

AMERICAN ACADEMY OF PEDIATRICS

Section on Radiology

Diagnostic Imaging of Child Abuse

ABSTRACT. The role of imaging in cases of child abuse is to identify the extent of physical injury when abuse occurs, as well as to elucidate all imaging findings that point to alternative diagnoses. Diagnostic imaging of child abuse is based on both advances in imaging technology, as well as a better understanding of the subject based on scientific data obtained during the past 10 years.¹⁻³ The initial recommendation was published in *Pediatrics* (1991;87:262-264).

ABBREVIATIONS. CT, computed tomography; MRI, magnetic resonance imaging.

The concept of child abuse as a medical entity has its origin in the studies of the pediatric radiologist, John Caffey, MD,⁴ as well as many other specialists in the field of diagnostic imaging. Kempe⁵ relied heavily on the work of Caffey and his protégé, Frederick Silverman, MD,⁶ when developing the familiar concept of the "battered child syndrome." When all cases of child abuse and neglect are studied, the incidence of physical evidence documented by diagnostic imaging studies is relatively small. However, imaging studies are often critical in the assessment of infant and young child with evidence of physical injury, and they also may be the first indication of abuse in a child who is seen with an apparent natural illness. When viewed in conjunction with clinical and laboratory studies, imaging findings commonly provide support for allegations of abuse.⁷ For severely abused infants, the imaging findings alone may form the basis for a diagnosis of the inflicted injury. The role of imaging in cases of suspected abuse is not only to identify the extent of physical injury when abuse has occurred, but also to elucidate all imaging findings that point to alternative diagnoses.^{8,9} As most conventional imaging studies performed in these settings are noninvasive and entail minimal radiation risks,¹⁰ recommendations about imaging should focus on examinations that provide the highest diagnostic yield at acceptable cost.¹¹

SKELETAL TRAUMA

Although skeletal injuries rarely pose a threat to the life of the abused child, they are often the strongest radiologic indicators of abuse. In fact, in an infant, certain patterns of injury are sufficiently char-

acteristic to permit a firm diagnosis of inflicted injury in the absence of clinical information.¹² This fact mandates that imaging surveys performed to identify skeletal injury be performed with at least the same level of technical excellence routinely used to evaluate accidental injuries. The "body gram" (a study that encompasses the entire infant or young child on 1 or 2 radiographic exposures) or abbreviated skeletal surveys have no role in the imaging of these subtle but highly specific bony abnormalities.

THE RADIOGRAPHIC SKELETAL SURVEY

Equipment

In general, the radiographic skeletal survey is the method of choice for global skeletal imaging in cases of suspected abuse.¹³ Low-dose all-purpose pediatric imaging systems provide insufficient anatomic detail to image the skeleton of the infant and young child. The American College of Radiology has published standards for skeletal survey imaging in cases of suspected abuse. Modern pediatric imaging systems commonly use special film cassettes and intensifying screens to minimize exposure. Although these low-dose systems are adequate for chest and abdominal imaging, they fail to provide the necessary contrast and spatial resolution to image subtle metaphyseal, rib, and other high specificity injuries that are characteristic of abuse. According to the American College of Radiology, imaging systems used for suspected abuse of infants should have a spatial resolution of at least 10 line pairs per millimeter and a speed of no more than 200.¹³ These systems should be used without a grid. Beyond infancy, faster general purpose systems are required for thicker body regions (eg, skull, lateral lumbar spine). Digital or filmless radiology is beginning to replace film screen radiography in some centers. Data are limited about the suitability of this technique for the evaluation of inflicted skeletal injury. This technique should be shown to perform comparably to high-detail film screen radiography before it is used routinely for suspected child abuse. In any case, an experienced radiologist must monitor the radiographic examination of the skeleton to ensure that appropriate high-resolution images are obtained.

Imaging Protocol

Once the appropriate imaging system is chosen, a precise protocol for skeletal imaging must be developed to ensure consistent quality. In routine skeletal imaging, an accepted principle is that film must be coned or restricted to the specific anatomic area of interest. It is common practice to encompass larger

The recommendations in this statement do not indicate an exclusive course of treatment or serve as a standard of medical care. Variations, taking into account individual circumstances, may be appropriate.

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anatomic regions when skeletal surveys are performed, and this results in areas of underexposure and overexposure, as well as loss of resolution resulting from geometric distortion and other technical factors. The standard skeletal survey imaging protocol that has been developed by the American College of Radiology is given in Table 1.¹³ Of special note is the inclusion of lateral views of the spine to assess for vertebral fractures and dislocations and separate views of the hands and feet to identify subtle digital injuries. Anteroposterior and lateral views of the skull are mandatory even when cranial computed tomography (CT) has been performed, because skull fractures coursing in the axial plane may be missed with axial CT. Studies must be monitored by a radiologist for technical adequacy. Skeletal injuries, especially those requiring orthopedic management, necessitate at least 2 radiographic projections. Oblique views of the thorax increase the yield for the detection of rib fractures. Recent evidence suggests that a follow-up skeletal survey approximately 2 weeks after the initial study increases the diagnostic yield,¹⁴ and this procedure should be considered when abuse is strongly suspected. The repeated study may permit more precise determination of the age of individual injuries. Lack of interval change may indicate that the initial radiographic finding is a normal anatomic variant or is related to a bone dysplasia.

Radionuclide Bone Scans

When performed by staff experienced with pediatric nuclear imaging, skeletal scintigraphy may offer an alternative or an adjunct to the radiographic skeletal survey in selected cases, particularly in children older than 1 year. Scintigraphy seems to provide increased sensitivity for detecting rib fractures, subtle shaft fractures, and areas of early periosteal elevation. However, data are limited about the sensitivity of scintigraphy for classic metaphyseal lesions of abuse, particularly when the lesions are bilateral, as well as subtle spinal injuries, features that carry a high specificity for abuse in infants.^{15,16} Skeletal scintigraphy usually requires sedation and is generally

more expensive than radiographic surveys. Bone scans often are used to supplement radiographic skeletal surveys in the acute care setting, but for the child who is placed in a "safe" environment, a follow-up skeletal survey is an attractive alternative to initial scintigraphy. If radionuclide bone scans are performed as the initial study, all positive areas must be evaluated further with radiography, and because scintigraphy is insensitive for detecting cranial injuries, skull radiography in at least 2 projections must supplement the bone scan.

Imaging Guidelines

The skeletal survey is mandatory in all cases of suspected physical abuse in children younger than 2 years. The screening skeletal survey or bone scan has little value in children older than 5 years. Patients in the 2- to 5-year-old group must be handled individually based on the specific clinical indicators of abuse. At any age, when clinical findings point to a specific site of injury, the customary radiographic protocol for imaging that anatomic region should be used.

Magnetic resonance imaging (MRI)¹⁷ and sonography may be indicated when epiphyseal separations are suspected based on plain film results. Application of these guidelines to selected cases of neglect and sexual abuse is appropriate when associated physical maltreatment is suspected. Evidence suggests that if 1 infant twin is injured, the other is at risk, and, therefore, a skeletal survey is advisable in such cases.

HEAD TRAUMA

High-energy forces associated with impact or violent shaking result in a variety of central nervous system injuries that can be detected by modern neuroimaging techniques. The evolution of these injuries, as well as processes developing secondary to the original insult, often are effectively displayed on serial imaging studies.¹⁸

All infants and children with suspected intracranial injury must undergo cranial CT or MRI, or both. Strategies should be directed toward the detection of all intracranial sequelae of abuse and neglect with a thorough characterization of the extent and age of the abnormalities.¹⁹ In the acute care setting, efforts are directed toward rapid detection of treatable conditions. Subsequent studies are designed to more fully delineate all abnormalities, determine the timing of the injuries, and monitor their evolution.

CT

The CT without intravenous contrast should be performed as part of the initial evaluation for suspected inflicted head injury. It has a high sensitivity and specificity for diagnosing acute intraparenchymal, subarachnoid, subdural, and epidural hemorrhage. Abnormalities that require emergency surgical intervention generally are well-demonstrated. The CT is readily available and rapidly performed for critically ill patients. The CT is better than MRI for evaluation of acute hemorrhage. Associated skull

TABLE 1. The Standard Skeletal Survey¹³

Appendicular skeleton
Humeri (AP)
Forearms (AP)
Hands (oblique PA)
Femurs (AP)
Lower legs (AP)
Feet (AP)
Axial skeleton
Thorax (AP and lateral)
Pelvis (AP; including mid and lower lumbar spine)
Lumbar spine (lateral)
Cervical spine (lateral)
Skull (frontal and lateral)
Technique
High resolution
High contrast
Screen/film speed not to exceed 200
Low kVp (bone technique)
Single emulsion or special film-screen combination

AP indicates anteroposterior; PA, posteroanterior; kVp, kilovolt peak.

and facial fractures also can be diagnosed with appropriate bone window setting images.

SONOGRAPHY

Sonography via the anterior fontanelle in young infants has gained a limited but important role for assessing the short- and long-term consequences of inflicted head injury. Subcortical white matter tears in the frontal and anterior parietal parasagittal regions can be demonstrated with this technique.²⁰ These lesions are less well-defined by CT, and sonography provides the advantage of a bedside technique. Because sonography reliably differentiates convexity subdural from subarachnoid collections, it is particularly useful for the infant with macrocephaly or any infant with large cerebral convexity collections demonstrated by CT.²¹ Because sonography is insensitive for detecting small acute subdural hematomas, particularly within the interhemispheric fissure, and many other acute intracranial injuries, it must be performed in conjunction with CT or MRI, or both.^{17,22}

MRI

The MRI is the best modality to fully assess intracranial injury, including extra-axial collections, intraparenchymal hemorrhages, contusions, shear injuries, and brain swelling, or edema. Imaging should be performed with T₁ and T₂ weighting with proton-density or inversion-recovery sequences to differentiate cerebrospinal fluid collections from other water-containing lesions. Gradient echo sequences should be included to detect hemorrhage or mineralization not demonstrable by other MRI techniques. Although the specific type and order of pulse sequences may vary, imaging must be performed at least in the axial and coronal planes. Because MRI may fail to detect acute subarachnoid or subdural hemorrhage, its use should be delayed for 5 to 7 days in acutely ill children. Diffusion imaging is a new and valuable technique for the evaluation of stroke and likely will have a role in the assessment of inflicted cerebral injury. Abused infants may not demonstrate neurologic signs and symptoms, despite significant central nervous system injury. The MRI offers the highest sensitivity and specificity for diagnosing subacute and chronic injury and should be considered whenever typical skeletal injuries associated with shaking or impact are identified.^{17,23}

SPINAL TRAUMA

Plain radiographs are often sufficient to evaluate vertebral compression and spinous process fractures. Complex fractures may require thin-section CT with multiplanar reformatted images. If a fracture or subluxation may compromise the spinal contents or if clinical findings indicate spinal cord or nerve root injury, MRI should be performed.

THORACOABDOMINAL TRAUMA

Blunt thoracoabdominal injury may occur in victims of child abuse. The evaluation and management of the acute problem is the same as for children with accidental injuries.²⁴ However, when an infant or

child sustains serious injury to the chest or abdomen without a known or observed mechanism, investigation of potential child abuse is warranted. Pancreatitis, duodenal hematomas, bowel perforation, and thoracoabdominal injury associated with rib fracture heighten the suspicion of child abuse. Unsubstantiated stories, such as falling out of bed, sibling stepping on infant, and rolling onto a child sleeping in bed, also should arouse suspicion of child abuse.

Chest, abdominal, and cervical spine radiographs often are obtained in the initial assessment of injured children. If internal chest or abdominal injury is suspected and the patient's condition is stable, a CT scan should be performed. A CT scan will best demonstrate many of the injuries associated with child abuse. The chest should be included if serious chest trauma is suspected.

The use of oral contrast is debatable. Oral contrast in the stomach and small bowel is useful to better define the lesser sac of the peritoneum, pancreas, and duodenum and jejunum. However, oral contrast may place the patient at greater risk of aspirating, especially if the patient is obtunded, sedated, or immobilized. If surgery or general anesthesia is likely, it is better to have an empty stomach.

Intravenous contrast is used routinely. Vascular injuries and injuries to the liver, spleen, pancreas, and kidneys are best demonstrated after administration of intravenous contrast material. Helical or dynamic axial scanning techniques with proper timing of the intravenous contrast bolus are important for accurate diagnosis. The only relative contraindications for intravenous contrast are a strong history of allergy to iodine, severe shock, and renal failure.

Abused children suffer some of the same injuries as children with accidental blunt trauma. In the chest, pulmonary contusion, pneumothorax, pleural effusion, rib fractures, vascular, or tracheobronchial injuries may occur. Abused children have an increased occurrence of pancreatic injuries and duodenal hematomas. Bowel injury should be suspected when there is peritoneal fluid without evidence of solid organ injury and when free intraperitoneal air or contrast is observed. Bone windows should be monitored not only for rib fractures, but also for signs of pelvic or spine fractures.

Peritoneal lavage rarely is used in pediatric practice. If performed before CT, it may decrease the diagnostic usefulness. It sometimes is used when emergency surgery is required to treat a patient whose condition is not stable enough for a CT scan.²⁴

The use of ultrasonography in pediatric trauma is controversial. Some institutions have used ultrasonography successfully for a more detailed, comprehensive evaluation of organ injury. However, for seriously injured children and those with suspected child abuse, CT scanning is the preferred initial diagnostic modality of choice in majority of the institutions. Peritoneal fluid alone, which can be detected well in both with ultrasonography and CT scan, is a poor predictor of major trauma in children. An upper gastrointestinal series sometimes is used to evaluate and follow-up duodenal hematomas.

Nonoperative management of injury to the liver,

TABLE 2. Imaging Recommendations for Thoracoabdominal Trauma

1. CT of abdomen and/or thorax helical of dynamic axial scanning intravenous contrast, nonionic preferable*, gastrointestinal contrast optional
2. Ultrasonography of abdomen usually as a follow-up examination
3. Upper gastrointestinal series

* Relative contraindication; strong history of allergy to iodine, severe shock, and renal failure.

spleen, kidney, or pancreas is common in most pediatric centers. Follow-up imaging usually is limited but may be useful to help determine recommendations for the level of physical activity (Table 2).

CONCLUSION

In summary, thoracoabdominal trauma in abused children should be evaluated and managed similar to accidental trauma. Abuse should be suspected and appropriate investigations initiated when the injury, clinical history, or the findings on the diagnostic imaging studies suggest the possibility of child abuse or nonaccidental injury.

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