The appropriate imaging for pediatric patients being evaluated for suspected physical abuse depends on the age of the child, the presence of neurologic signs and symptoms, evidence of thoracic or abdominopelvic injuries, and whether the injuries are discrepant with the clinical history. The clinical presentations reviewed consider these factors and provide evidence-based consensus recommendations by the ACR Appropriateness Criteria® Expert Panel on Pediatric Imaging.

Key Words: Appropriateness Criteria®, child abuse, shaken baby syndrome, children, trauma, pediatric

SUMMARY OF LITERATURE REVIEW

In 2007, on the basis of reports to child and protective service agencies, an estimated 794,000 children were victims of maltreatment (neglect, emotional abuse, sexual abuse, and physical abuse) in the United States [1]. Of these children, more than 79,000 were victims of physical abuse, and an estimated 1,760 children died from abuse or neglect [1]. As high as these numbers are, the extent of the problem is actually much greater, as officially reported cases grossly understate the true incidence of abuse [2,3].

In some children, physical examination and history may clearly indicate that physical abuse has occurred. In other children, however, the diagnosis of physical abuse is not so straightforward. It requires consideration of possible underlying metabolic and genetic conditions [4-8] and usually relies on the findings of a multidisciplinary team that includes physicians, social workers, and legal authorities. Imaging often plays a major role in the detection and documentation of physical injury. The type and extent of imaging performed in a child who is a suspected victim of abuse depend on the child’s age, signs, symptoms, and other social considerations, such as being the twin of a physically abused infant [9].

Child abuse injuries can involve any site in the human body. Physically abused children may present with hollow viscous and solid organ injuries, superficial and deep soft tissue injuries, thermal injuries, or fractures [10]. Fractures occur in up to 55% of child abuse victims [11]. Fractures most often involve the long bones with lesser involvement of the skull, ribs, clavicles, pelvis, and other bones [10,12].
Fractures that are highly specific for nonaccidental trauma in normal children include those involving the ribs, metaphyseal-epiphyseal injuries, and avulsive fractures of the clavicle and acromion process [13]. Highly suggestive skeletal injuries include fractures that are unsuspected or inconsistent with the provided history or age of the child, multiple fractures involving more than one skeletal area, fractures of differing ages, and a combination of skeletal and nonskeletal injuries [13]. In addition, fractures of the radius, ulna, fibula, or femur that occur in children aged < 1 year and midshaft or metaphyseal humeral fractures should be considered suspicious for abuse [14]. A recent systematic review of the literature on fractures and child abuse found the child’s motor developmental level to be a key discriminator for abuse in certain fractures [15]. In particular, femoral fractures in a child who is not yet walking and unexplained humeral fractures in children aged < 15 months should be considered suspicious for abuse. This review also found that multiple rib fractures in any location without overt trauma were strongly associated with abusive injury but that the posterior location of a rib fracture was not a discriminator for abuse [15].

**Radiographic Skeletal Survey**

The radiographic skeletal survey is the primary imaging examination for detecting fractures [12,16-19]. Compared with bone scintigraphy, the radiographic skeletal survey is more sensitive for detecting skull and metaphyseal long-bone fractures [20]. The skeletal survey should be composed of frontal and lateral views of the skull, lateral views of the cervical spine (if not included on the lateral skull view) and thoracolumbosacral spine, and single frontal views of the long bones, chest, and abdomen. Oblique views of the ribs should be obtained to increase the accuracy of diagnosing rib fractures [21,22], which, as previously noted, are strong positive predictors [15,23] and may be the only skeletal manifestation of abuse. The images should be obtained using high-detail imaging systems and coned to the specific area of interest for each of the body parts with separate views of each arm, forearm, thigh, leg, hand, and foot to improve image quality and diagnostic accuracy [19,24-26] (see Appendix).

The recommendations for use of skeletal surveys vary with the child’s age and type of presentation [19]. A majority of skeletal surveys that are positive for fractures are performed in children aged < 1 year [12,27], and 80% of children with fractures due to child abuse are aged < 18 months [10,15]. Radiographic skeletal survey is recommended in all children aged < 2 years in whom there is suspicion of abuse (Variant 1). In children aged 2 to 5 years, performance of skeletal survey should be based on the presence of other clinical findings and the need to document the presence or absence of injuries. In this older group of children, however, skeletal imaging should be strongly considered in a child who has unexplained cranioencephalic or abdominal injuries or fractures that are suspicious for abuse. In addition, a repeat skeletal survey performed approximately 2 weeks after the initial examination can provide additional information on the presence and age of child abuse fractures [25,26] and “should be performed when abnormal or equivocal findings are found on the initial study and when abuse is suspected on clinical grounds” [19]. These follow-up studies should include all the images except the skull radiographs that were included in the initial skeletal survey. Skull radiographs can be omitted because new findings would not be expected on these images [26].

<table>
<thead>
<tr>
<th>Variant 1. Child aged ≤ 24 months, no focal neurologic signs or symptoms</th>
<th>Radiologic Procedure</th>
<th>Rating</th>
<th>Comments</th>
<th>Relative Radiation Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray skeletal survey</td>
<td>9</td>
<td>Particularly for those patients who are “high risk” (eg, rib fractures, multiple fractures, facial injuries, or age &lt; 6 mo).</td>
<td>❀❀❀</td>
<td></td>
</tr>
<tr>
<td>CT head without contrast</td>
<td>7</td>
<td>If further evaluation is indicated after CT examination. See statement regarding contrast in text under “Anticipated Exceptions.”</td>
<td>❀❀</td>
<td></td>
</tr>
<tr>
<td>MRI head with or without contrast</td>
<td>5</td>
<td></td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>$^{99m}$Tc bone scan whole body</td>
<td>4</td>
<td>If skeletal survey is negative and high clinical suspicion remains.</td>
<td>❀❀</td>
<td></td>
</tr>
</tbody>
</table>

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.
Bone Scintigraphy

Bone scintigraphy is a complementary examination for detecting bone injuries [11,20,28]. It should be used when the radiographic skeletal survey is negative but clinical suspicion remains high and a search for further evidence of skeletal trauma is still necessary. To increase sensitivity, the bone scan should include the use of pinhole collimators and differential counts of the metaphyses. A bone scan is especially good for detecting periosteal trauma and rib, spine, pelvic, and acromion fractures [28].

Head Trauma

Although less frequent than skeletal injuries, most child abuse fatalities are the result of head trauma [7], and head injury due to child abuse is the principal cause of death in children aged < 2 years [29]. Subdural hematoma is the most commonly seen intracranial abnormality [30]. Additional cranioencephalic injuries include cerebral contusion, epidural hematoma, cerebral edema, subarachnoid hemorrhage, and unilateral hypoxic-ischemic injury [30-34].

Imaging the head in children with suspected abuse depends on the child’s age and type of presentation (Variant 2). In children with skull fractures or clinical signs and symptoms of intracranial injury, an immediate noncontrast CT scan of the head should be performed (Variants 3 and 4). If the CT scan does not detect significant lesions that require rapid neurosurgical intervention and the clinical presentation warrants further assessment, an MRI scan of the head should be performed. The MRI study should include T1-weighted and T2-weighted sequences with proton density or inversion recovery and gradient-echo sequences. In addition, diffusion-weighted sequences are suggested to indicate whether acute cerebral injury is present [19]. In a child with abnormal CT findings, additional assessment with MRI should be considered to further assess the extent of posttraumatic injury.

There are varying opinions on how to image children who are suspected abuse victims and have no objective evidence suggesting intracranial injury [29,33,35,36]. Children, especially those aged < 12 months, may have significant intracranial injury without signs or symptoms...
of head injury [18,29,33]. Physical examination, in particular the absence of retinal hemorrhages, should not be used to determine the need for imaging, as intracranial injury may occur in the absence of retinal hemorrhages [29,33]. Skull radiographs are also unreliable. Although skull radiographs may detect fractures associated with intracranial pathology [37], they do not provide adequate screening, since significant traumatic intracranial pathology may occur in the absence of skull fractures [33,38,39].

In one study [29], 37% of children aged < 2 years with “high-risk” criteria (defined as rib fractures, multiple fractures, facial injuries, or age < 6 months) and without overt signs of head injury who underwent head CT or MRI had occult head injuries. In this study, 18 of the 19 children with occult head injuries were aged < 1 year. Another study [33] of 51 children aged < 4 years with no signs of intracranial injury who underwent skeletal survey for abuse found that 29% of children who underwent neurologic imaging had evidence of intracranial injury that included subdural hematoma, epidural hematoma, or cerebral edema. Given these studies, clinicians should have a relatively low threshold for performing either CT or MRI of the head in children with suspected abuse. Magnetic resonance imaging avoids the radiation of CT and is a particularly good choice in the nonemergent setting to image these “high-risk” children without overt neurologic signs or symptoms.

**Nonskeletal Chest, Abdominal, and Pelvic Injuries**

Nonskeletal injuries to the chest, abdomen, and pelvis can occur as the result of child abuse. Injuries to the chest are rare but may include hemopericardium, cardiac contusions, and lacerations; pleural effusion, lung contusions, and chylothorax [7,40,41]. Nonskeletal injuries to the abdomen and pelvis include pancreatitis, pancreatic pseudocysts, and lacerations and contusions of the liver, adrenal gland, spleen, and kidneys, as well as injury and rupture of the bladder and bowel [40,42]. Victims of nonaccidental abdominal trauma tend to be younger and have a more delayed presentation than those who experience accidental trauma [43]. The delay in presentation may be related to the caretaker’s delay in bringing the patient to medical attention, inconsistent history, or the vagueness of symptoms that may accompany the injuries. In addition, independent of concomitant injury, blunt trauma due to child abuse “is associated with a 6-fold increased odds of death compared to children whose injuries resulted from other mechanisms” [44].

In most cases, imaging for assessing these injuries will be directed by the patient’s clinical presentation and consist of a CT scan of the involved body part. A CT scan of the chest should generally be performed with intravenous contrast to detect vascular injuries. A CT scan for suspected intra-abdominal injury should include both the abdomen and pelvis and should be performed with intravenous contrast. The need for oral contrast is at the discretion of the radiologist, and its use should be strongly considered when there is concern for duodenal hematoma. Parenchymal or late arterial phase imaging is most helpful for detecting solid organ injury. Delayed, excretory phase imaging is suggested detecting disruption of the genitourinary tract. In patients with spinal injury, ei-
ther CT or MRI should be performed depending on the severity of the patient’s signs and symptoms.

Child abuse should be considered in any age child with thoracoabdominal injuries that are not consistent with the provided history (Variants 5 and 6). A skeletal survey can be helpful by detecting the presence of other injuries and may confirm the diagnosis of abuse. As a result, skeletal survey is recommended in children aged \( \leq 24 \) months when an apparently isolated thoracoabdominal injury is found and raises the possibility of physical abuse. In addition, a skeletal survey should be strongly considered in older patients in the same clinical setting.

### Variant 5. Child aged \( \leq 24 \) months, thoracic and/or abdominopelvic injuries, discrepancy with history

<table>
<thead>
<tr>
<th>Radiologic Procedure</th>
<th>Rating</th>
<th>Comments</th>
<th>Relative Radiation Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray skeletal survey</td>
<td>9</td>
<td></td>
<td>☀️☀️☀️☀️</td>
</tr>
<tr>
<td>CT abdomen and pelvis with contrast</td>
<td>9</td>
<td></td>
<td>☀️☀️☀️☀️</td>
</tr>
<tr>
<td>CT head without contrast</td>
<td>8</td>
<td></td>
<td>☀️☀️☀️☀️</td>
</tr>
<tr>
<td>CT chest with contrast</td>
<td>6</td>
<td>When indicated on the basis of abnormal chest radiographic findings or patient’s signs and symptoms.</td>
<td>☀️☀️☀️☀️</td>
</tr>
<tr>
<td>MRI head with or without contrast</td>
<td>5</td>
<td>If further evaluation is indicated after CT examination. See statement regarding contrast in text under “Anticipated Exceptions.”</td>
<td>☀️</td>
</tr>
<tr>
<td>CT abdomen and pelvis without contrast</td>
<td>1</td>
<td>Should be considered only if there is an absolute contraindication to intravenous contrast administration.</td>
<td>☀️☀️☀️☀️</td>
</tr>
</tbody>
</table>

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.

### Variant 6. Child aged \( > 24 \) months, thoracic and/or abdominopelvic injuries, discrepancy with history

<table>
<thead>
<tr>
<th>Radiologic Procedure</th>
<th>Rating</th>
<th>Comments</th>
<th>Relative Radiation Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT abdomen and pelvis with contrast</td>
<td>9</td>
<td></td>
<td>☀️☀️☀️☀️</td>
</tr>
<tr>
<td>CT head without contrast</td>
<td>8</td>
<td></td>
<td>☀️☀️☀️☀️</td>
</tr>
<tr>
<td>X-ray skeletal survey</td>
<td>6</td>
<td>Value of survey is less as age rises. Radiographs should usually be tailored to the areas of suspected injury.</td>
<td>☀️☀️☀️☀️</td>
</tr>
<tr>
<td>CT chest with contrast</td>
<td>6</td>
<td>When indicated on the basis of abnormal chest radiographic findings or patient’s signs and symptoms.</td>
<td>☀️☀️☀️☀️</td>
</tr>
<tr>
<td>MRI head with or without contrast</td>
<td>5</td>
<td>If further evaluation is indicated after CT examination. See statement regarding contrast in text under “Anticipated Exceptions.”</td>
<td>☀️</td>
</tr>
<tr>
<td>CT abdomen and pelvis without contrast</td>
<td>1</td>
<td>Should be considered only if there is an absolute contraindication to intravenous contrast administration.</td>
<td>☀️☀️☀️☀️</td>
</tr>
</tbody>
</table>

Note: Rating scale: 1, 2, and 3 = usually not appropriate; 4, 5, and 6 = may be appropriate; 7, 8, and 9 = usually appropriate.
SUMMARY

- The appropriate imaging of pediatric patients being evaluated for suspected physical abuse depends on the age of the child, the presence of neurologic signs and symptoms, evidence of thoracic or abdominopelvic injuries, and whether the child’s injuries are discrepant with the clinical history.
- An x-ray skeletal survey is always indicated in a child aged ≤ 24 months. In older children, a skeletal survey can be performed, but it is often more appropriate to tailor the radiographs to the areas of suspected injury.
- A CT scan of the head without contrast is always indicated in a patient with seizures or neurologic signs and symptoms and when there is a history of head trauma.
- A CT scan of the head should be strongly considered in “high-risk” children (rib fractures, multiple fractures, facial injuries, or age ≤ 6 months) and children with thoracic or abdominopelvic injuries and discrepant clinical histories.
- MRI of the head may be needed for further assessment after head CT and may be useful whether head CT results are positive or negative. When the child is symptomatic, however, head CT should not be delayed if MRI is to be obtained.
- A whole-body $^{99m}$Tc bone scan may be helpful if the x-ray skeletal survey is negative and high clinical suspicion remains.
- CT scans of the chest, abdomen, or pelvis are indicated if there are signs and symptoms of abuse or if abnormal findings are seen on conventional radiography, particularly when there is a discrepancy with clinical history.
- A CT scan of the abdomen and pelvis should always be performed with intravenous contrast unless the patient has an absolute contraindication to it.

ANTICIPATED EXCEPTIONS

Nephrogenic systemic fibrosis is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It seems to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rates (ie, <30 mL/min/1.73 m²), and almost never in other patients. There is growing literature regarding nephrogenic systemic fibrosis. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk and to limit the type and amount in patients with estimated glomerular filtration rates < 30 mL/min/1.73 m². For more information, please see the ACR’s Manual on Contrast Media [45].

RELATIVE RADIATION LEVEL INFORMATION

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level indication has been included for each imaging examination. The relative radiation levels are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the relative radiation level dose estimate ranges for pediatric examinations are lower compared with those specified for adults (Table 1). Additional information regarding radiation dose assessment for imaging examinations can be found in ACR Appropriateness Criteria®: Radiation Dose Assessment Introduction [46].

Disclaimer: The ACR Committee on Appropriateness Criteria® and its expert panels have developed criteria for determining appropriate imaging examinations for the diagnosis and treatment of specified medical conditions. These criteria are intended to guide radiologists, radiation oncologists, and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient’s clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for the evaluation of a patient’s condition are ranked. Other imaging studies necessary to evaluate other coexistent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures, and the user should refer to appropriate literature for more information.

<table>
<thead>
<tr>
<th>Relative Radiation Level</th>
<th>Adult Effective Dose Estimate Range (mSv)</th>
<th>Pediatric Effective Dose Estimate Range (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>&lt;0.1</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>2</td>
<td>0.1-1</td>
<td>0.03-0.3</td>
</tr>
<tr>
<td>3</td>
<td>1-10</td>
<td>0.3-3</td>
</tr>
<tr>
<td>4</td>
<td>10-30</td>
<td>3-10</td>
</tr>
<tr>
<td>5</td>
<td>30-100</td>
<td>10-30</td>
</tr>
</tbody>
</table>

Note: Relative radiation level assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The relative radiation levels for these examinations are designated as not specified.
ate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria, but the study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

Appendix. Complete Skeletal Survey Table

<table>
<thead>
<tr>
<th>Appendicular skeleton</th>
<th>Pelvic skeleton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humeri (AP)</td>
<td>Thorax (AP and lateral), to include ribs,*</td>
</tr>
<tr>
<td>Forearms (AP)</td>
<td>thoracic and upper lumbar spine</td>
</tr>
<tr>
<td>Hands (PA)</td>
<td>Pelvis (AP), to include the mid lumbar spine</td>
</tr>
<tr>
<td>Femurs (AP)</td>
<td>Lumbosacral spine (lateral)</td>
</tr>
<tr>
<td>Lower legs (AP)</td>
<td>Cervical spine (AP and lateral)</td>
</tr>
<tr>
<td>Feet (PA) or (AP)</td>
<td>Skull (frontal and lateral)</td>
</tr>
</tbody>
</table>

*The addition of both oblique projections to the AP view of the rib cage may increase the yield of rib fractures.

REFERENCES


