurred at different times than the hematomas.3 Caffey wrote many scholarly articles, some of them seminal, including a description of infantile cortical hyperostosis, now known as Caffey disease. For 10 years, Caffey studied child abuse and urged his colleagues to recognize multiple fractures in infants caused by trauma and to be aware of false histories given by parents.4 He coined the terms “bucket-handle” and “corner” fracture, which are the unique skeletal metaphyseal fractures found in abused infants.5 Today, classical metaphyseal lesions (CMLs) or fractures are strong radiological indicators of child abuse.6,7,8

C Henry Kempe, a professor of pediatrics, is credited with raising the public’s interest in and physicians’ awareness of child abuse. Kempe was the first to collect and organize information on the clinical and radiologic manifestations, psychiatric factors, evaluation, and incidence of child abuse.9 Troubled by the number of abused and misdiagnosed children, Kempe organized a child abuse symposium in 1961 and a year later wrote the landmark article, “The Battered-child Syndrome.”10 In the article, Kempe urged consideration of abuse in any child who showed evidence of a fracture of any bone, subdural hematoma, failure to thrive, soft-tissue swellings, or bruising. This publication is regarded as the single most significant event in creating awareness and exposing the reality of child abuse. The phrase “battered child” was partly chosen to create public interest in an idea most people thought too revolting to discuss and many physicians were too wary to diagnose.11

**Federal and State Laws**

By 1973, the need for a federal stand on the issue of child abuse was obvious, and the federal Child Abuse Prevention and Treatment Act was enacted. The act offers states federal funding to prevent, assess, investigate, prosecute, and treat child abuse, and it offers grants to public agencies and nonprofit organizations for child abuse programs and projects.12 In May 2015, President Obama signed into law an amendment to CAPTA, called the Justice for Victims of Trafficking Act, that requires each state to report the number of children determined to be victims of sex trafficking.13

The states are responsible for determining levels of tolerance of abusive actions and describing any type of abuse that is subject to arrest and prosecution. States also are responsible for prosecuting child abuse perpetrators.14 Many states have laws that permit physicians to evaluate children who are suspected victims of abuse, including acquiring tests and obtaining photographs without parental consent.15

**Mandatory Reporting Requirements**

Reporting allegations of suspected child abuse and neglect is critical. Most reports are initiated by educational personnel, legal and law enforcement workers, individuals who work for social services agencies, and medical personnel. Neighbors and relatives also play a critical role in reporting suspected child abuse.16

State laws determine which individuals are legally responsible for reporting allegations of possible child abuse, which usually include any person who is in contact with children on a regular basis in a professional setting (see Box 1).17 Medical personnel constitute the fifth most common group to make child abuse referrals, accounting for 9.1% of reported cases and approximately 648 000 children in 2015.18 Mandatory reporting laws generally hold the reporter of suspected child abuse immune from legal liability if the suspicions later are determined to be untrue. As long as the reporter was acting in good faith, he or she is protected from lawsuits for libel, slander, invasion of privacy, and breach of confidentiality.19 Imaging technologists should know the child abuse reporting laws in the state where they practice, as well as the child abuse reporting protocol for the facility where they work. When in doubt, technologists should report...
The rate of child abuse is 2 times higher among children with disabilities than with children without disabilities. Infants cannot communicate pain or explain how an injury occurred. Their bodies are more fragile than older children’s bodies and the variety of childhood diseases that can mimic abuse is higher in infants. Disabled children pose similar challenges because of possible inability to communicate or physical differences that make their bodies more susceptible to serious injury. Imaging might be the only way to tell a story that abused children are too young, challenged, or frightened to tell.

Diagnostic images reveal clues that enable radiologists to determine the severity and timing of injuries and can demonstrate additional, occult trauma. The findings are compared with the medical history provided by the parent or caregiver, and a determination of abuse or nonabuse is given to the patient’s pediatrician. On a different level, radiologic findings also protect families who could be wrongly accused of child abuse. These findings can provide information on possible alternative causes of injury, such as metabolic diseases or bone fragility syndromes.

The initial step in helping abused or neglected children is recognizing the signs of child abuse and neglect (see Table 2). One solitary finding does not necessarily mean a child is being abused. However, a more critical analysis of the situation might be warranted when the signs are seen repeatedly or a combination of signs point to abuse. Physicians must compare the medical history provided by the parent or caregiver with the type and severity of injuries revealed by clinical investigation and diagnostic images.

Child abuse in young children and the disabled is a serious problem. Significant injuries and fatal abuse are more common among infants and children younger than 2 years compared with other age groups, and the皮肤损伤

Bruises are the most common and visible injuries of child abuse, yet they frequently go unnoticed. Accidental bruises during the first 9 months of life are rare and a strong indication of abuse. As a child begins to walk, accidental bruises are more common. Simply stated: “Those who don’t cruise, rarely bruise.”
The anatomical site, number, and pattern of bruises can be giveaways for abuse. Bruises on the torso, ears, head, face, hands, and buttocks are suggestive of abuse, especially in children younger than 4 years. Abused children generally have more bruises than nonabused children. The number of accidental bruises generally increases with age. It is perfectly normal for preschool and grade school children to sustain a number of accidental bruises, with the majority of them occurring over bony prominences such as the knees and shins. A toddler presenting with many bruises would not be commonplace. The clinical appearance and pattern of accidental bruising differs from inflicted bruises. An intentional bruise might have the imprint of an instrument that was used, such as a hand or belt, and the bruises might be in clusters that are characteristic of a defensive injury.

Burns can be common in abuse and nonabuse. Two of the most common types of abusive burns are due to scalding, which occurs from contact with hot liquids, and thermal burns, which are caused by contact with a hot object. Burns on the head, neck, arms, or anterior region of the trunk are more commonly accidental. Burns involving the hands, feet, and buttocks are associated more with abuse. A burn on the anterior aspect of the hand is more likely due to an accidental injury than a burn on the dorsum of the hand. Inflicted burns tend to be more serious than accidental burns and usually require medical treatment. A child who touches a hot object usually withdraws his or her hand quickly, whereas with an abusive burn, the hand is held in place and consequently the burn is

<table>
<thead>
<tr>
<th>Sign</th>
<th>Type</th>
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<tbody>
<tr>
<td>Always watchful and wary, fearful of others</td>
<td>AN</td>
</tr>
<tr>
<td>Overly compliant, passive, or withdrawn</td>
<td>AN</td>
</tr>
<tr>
<td>Reluctant to be around a particular person</td>
<td>AN</td>
</tr>
<tr>
<td>Discloses maltreatment, admits parents harmed them</td>
<td>P</td>
</tr>
<tr>
<td>Seems frightened of parents</td>
<td>P</td>
</tr>
<tr>
<td>Shrinks at the approach of parents</td>
<td>P</td>
</tr>
<tr>
<td>Is dirty and has severe body odor</td>
<td>N</td>
</tr>
<tr>
<td>Lacks sufficient clothing for weather</td>
<td>N</td>
</tr>
<tr>
<td>Has unexplained burns, bites, bruises, black eyes, or fractures</td>
<td>P</td>
</tr>
<tr>
<td>Has difficulty walking or sitting</td>
<td>S</td>
</tr>
<tr>
<td>Has multiple bruises and is nonambulatory</td>
<td>P</td>
</tr>
<tr>
<td>Demonstrates bizarre, sophisticated, or unusual sexual knowledge or behavior</td>
<td>S</td>
</tr>
<tr>
<td>Reports sexual abuse by parent or caregiver</td>
<td>S</td>
</tr>
<tr>
<td>Attaches very quickly to strangers</td>
<td>S</td>
</tr>
<tr>
<td>Shows extremes in behaviors (eg, overly compliant, demanding, passive, or aggressive)</td>
<td>E</td>
</tr>
<tr>
<td>Appears to be delayed physically or emotionally</td>
<td>E</td>
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<table>
<thead>
<tr>
<th>Sign</th>
<th>Type</th>
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</thead>
<tbody>
<tr>
<td>Blames, belittles, or berates the child</td>
<td>E</td>
</tr>
<tr>
<td>Overtly rejects the child</td>
<td>E</td>
</tr>
<tr>
<td>Looks to the child for care, attention, and satisfaction of parent’s emotional needs</td>
<td>AN</td>
</tr>
<tr>
<td>Shows little concern for the child</td>
<td>AN</td>
</tr>
<tr>
<td>Offers conflicting, unconvincing, or no explanation of the child’s injury</td>
<td>P</td>
</tr>
<tr>
<td>Provides an explanation that is not consistent with injury</td>
<td>P</td>
</tr>
<tr>
<td>Describes the child as “evil” or in some other negative way</td>
<td>P</td>
</tr>
<tr>
<td>Appears to be indifferent to the child</td>
<td>N</td>
</tr>
<tr>
<td>Behaves in a bizarre or irrational manner or seems depressed or apathetic</td>
<td>N</td>
</tr>
<tr>
<td>Unduly protective of the child, secretive, or isolated</td>
<td>S</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sign</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rarely look at or touch each other</td>
<td>AN</td>
</tr>
<tr>
<td>State they do not like each other</td>
<td>AN</td>
</tr>
</tbody>
</table>

Abbreviations: AN, abuse or neglect of any type; P, physical abuse; S, sexual abuse; E, emotional abuse; N, neglect.
more serious. Abusive scald burns are often severe, with immersion burns having sharp lines of demarcation, and frequently involve the genitals and lower extremities.\textsuperscript{13,22,23}

Burns caused by hot objects can be challenging. Suspicious burns are characteristically deep and include a distinct pattern of the object that was used to burn (eg, a curling iron or a cigarette).\textsuperscript{22,23} In the case of any burn, if medical treatment was delayed, the parents could be hiding abuse.\textsuperscript{22} Bite marks can be a decisive clue of abuse and could be caused by an adult, another child, an animal, or the child himself or herself. The source of a bite is determined by analyzing its size, dentition characteristics within the wound, and anatomical location. If the bite has puncture marks, a DNA analysis might be possible.\textsuperscript{4,13,20}

\textbf{Skeletal Fractures}

Skeletal fractures are the second most common injury cited in child abuse and usually the most powerful radiologic indicator of a child who has sustained inflicted injuries.\textsuperscript{13,23,28-31} Because childhood fractures caused by accidental trauma are relatively common, the physician must thoroughly analyze the child and the situation before an allegation of abuse.\textsuperscript{13,14,26-31}

The true incidence of child abuse is difficult to determine, but it has been estimated to account for 10% of trauma evaluated in the emergency department and 85% of fractures occurring in children younger than 3 years.\textsuperscript{28} In a wide-scale database study that included discharge data on 80% of acute pediatric hospitalizations in the United States, researchers assessed the proportion of fractures caused by and attributed to abuse. Among children younger than 3 years, the proportions of cases attributable to abuse were 11.9% in 1997, 11.9% in 2000, and 12.1% in 2003. The proportion of cases attributable to abuse decreased with increasing age.\textsuperscript{32}

Diagnosing child abuse rarely is easy and requires a careful and thorough consideration of sociobehavioral factors and clinical findings.\textsuperscript{13,14} The majority of abuse-related fractures occur in children younger than 18 months, with 1 in 9 fractures due to confirmed abuse.\textsuperscript{23} Most fractures reported in abused children are in the long bones, skull, and ribs\textsuperscript{4}; however, no specific fracture type or pattern excludes abuse.\textsuperscript{13,14,29,30}

Awareness is the most critical component in making a diagnosis.\textsuperscript{13,14,28} The physician must conduct a comprehensive physical evaluation and analyze the medical history, mechanism of injury, overall injury pattern, and the child’s developmental level.\textsuperscript{28-31} Additional findings that might influence a child abuse diagnosis are multiple fractures at different stages of healing, delay in obtaining medical treatment, and the presence of other suspicious injuries (eg, bruises or burns).\textsuperscript{13,23}

Approximately 20% of abuse-related fractures go undetected or are attributed to other causes at the time of the initial medical evaluation. This is especially true in nonambulatory children.\textsuperscript{28} In a retrospective study of a 7-year sample of children diagnosed with abuse, one-third of the children with healing abusive fractures had previous medical visits at which the abuse was not diagnosed. Multiple previous visits with missed abuse were found in 25% of the patients. The most common reason for missing a diagnosis was failure to recognize a suggestive sign of abuse, such as bruising or swelling.\textsuperscript{28} Boys who present to a primary care physician or emergency setting with an extremity fracture are at a significantly high risk for delayed diagnosis of child abuse.\textsuperscript{37}

Another reason contributing to a missed diagnosis of child abuse is a lack of knowledge about child abuse on the part of the physician or radiologist. Signs of abuse (eg, inflicted fractures) often are subtle or occult and, in most cases, include no external physical findings (eg, bruises).\textsuperscript{28} In early injuries, the radiographic study might be performed before anatomical changes even are apparent. When a parent or caregiver relays a false history, the physician could focus on the less acute findings, causing a more substantial one to be overlooked.\textsuperscript{28}

Physicians should recognize the importance of evaluating a child suspected of being abused in a facility where child abuse studies are performed frequently and the radiologist has a background in diagnosing abuse and pediatric conditions related to abuse.\textsuperscript{13,23} Pediatricians or other physicians treating children should be familiar with which facilities offer child abuse services and be prepared to make referrals to such facilities when child abuse-related imaging or hospitalization is required. Developing a working relationship with a radiologist or orthopedic surgeon who has clinical experience with child abuse cases could be advantageous to the patient.\textsuperscript{13,23}

The consequences of a missed diagnosis of abuse are serious because children returned to their environment
without intervention are likely to face further abuse and have increased mortality risk.\textsuperscript{2,23,38} Diagnosis requires a collaborative evaluation by a multidisciplinary team, in which communication is essential to completing a comprehensive diagnosis of the potentially abused child. Physicians should interact with radiologists directly when abuse is being considered—before and after the radiographic study—to increase awareness of possible occult and subtle findings.\textsuperscript{39}

In all cases of skeletal fractures, the physician and the radiologist must consider several pediatric conditions or syndromes that could cause bone fragility and result in fractures of all types, even though the incidence of these conditions is rare, occurring in less than 1\% of children who have fractures. Metabolic diseases that must be considered with any skeletal fracture include osteogenesis imperfecta, rickets, osteopenia, ligamentous laxity, fibrous dysplasia, Langerhans cell histiocytosis, dysplasia, and renal disease.\textsuperscript{2,13,14,20,23,29}

\textbf{Fracture Classifications}

The universal system of fracture classification as it relates to abuse was published in an early report of Dr Paul Kleinman.\textsuperscript{40} The system categorizes fractures as high, moderate, and low specificity for abuse based on research data and child abuse guidance organizations.\textsuperscript{13,14,40} Attempts have been made to develop algorithms to predict the likelihood of nonaccidental trauma, yet no particular tool is recommended at this time. The classifications serve as guidance for physicians and radiologists who are screening children for child abuse and increase awareness among physicians and other professionals.\textsuperscript{13,22} Research has demonstrated that virtually any type of fracture could be the result of abuse, and, it bears repeating, no specific pattern excludes abuse.\textsuperscript{13,14}

\textbf{High Specificity for Abuse}

\textbf{Rib Fractures}

Posteromedial rib fractures have the highest specificity for abuse, with a demonstrated predictive value of 95\% as an indicator of abuse in children younger than 3 years.\textsuperscript{13,41} Rib fractures are atypical in children younger than 2 years because of their relatively flexible skeleton.\textsuperscript{13,29} In a systematic review of skeletal fracture patterns in child abuse, 7 studies that included 233 children with rib fractures were identified and the cause of injury was noted. Among these children, 128 were abused, 24 had a bone dysplasia, 17 were preterm infants with perinatal complications, 43 had fractures involving a motor vehicle accident or violent trauma, 7 had postsurgical fractures, 3 had birth injuries, and 11 had fractures from unknown causes.\textsuperscript{13} In isolated instances, direct impact at the site of the fracture might cause a rib fracture. If this is the case, a bruise from the impact most likely is visible.\textsuperscript{13,29}

Posterior rib fractures require excessive levering of the posterior ribs at the costotransverse process articulation. This mechanism of injury is common in child abuse cases. It often is seen when the adult picks up the child, with his or her hands encircling the child’s rib cage, and vigorously shakes the child (see \textit{Figure 1}). This action generally is used in response to a crying child.\textsuperscript{14} For an accidental posterior fracture to occur, massive forces that resemble the mechanics similar to those occurring in child abuse must be exerted.\textsuperscript{14}

A diagnostic dilemma occurs when a child presents with rib fractures after cardiopulmonary resuscitation (CPR) in which child abuse is suspected as the cause of collapse.\textsuperscript{14} Rib fractures caused by CPR are extremely rare and virtually impossible in the posteromedial region when the child is supine and the back is supported. The forces involved in CPR generally cause fractures to begin on the external surface of the rib rather than its inner surface, resulting in an anterior rib fracture.\textsuperscript{14,29,43}

Fractures of the ribs create diagnostic challenges that can lead to a missed diagnosis, especially when little displacement occurs (see \textit{Figure 2}). The fracture lines usually are oblique to the radiographic projection and frequently are obscured by superimposed soft-tissue structures and vertebral transverse processes. Oblique projections of the ribs and a follow-up study 2 weeks after the initial evaluation can assist in the diagnosis of rib fractures.\textsuperscript{29,44,45} Once a rib is healing, the fracture becomes more obvious radiographically because of callus formation and subperiosteal new bone growth (see \textit{Figure 3}).\textsuperscript{33} The radiographic appearance of a healing fractured rib fades over time; therefore, CT might be considered because it better demonstrates the healing process.\textsuperscript{14,29} When rib displacement occurs, a chest radiograph or CT scan could...
Classical Metaphyseal Lesions

CMLs, also referred to as avulsion fractures, are highly specific for abuse and the most noticeable form of abuse radiographically. A CML almost always is caused by abuse in nonambulatory infants, who are incapable of exerting the force necessary for this fracture to occur.13,14,23,41,46 Because accidental CMLs have been documented in toddlers and young children, the predictive value of a CML to indicate abuse decreases in children older than 1 year.13,14,31

CMLs are a series of microplanar fractures that travel across the metaphysis region of the bone in a
parallel arrangement (see Figure 4).\textsuperscript{13,14,29} The fractures are caused by torsional and tractional shearing strains applied to the bone as a result of violent shaking, pulling, or twisting of an infant’s extremity.\textsuperscript{14} CMLs are frequently bilateral and most prevalent in the knees, followed by the ankle and proximal humerus.\textsuperscript{5,41,46}

The CML often is unremarkable initially on radiographic examination, and the appearance depends on the radiographic projection.\textsuperscript{41} The fracture can look either like it occurs at the “corner” of the metaphysis or can assume the shape of a “bucket handle” (see Figure 5).\textsuperscript{13,14} When the x-ray beam is 90° to the long axis of the diaphysis, it is a corner fracture; if the radiographic tube is angled more or less than 90°, the fracture is a bucket handle. If the CML is difficult to detect, the radiologic technologist should use a slight cranial or caudal angle to make it more visible.\textsuperscript{14,29} The healing cycle of a CML is short; it becomes undetectable radiographically within 4 to 8 weeks. A 2-week follow-up study can increase the detection of a CML fracture.\textsuperscript{13,14}

Regardless of the high specificity of CMLs for abuse, the physician must consider diseases and syndromes that might cause bone fragility in children when a CML is diagnosed. Household falls rarely cause CMLs; however, fractures resembling CMLs have been detected after breech delivery. CMLs also have been documented following treatment of clubfoot.\textsuperscript{13,31,41}

### Scapula, Sternum, and Spinous Processes

Fractures involving the scapula, sternum, or spinous processes of the vertebrae also have a high specificity for child abuse, mainly because of their infrequency in accidental trauma.\textsuperscript{5,13,41,47} The acromion is the most common site of a scapula fracture as a result of abuse.\textsuperscript{5,13}

All spinal fractures without a plausible explanation should be considered suggestive of abuse because of the amount of force necessary to cause such a fracture.\textsuperscript{13,22,26,47-49} In 1984, Kleinman made the first correlation of thoracic and lumbar spinous process fractures in shaken infants.\textsuperscript{47} A shaking episode lasting 5 seconds can cause extreme extension and flexion at the thoraco-lumbar junction, resulting in spinous process fractures.

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**Figure 4.** Illustration depicts the discoid metaphyseal fracture fragment (arrows). Reprinted with permission from Lonergan GJ, Baker AM, Morey MK, Boos SC. From the archives of the AFIP. Child abuse: radiologic-pathologic correlation. Radiographics. 2003;23(4):811-845.

**Figure 5.** Classical metaphyseal fracture in an abused 2-month-old girl. Lateral radiograph depicts the tibial and fibular fractures as corner fractures (arrows). Reprinted with permission from Lonergan GJ, Baker AM, Morey MK, Boos SC. From the archives of the AFIP. Child abuse: radiologic-pathologic correlation. Radiographics. 2003;23(4):811-845.
and, at times, thoracolumbar compression. External injury usually is absent but can have serious consequences. According to the literature, shaking trauma causes death in 12% to 20% of cases. For children who survive a shaking episode:
- 5% to 10% of victims remain in a vegetative state.
- 30% to 40% are blind or visually impaired in one or both eyes.
- 30% to 50% suffer from spastic paralysis or marked motor developmental delays.
- 30% develop epileptic seizures.

Vertebral fractures can be underestimated and easily overlooked. Most physicians consider them extremely rare in cases of abuse and, as a result, might eliminate radiographic projections of the spine during the initial evaluation. At other times, spinal fractures are overdiagnosed as being caused by abuse. False positives occur when the interpreter confuses the normal anterior wedging of vertebral bodies commonly seen in childhood with an abusive fracture. For a more accurate diagnosis, the radiologist should search for multiple levels of vertebral involvement. In abusive head trauma cases, spinal evaluation is warranted because vertebral body compression is strongly associated with abusive head trauma. As with all injuries, it is possible for accidental trauma to cause a fracture of the sternum, scapula, or vertebra if an appropriate mechanism of injury is presented. Therefore, the patient’s history and images always must be correlated. For example, loss of vertebral body height also can be attributed to a metabolic disorder.

**Moderate Specificity for Abuse**

The evaluation of injuries that are moderately specific for abuse is more circumstantial and depends on the child’s mobility. The plausibility of the medical history offered or denied by the parent or caregiver is important. For many patients, it is a combination of factors that raises concern. The physician can consider the predictive value of the fracture, whether the injury is bilateral or unilateral, and the presence or absence of multiple fractures in different healing stages. If a child has multiple fractures, particularly bilaterally, and several of them are in different stages of healing, the diagnosis of abuse becomes more obvious.

**Dating Fractures**

Conventional radiography can determine an approximate timing of injuries because of the sequence of healing stages that are radiographically visible. In the presence of multiple fractures, each must be evaluated closely for type and specificity. The responsible adult should be able to provide a convincing history of each event. In most family situations, children are cared for by various individuals and determining the timing of injuries is helpful for prosecuting the correct perpetrator.

Radiographic dating of fractures is not an exact science, yet findings significantly affect decisions in child protection. Because of the lack of standardized reproducible guidelines, most radiologists base the timing of fractures on their clinical experience and guidance from textbooks. Experienced pediatric trauma radiologists can determine the presence of multiple fractures in different stages of healing and differentiate them as being acute, healing, and healed. Authors generally agree that an acute fracture has well-defined margins. However, considerable overlap can exist when estimating the timing of fracture healing, especially in the later healing stages. Infants create a further challenge because of the acceleration of the healing process common to this age group.

In general, the first radiologic finding of a healing fracture is a periosteal reaction, which typically appears 10 to 14 days following an injury. This finding can appear as early as 4 days after the injury occurs and last up to 21 days after the injury. Subsequent findings include the loss of fracture line definition, soft callus formation, hard callus development, and remodeling, which is the stage of acute healing. About 8 weeks after the injury, a hard callus and early remodeling usually are visible. Because many abused children are subjected to trauma repeatedly, and medical treatment generally is not sought for each episode, an abundance of callus might be evident. Once the fracture reaches the remodeling stage, the fracture line is discernible. Other radiologic findings can be seen months to years after abusive trauma, such as an abnormal curvature of a long bone or leg length discrepancy.

CMLs and skull fractures are the exception to the healing process because they usually do not mend with a periosteal reaction. The most reliable method
of dating a CML or skull fracture is by assessing the fracture line.\textsuperscript{29,52} For skull fractures, evidence of scalp swelling can assist with dating and is best evaluated on CT using bone window settings.\textsuperscript{29}

Long Bone Diaphyseal Fractures

Single long bone diaphyseal fractures are seen frequently in nonaccidental trauma and inflicted injuries.\textsuperscript{13,29,33} Childhood fractures of long bones from short falls are not unusual and rarely result in significant injury. The physician, radiologist, or both must consider the mechanism of injury that resulted in a specific fracture type. A transverse fracture is caused by the application of a bending load perpendicular to the bone or direct impact of a hard object at the site of the fracture. In contrast, a spiral fracture is caused by torsion or twisting of a long bone along its axis.\textsuperscript{33} Oblique fractures are a result of combined bending and torsional loads.\textsuperscript{13,14,29}

Although studies vary regarding the most common inflicted diaphyseal fracture, fractures involving the femur, humerus, and tibia are cited most often.\textsuperscript{29} Accidental fracture of the humerus in a nonambulatory child occurs rarely and should initiate a complete nonaccidental trauma evaluation. In a database analysis of common childhood fractures, the most common pattern of an abusive humeral fracture was spiral oblique.\textsuperscript{33} In contrast, supracondylar fractures of the humerus in ambulatory children usually are noninflicted injuries from short falls.\textsuperscript{13,33}

Femur fractures are the most common musculoskeletal injury requiring hospitalization and commonly are evaluated by clinicians in the emergency department (see Figure 6).\textsuperscript{31,54} Accidental femur fractures in ambulatory children can occur with a low-velocity injury such as a short fall or a twisting, stumbling injury.\textsuperscript{13,54} Conversely, a femur fracture in a nonambulatory child is concerning.\textsuperscript{13,26,30,33} The prevalence of abusive femur fractures in children younger than 3 years ranges from 11.0% to 31.2%.\textsuperscript{54} One-third of femur fractures in children younger than 4 years and 80% of femur fractures in children who are not yet walking have an abusive etiology.\textsuperscript{51}

In 2009, the American Academy of Orthopedic Surgeons published clinical practice guidelines about the treatment of pediatric diaphyseal femur fractures, which recommended a nonaccidental trauma evaluation for all patients younger than 3 years who present with a femur fracture. However, fewer than half of physicians comply with the practice.\textsuperscript{56}

Tibia fractures associated with abuse have been documented, but the prevalence is low compared with fractures of the humerus and femur. A tibia fracture in a nonambulatory child should be evaluated closely.\textsuperscript{13,26,30,33} A hairline fracture of the tibial shaft, known as a “toddle fracture,” occurs accidentally in early ambulatory children.

The radius and ulna are the least-fractured long bones in child abuse, although these fractures easily can occur accidentally in the ambulatory child. However, cases of inflicted forearm fractures in older children as a result of a child falling during an abusive episode or attempting to fend off an abusive blow have been documented.\textsuperscript{28}

Epiphyseal Separation Fracture

Epiphyseal separation fractures are moderately specific for abuse, with the shoulder and elbow being frequent sites of injury. A separation becomes more evident in delayed images because of the periosteal hemorrhage that occurs along the humeral shaft. An epiphyseal separation in the elbow often is mistaken for a dislocation, even though dislocations of infant elbows are nearly nonexistent. When an epiphyseal separation is suspected based on radiography, the diagnosis can be confirmed with sonography or MR imaging.\textsuperscript{14,23}

Vertebral Body Fractures and Subluxation

Vertebral body fractures and subluxation are moderately specific for abuse.\textsuperscript{13,31} The biomechanical properties of a young child’s immature spine differ from those of an adult, which results in unique characteristics of trauma. Furthermore, significant differences are seen in spinal injury of infants and toddlers compared with older children because of the increased size of infants’ heads compared with their body sizes.\textsuperscript{5,57} Very young are susceptible to severe injuries of the spine and spinal cord in abusive situations.\textsuperscript{58} Infants who have suffered a rigorous shaking episode can incur devastating injuries to their upper cervical vertebrae and brainstem.\textsuperscript{7} In a retrospective review of 342 cases of pediatric spinal injury across age groups, 3.2% were caused by child abuse. However, among patients younger than 2 years with spinal trauma, child abuse was
the mechanism in 38% of the cases, with 73% of these patients having associated head injuries. These data support the inclusion of a spine assessment in all young nonaccidental trauma patients.57

Pediatric spinal cord injury is a rare consequence of child abuse, which leads to some practices eliminating the spinal evaluation during acute medical treatment. As a result, spinal fractures frequently go undiagnosed and most likely underreported.24,57 In nonfatal cases of child abuse involving the head, the focus of clinical diagnosis is on evaluating intracranial injuries because of their potential high risk. Spinal injuries that are vague on imaging might go unnoticed.5,22,57 In a clinical review, spinal injuries were not recognized in more than 50% of child abuse cases involving the head.35,57 When spinal trauma is diagnosed, multiple levels of vertebral involvement generally are found.25

Complex Skull Fractures

Abusive head trauma is the most common cause of death in young abused children, with 80% of child abuse fatalities occurring in children younger than 1 year.22,59 Skull fractures might or might not be present in cases of abusive head trauma. If an infant presents with a skull fracture, there is a 30% probability that it was caused by abuse.60

Abusive skull fractures are caused by a blunt impact to the cranium.14,28,29 The speed of the object striking

![Image](image-url)

Figure 6. A. Femoral shaft fracture in an abused 5-year-old boy. Frontal radiograph shows a transverse fracture of the diaphysis in femoral pin traction. The mother’s boyfriend confessed to pushing a television cabinet on top of the boy. B. Spiral femoral fracture in an abused 3-month-old boy. Lateral radiograph shows a displaced, spiral fracture of the femur. Reprinted with permission from Lonergan GJ, Baker AM, Morey MK, Boos SC. From the archives of the AFIP. Child abuse: radiologic-pathologic correlation. Radiographics. 2003;23(4):811-845.)
the skull or the skull striking a stationary object determines the magnitude of the contact forces and the likelihood of a fracture.\textsuperscript{24}

Linear skull fractures of the parietal bone as a result of accidental trauma have been seen in children younger than 1 year. Although rare, a simple linear fracture can occur with falls from a height of 3 to 6 feet. A fall from a height of more than 6 feet usually results in a more complex fracture. The majority of stairway falls are insignificant to the skull because of their low height and subsequent impact. If a child presents with a solitary skull fracture with a history of a fall, an abuse evaluation likely is unwarranted. Conversely, if a child presents with a skull fracture and multiple other injuries, child abuse should be considered.\textsuperscript{7,13,14,28,29}

The majority of skull fractures resulting from child abuse cannot, on their own, be differentiated from those occurring in accidental trauma.\textsuperscript{29} However, nonparietal fractures, complex skull fractures (especially if both sides of the head are affected), multiple fractures, fractures equal to or greater than 4-mm wide, growing fractures, and fractures associated with intracranial injury are more suggestive of abuse.\textsuperscript{13,29} A skull fracture crossing a suture line and involving more than 1 cranial bone could be the result of a single blow. This injury is seen most often in the parietal bones and occasionally the occipital.\textsuperscript{29} Patterns of fractures having a higher association with abuse compared with accidental trauma include depressed fractures (especially in the occipital bone), diastatic fractures, and compressed fractures.\textsuperscript{5} Figure 7 shows a complex skull fracture in an abused infant.

Diagnosis of head trauma in pediatric patients is difficult for several reasons. The caregiver might lie about the injury or be unable to explain how it happened, the symptoms might be mild and nonspecific, and clinical diagnosis of an infant is extremely difficult. In some cases, minor head injuries, such as bruises or abrasions, do not raise suspicions, the images are misinterpreted, or both.\textsuperscript{2,61}

Distinguishing between abusive and nonabusive head trauma is critical because failing to do so can result in re-injury and even death.\textsuperscript{3} Specific patterns of abusive head trauma and the prevalence of other findings can assist physicians in distinguishing abuse from nonabuse. Factors associated with abusive head trauma include subdural hemorrhage, cerebral ischemia, skull fractures in conjunction with intracranial injury, and retinal hemorrhage.\textsuperscript{41} Subdural hemorrhage is a common imaging finding associated with abuse. The incidence of subdural hemorrhage is low and often not the direct cause of devastating brain injuries in abused children.\textsuperscript{21} In many head trauma cases, abuse can be confirmed by the presence of extensive and multilayered retinal hemorrhages. This finding can be confirmed easily with a clinical ophthalmological examination.\textsuperscript{5}

Skeletal injuries commonly are associated with abusive head trauma in infants and young children. Therefore, a skeletal fracture might influence the diagnosis of abusive head trauma.\textsuperscript{50} Abusive head trauma also has been linked to the presence of seizures, apnea, or both at the time of medical treatment or within 24 hours of treatment and in cases where no medical history is available.\textsuperscript{41}

Digital Fractures

Fractures of the small tubular bones of the hands and feet in the first year of life should be considered as...
a possible result of abuse. Research data on digital fractures are scarce, yet child abuse case studies have demonstrated the presence of fractures in the hands and feet. These fractures usually are caused by an adult forcefully gripping and twisting the tiny extremity.

**Low Specificity for Abuse**

Injuries considered to have a low specificity for abuse are usually common fractures that are incompatible with the history and include:
- Clavicle fractures.
- Linear skull fractures.
- Isolated findings of subperiosteal new bone growth.
- Long bone fractures other than a CML.

There are 2 ways subperiosteal new bone growth is seen in child abuse cases: as a normal response to a fracture healing or, in the absence of a fracture, as a radiological feature of abuse. Periosteal trauma is caused by the rough gripping, twisting, or pulling of an extremity. This causes the osteogenic layer of the periosteum to be stripped from the underlying cortex and collections of subperiosteal blood to pool around the shaft and ends of the bone. The finding often is overlooked or nonevident because the bone changes are subtle and usually only seen approximately 7 days after the injury. If detected, a careful analysis of the underlying bone should be made to look for a subtle hairline fracture. Subperiosteal new bone growth also can be caused by an infection or neoplastic disease.

**Imaging Studies in the Diagnosis of Child Abuse**

Conventional radiography is the standard modality for imaging children when abuse is suspected or confirmed. Radiographic studies are performed on obvious areas of trauma and a skeletal survey is used to screen a child for abuse or search for additional areas of injury in a child with confirmed abuse. Studies have shown that the results of a skeletal survey directly influence the decision to diagnose abuse. Skeletal surveys also are used to rule out alternative reasons for skeletal abnormalities, such as skeletal dysplasias, certain syndromes, metabolic disorders, and neoplasia.

A skeletal survey is considered mandatory for any child younger than 2 years who is suspected of being physically harmed. The survey’s effectiveness decreases in children older than 2 years and is questionable in children aged 5 years or older. Research data have shown that skeletal surveys can be effective for diagnosing fractures in children up to 3 years of age. Decisions regarding the types of imaging needed for children aged 2 to 5 years often are made on an individual basis. From 2 to 3 years of age, a child’s verbal ability significantly increases and he or she becomes able to communicate pain and other symptoms to some degree. A survey might be considered in children older than 5 years if he or she has developmental delays or limited verbal skills.

Children who have siblings close to their age are at greater risk for abuse than are children whose siblings are several years apart. This situation is referred to as close spacing, and twin births are an extreme example. Health providers should be aware that multiple pregnancies and births, especially twins, could result in significant stress on families, and the providers should provide appropriate support and intervention. Twins are at a higher risk of abusive fractures compared with nontwins. Families with multiple births also have an elevated risk for fatal child maltreatment. In cases of twins, siblings, or other children in a household, if 1 is injured, the other is at risk and should undergo a skeletal survey if he or she is younger than 2 years. In acute settings, hospitalization of all potentially involved children within the abusive household might be necessary until a complete and accurate diagnosis of abuse can be made.

The American College of Radiology and the Royal College of Radiologists published practice parameters for skeletal surveys, recommending the acquisition of 21 radiographic images that encompass the entire skeleton (see Table 3). The radiologist might request supplemental images if clinically indicated. Adhering to standardized imaging protocols for the initial skeletal survey is essential. The value of certain projections, such as the hands, feet, and spine, in the initial skeletal survey has been debated. Until guidelines are updated, it is strongly recommended that all of the radiographic projections be included in the initial study. In cases where other diseases, conditions, or syndromes are suspected, the skeletal survey is adjusted according to the clinical indication (see Box 2).
Initially, skeletal damage might not be evident radiographically because some injuries require 14 days to be noticeable. For this reason, a 2-week follow-up survey is recommended for a more thorough and accurate assessment of any skeletal injury. Research data have shown that follow-up studies increase the diagnostic yield by approximately 20%. Conversely, a lack of interval change could demonstrate that an apparent abnormality found on the initial study is a normal variant or is related to a bone dysplasia. Many times a complete repeat examination is appropriate, although a limited examination could be considered. Eliminating nonessential projections, such as the spine and pelvis, could reduce the relatively high levels of radiation exposure to sensitive organs. This practice is endorsed by the American College of Radiology.

Radiographic Positioning and Technical Considerations
For best results, child abuse imaging should be performed by a radiologic technologist who has knowledge of and experience in pediatric imaging and is competent in positioning, patient restraint, and practices that minimize radiation exposure. A keen awareness of the circumstances specific to abuse is helpful. The technologist must realize that the emotions of an abused child might be exaggerated and include a high level of fear, stress, and lack of trust.

Effective communication is imperative for the safety and cooperation of the child. Depending on age, the child’s verbal abilities could be limited or nonexistent. Because children think and act differently from adults, efficacious communication requires an understanding of the variances among children of different ages and adults. Children react to pain and discomfort in their own way. The technologist should recognize common misunderstandings and misconceptions that can occur.

### Table 3
**Recommended Radiographic Projections for a Complete Pediatric Skeletal Survey**

<table>
<thead>
<tr>
<th>Body Part</th>
<th>Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Appendicular Skeleton</strong></td>
<td></td>
</tr>
<tr>
<td>Humeri</td>
<td>AP</td>
</tr>
<tr>
<td>Forearms</td>
<td>AP</td>
</tr>
<tr>
<td>Hands</td>
<td>PA</td>
</tr>
<tr>
<td>Femurs</td>
<td>AP</td>
</tr>
<tr>
<td>Lower legs</td>
<td>AP</td>
</tr>
<tr>
<td>Feet</td>
<td>AP</td>
</tr>
<tr>
<td><strong>Axial Skeleton</strong></td>
<td></td>
</tr>
<tr>
<td>Thorax</td>
<td>AP, lateral, right and left oblique (to include the sternum, ribs, thoracic and upper lumbar spine)</td>
</tr>
<tr>
<td>Abdomen</td>
<td>AP (to include the pelvis)</td>
</tr>
<tr>
<td>Lumbosacral spine</td>
<td>Lateral</td>
</tr>
<tr>
<td>Skull</td>
<td>Frontal and lateral (to include cervical spine if not completely demonstrated on lateral skull image)</td>
</tr>
</tbody>
</table>

Abbreviations: AP, anteroposterior; PA, posteroanterior.

### Box 2

**Skeletal Survey Modifications by Condition**

#### Skeletal Dysplasias and Syndromes
- Entire arms and legs can be exposed on a single image when the size of the child permits.
- For newborns and infants: Whole-body AP and lateral radiographs might be appropriate. Separate projections of the skull, hands, and feet are advisable. Lateral projections of the feet and ankles are useful in selected cases.
- Review by a physician is essential; extra projections, including flexion and extension laterals of the cervical spine, might be required for certain types of skeletal dysplasia.
- For some patients, selected images of specific regions or additional projections are appropriate depending on the differential diagnosis being considered.

#### Metabolic Disorders (eg, Rickets/Rickets-like Disorders)
- Entire survey not required but might be warranted.
- Examination should focus on anatomic region of interest.
- Recommended: PA projections of the wrist and AP projections of knees.

#### Neoplasias, Metastases, and Related Conditions
- Langerhans cell histiocytosis can present with a single bone lesion or widely disseminated disease.
- Complete survey is recommended for initial evaluation.
- A complete skeletal survey may be obtained for the evaluation for metastatic bone disease.

Abbreviations: AP, anteroposterior; PA, posteroanterior.
during an imaging procedure and realize that the necessary steps for a procedure most likely will be unfamiliar and frightening to a child.68

For older children, the technologist can explain the procedure with wording appropriate to the patient’s level of understanding. Each topic should be separated into fundamental elements and every action should be slow and gentle. This approach helps alleviate fear and encourages cooperation, which in turn aids in producing a high-quality imaging study.62,68

The skeletal study should be performed following standard traditional principles of radiographic imaging, diligently observing practices that enhance the contrast and resolution of images.62,69 To visualize the subtle, highly specific, bony abnormalities characteristic of abuse, the radiologic technologist must62:

- Ensure proper technique factors to produce high-quality images.
- Use correct positioning that might require restraining methods.
- Apply precise collimation to limit the field of exposure.
- Use conventional image identification.
- Use shielding devices to ensure radiation protection.

Each anatomic area should be imaged with a separate exposure to ensure uniform image density and maximize sharpness. The practice of acquiring a single projection of the child or infant with 1 exposure, commonly referred to as a “baby gram,” is unacceptable and contrary to traditional principles of imaging.13,19,23,62 Exposing the anatomy this way causes areas of underexposure and overexposure and loss of resolution due to geometric distortion.23

Precise positioning should be exercised, using immobilization devices when needed.69 The radiographic beam must be restricted to the area of interest and a 40-inch source-to-image-receptor distance should be used. Both joints should be included on all long bone images.23,29,62

When using analog film-screen systems, a high detail combination should be selected. For toddlers and older children, a medium-speed system can be used to minimize patient dose. Radiographic images of infants should be obtained table-top; however, a grid can be used for toddlers and older patients. The kilovoltage peak used in skeletal survey imaging is 55 to 70, which is appropriate for all images of the appendicular skeleton, skull, and spine of infants. For toddlers, the kilovoltage peak can be increased as necessary for images of the skull and spine. Chest images require the use of a bone detail technique to visualize rib fractures adequately. The amount of milliampere second is calculated according to the kilovoltage peak and equipment design, including filtration and generator type.29,62

Most imaging facilities have converted to digital radiographic systems with inherent capabilities of high diagnostic efficiency, high spatial resolution, and the ability to use the lowest possible dose consistent with acceptable diagnostic image quality. If the digital system has multiple resolution mode capability, the higher resolution mode should be employed. This might require an increase in milliampere second to maintain the signal-to-noise ratio and optimize visualization of the skeletal structures. The use of digital processing menus and image display parameters enhances bone detail.62

Radiation Protection

Radiographers are responsible for keeping radiation exposure to patients and themselves as low as reasonably achievable (ALARA). Without question, the radiographer involved in child abuse imaging must understand the critical principles of justification, optimization of protection, application of dose limits, and the proper management of radiation dose to patients.62,69

Skeletal surveys require relatively high doses of radiation exposure because of the necessity of acquiring multiple images of different body regions, the high number of repeat images to ensure high-quality images, and the use of follow-up imaging to identify bone fractures and evidence of healing.79 Any increase in patient dose must be within acceptable limits and improve the clinical indication. Dose increases due to high-resolution systems can be offset with meticulous positioning and avoiding repeats. Obtaining a current and complete medical history ensures that images are not being repeated unnecessarily from prior studies.23,62

Automated dose reduction features should be used as long as they do not interfere with the technique necessary for skeletal images. The technologist should formulate manual techniques individually based on the size of the infant. An antiscatter grid should not be used for any body part that is less than 12 cm thick. Gonadal
shielding should be used when appropriate or required by department protocol.69

**Radionuclide Bone Scan**

A radionuclide bone scan (bone scintigraphy) can be used as an adjunct to the skeletal survey to solve a diagnostic problem or when a clinical suspicion of abuse remains high and documentation is necessary.23,71,72 Bone scans have high sensitivity and low specificity in cases of child abuse.75 They have proven useful in diagnosing rib and long bone fractures and have a high diagnostic yield in fractures of complex anatomical areas, such as the spine, pelvis, and feet.19,72 This imaging technique rarely is used in the acute setting and is limited in the diagnosis of skull fractures because of the lack of radioisotope uptake in the skull. Conversely, high radioisotope uptake around a growth plate fracture obscures this particular finding. Estimating the time of injury is not possible with a bone scan.19,29 Any abnormal finding on a bone scan must be documented with conventional radiography.19,72 Clinical studies comparing bone scintigraphy to the skeletal survey have demonstrated neither procedure alone is as good as the 2 combined. Potential harms and limitations of bone scans include limited availability, high radiation dose, increased risk due to sedation, and high procedural costs.19

**Computed Tomography**

The use of computed tomography (CT) in diagnosing child abuse is increasing, and CT is the standard choice for first-line triage in the acute setting.13,71 CT can detect treatable emergency conditions quickly and efficiently and guide acute surgical and medical interventions.13,75 Evidence suggests that CT outperforms conventional radiography in detecting rib fractures. Because of the relatively high radiation exposure from CT, this modality often is restricted to the critically ill.31

CT has had a dramatic effect on diagnosing acute emergent cases of infant abuse because of its ability to identify small subdural collections quickly and efficiently.40 CT can help physicians differentiate between subdural and epidural hemorrhages. Because epidural hemorrhages more commonly are associated with accidental injuries, this is a critical finding.5,13,16,75 The American College of Radiology recommends noncontrast head CT for children who have neurological signs or symptoms, difficulty breathing, a complex skull fracture, or other fractures or injuries highly suspicious for child abuse.71 In clinical practice, a head CT scan often is acquired on any child younger than 1 year who has a suspicious fracture of any type.25,29

Multidimensional reconstructions of head and facial CT scans are important because fractures could be missed if they are oriented in the same plane as the axial slice.5,19,29 The decision to eliminate skull projections in the skeletal survey when a head CT scan is performed is a debatable practice. Advocates for retaining skull projections believe that adherence to skeletal survey protocol is essential for consistency, and conventional radiographic images still are needed to measure the size of any skull fracture. Opponents argue that a CT scan should capture any necessary cranial information.14,19,25,29

In cases where chest or abdominal injuries are involved, the use of CT is beneficial. Such injuries are more common in toddlers and older children, as opposed to infants.19,23,73 Abused children have a high incidence of pancreatic and duodenal injury in addition to bowel perforations caused by blows to the abdomen.19,74 The use of oral contrast depends on the stability of the child at the time of imaging. Contrast is generally the best choice for evaluating abdominal injuries; however, a risk of aspiration is evident or a possibility that surgery is necessary, it is best to forgo the use of contrast.23,74

**Magnetic Resonance Imaging**

MR imaging primarily is used to diagnose subacute and chronic brain injury in the nonemergent setting.71 A head MR scan without contrast that includes the cervical spine is the superior choice for assessing intracranial injury, including cerebral hypoxia, ischemia, extra-axial collections, intraparenchymal hemorrhages, contusions, shear injuries, and brain edema. MR imaging is indicated in children who have abnormal CT scans and in some cases for those who have normal CT results but show strong clinical concerns for intracranial injury.23,71,75

MR imaging, either in addition to CT or alone, is being used more frequently in early, first-line abuse trauma imaging for specific indications, such as venous thrombosis in the brain.23,60,75 The use of
diffusion-weighted imaging in the initial days of treating a critically injured infant can provide information about cerebral blood flow before any abnormalities are visible on CT.\textsuperscript{23,75} Because abused infants might not demonstrate neurologic signs and symptoms of significant central nervous system injury, it is imperative to use MR imaging in cases of skeletal injuries that result from shaking or impacts.\textsuperscript{23}

**Sonography**

The use of sonography in diagnosing child abuse is limited. However, the modality is cited as a useful supplement to the skeletal survey or head CT scan in cases of head trauma. Sonography can be used as a rapid screening tool prior to CT or conventional radiographic imaging to screen for a skull or long bone fracture.\textsuperscript{2,19,23} Sonography also can demonstrate early periosteal bone reactions that might not be evident radiographically.\textsuperscript{19}

**Conclusion**

Imaging plays a significant role in the diagnosis of child abuse. All radiologic technologists have the ethical responsibility to be prepared for potential child abuse cases, regardless of the type of facility in which they practice. When a child presents with signs of abuse, the technologist should understand how to report the findings and to whom. If the technologist is assigned to complete an imaging study on a child for whom abuse is suspected or confirmed, he or she must be vigilant in observing the patient and confident in producing a diagnostically useful and high-quality study. The extra time, patience, and expertise required to image an abused child can make a substantial difference in that child’s life.

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**References**


Directed Reading Quiz

Imaging and Diagnosis of Physical Child Abuse

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Read the preceding Directed Reading and choose the answer that is most correct based on the article.

1. Significant injuries and fatal abuse are more common among children and infants younger than _______ compared with other age groups.
   a. 2 months
   b. 6 months
   c. 2 years
   d. 3 years

2. Which of the following is a sign of physical abuse?
   a. child shrinks at approach of parents
   b. child is dirty and has severe body odor
   c. ambulatory child has a few bruises on his or her knees
   d. child attaches very quickly to strangers

3. What are the most common and visible injuries of child abuse?
   a. fractures
   b. burns
   c. bite marks
   d. bruises

4. Which of the following findings might influence a child abuse diagnosis?
   1. delay in obtaining medical treatment
   2. multiple fractures of different stages of healing
   3. additional suspicious injuries, such as bruises or burns
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

5. Which of the following fractures have the highest specificity for abuse and commonly are seen in babies who have been shaken vigorously?
   a. classical metaphyseal lesions (CMLs) of the lower leg
   b. posteromedial rib fractures
   c. transverse process of the femur
   d. linear skull fractures

continued on next page
6. If the CML is difficult to detect, the radiologic technologist should:
   a. decrease the source-to-image-receptor distance to 32 inches.
   b. turn the body part 90º.
   c. apply stress to the extremity.
   d. use a slight cranial or caudal angle.

7. In general, the first radiologic finding of a healing fracture is a _______, which typically appears _______ days following an injury.
   a. remodeling; 2 to 5
   b. soft callus development; 5 to 9
   c. periosteal reaction; 10 to 14
   d. hard callus development; 8 to 12

8. _______ fractures frequently are seen in nonaccidental trauma and inflicted injuries.
   a. Single long bone diaphyseal
   b. Scapula
   c. Clavicle
   d. Posterior rib

9. What are the 3 most common inflicted diaphyseal fractures cited in studies concerning child abuse cases?
   a. femur, tibia, clavicle
   b. femur, ulna, humerus
   c. humerus, femur, tibia
   d. fibula, radius, humerus

10. A follow-up skeletal survey is recommended in _______ to more thoroughly and accurately assess any skeletal injury in cases of suspected child abuse.
    a. 5 days
    b. 1 week
    c. 2 weeks
    d. 30 days

11. The American College of Radiology recommends _______ imaging in children who have neurological signs or symptoms, difficulty breathing, complex skull fractures, or other fractures or injuries highly suspicious for child abuse.
    a. noncontrast head computed tomography (CT)
    b. contrast-enhanced head CT
    c. noncontrast head and neck magnetic resonance (MR)
    d. contrast-enhanced head and neck MR

12. A head MR scan without contrast that includes the cervical spine is the superior choice for assessing nonemergent:
    1. brain edema.
    2. intraparenchymal hemorrhages.
    3. shear injuries.
    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3
Imaging and Diagnosis of Physical Child Abuse

Expiration Date: October 31, 2020*
Approved for 1.5 Category A credits

- A passing score is 75% or better.
- ASRT must receive this answer sheet before the quiz expires and before the end of the CE biennium for which you want credit.
- To see a list of the Directed Readings available to you, visit asrt.org/drquiz.
- To evaluate this Directed Reading, visit asrt.org/dreval.
- Take the quiz online at asrt.org/drquiz for immediate results and your CE certificate.
- Or, mail the original answer sheet to Processing Center 2908 Stewart Creek Blvd., Charlotte, NC 28216.

### Identification Section

We need your ASRT Member ID and your two-digit Birth Month to track your CE credits. Be sure to use your ASRT Member ID and not your ARRT Registry Number.

- ASRT Member ID: __________________  
- Birth Month: __________

### CE Answers Section

**Note:** For true/false questions, A=true, B=false.

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*Some quizzes are renewed and the expiration date extended. Check online at asrt.org/drquiz or call Member Services at 800-444-2778.