Nita Jain, MD, FRCPC

The role of diagnostic imaging in the evaluation of child abuse

Radiologists experienced in pediatric imaging can provide invaluable assistance to health care teams working to identify child maltreatment and differentiate abusive trauma from accidental trauma and other unusual medical conditions.

ABSTRACT: The assessment of suspected child physical abuse relies heavily on the use of diagnostic imaging. The skeletal survey, bone scan, cross-sectional intracranial and body imaging, and the recent use of bedside diagnostic ultrasound all present advantages and disadvantages in the investigation of child maltreatment. Since physicians may be expected to provide evidence in court, it is mandatory that they work in close collaboration with radiologists experienced in pediatric imaging to ensure that imaging studies are performed to the highest possible standard, and reported in a thorough and informed fashion. Consultation and communication with the radiologist is invaluable in coming to an accurate diagnosis in these challenging cases.

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Radiological investigations are absolutely essential when assessing children who may have been subjected to physical abuse. These investigations play a key role in child abuse cases because the history provided is often incomplete or misleading and the physical examination may not readily identify occult injuries, especially in infants and young children. Diagnostic imaging can provide objective information about skeletal trauma, head trauma, and thoraco-abdominal trauma. This information is of greatest benefit when high-quality images have been obtained by trained staff and the images have been interpreted by a radiologist who is familiar with the findings seen in child abuse. It is important to emphasize that diagnostic imaging not only helps to identify the extent of injury when physical abuse is present, but it may also point to a medical diagnosis when abuse is not present.[1,2] Fortunately, pre-existing medical conditions that result in increased bone fragility are very rare, occurring in less than 1% of children presenting with fractures.[3]

Imaging skeletal trauma

In cases of suspected physical abuse, the radiographic skeletal survey is the first choice for imaging the entire bony skeleton in children. To ensure consistent quality, the American College of Radiology has joined with the Society for Pediatric Radiology to publish a practice parameter for skeletal surveys in children.[4] It is important to note that although bony injuries are rarely life threatening, they can provide compelling evidence for the diagnosis of physical abuse. Skeletal surveys can help to identify characteristic injury patterns such as the classic metaphyseal lesion in long bones, previously referred to as "bucket-handle" and "corner" fractures (**Figure 1**), or posterior rib fractures (**Figure 2**), both of which are strongly suggestive of abuse even when clinical information is lacking. Radiological investigations can provide important information on the dating of skeletal

Dr Jain is a clinical assistant professor in the Department of Pediatrics at the University of British Columbia and a staff pediatrician at BC Children's Hospital.

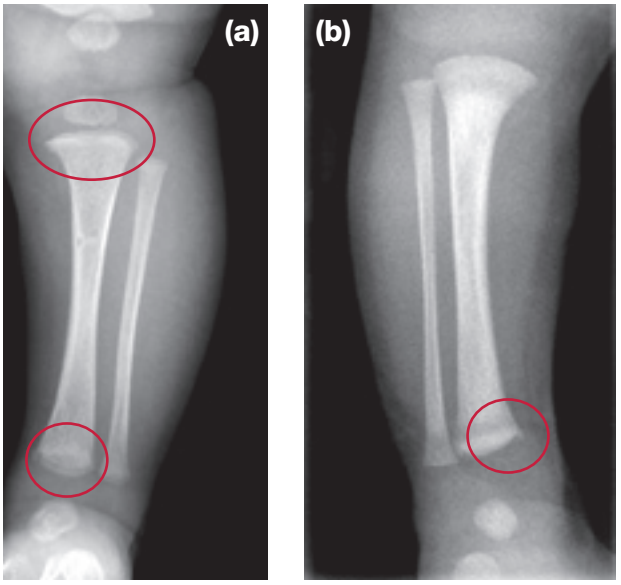

Figure 1. Classic metaphyseal lesions: (a) "bucket-handle" fracture and (b) "corner" fracture.

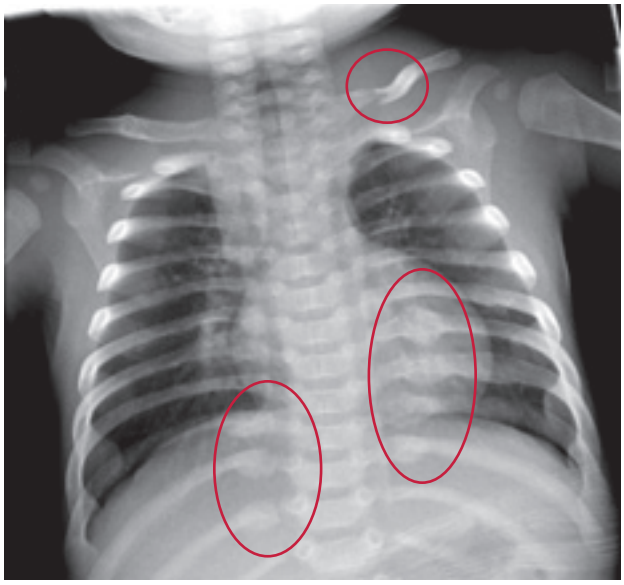

Figure 2. Multiple bilateral posterior rib fractures that are healing can be seen in an infant who also has an acute left clavicle fracture.

injuries and may help identify perpetrators of abuse and confirm the innocence of nonabusive caregivers. In addition, the information obtained from imaging studies may be presented during legal proceedings. For all of these reasons the skeletal survey needs to be performed at an optimal level of technical quality using high-detail imaging systems, and the images must be obtained according to a rigorous protocol, with special attention paid to patient positioning (which may require restraining devices) and proper centring and coning of images to relevant body parts (with shielding of others). This will ensure the images provide the necessary detail to view subtle skeletal injures while keeping the patient radiation dose "as low as reasonably achievable."[4]

A separate radiographic image is required for each anatomic region, and some body areas need to be captured in two or more projections. The inclusion of right and left oblique views of the thorax increases the yield for the detection of rib fractures and should be standard protocol.[4] In contrast to the skeletal survey examination for medical conditions such as skeletal dysplasias or metabolic disorders, where a greater portion of the skeleton may be imaged on one radiograph, there is no role for a "babygram" (**Figure 3**) in the assessment of suspected child abuse.[1,4]

A radiologist should be available to review the skeletal survey images during their acquisition to ensure that high-quality images and appropriate views are obtained and to

Figure 3. A "babygram"—a radiograph showing the entire body of the infant using an inappropriately large field of view—is inadequate when evaluating for possible skeletal injury.

request additional images of areas where there is initial uncertainty. In some jurisdictions, there is a recommended standard of having two radiologists with expertise in child abuse imaging review all such skeletal surveys.[5] This is the standard practised in the Department of Radiology at BC Children's Hospital.

The skeletal survey with oblique views of the ribs still remains the gold standard for evaluating occult skeletal trauma.

A limited repeat skeletal survey, done approximately 2 weeks following the initial one, is recommended when there is a high clinical suspicion for abuse and when the initial survey shows findings that are abnormal or equivocal.[1] The follow-up survey can increase the likelihood of detecting an occult fracture not visible at the time of the initial skeletal survey, can clarify indeterminate findings, and can be valuable in estimating the age of fractures.[6] A large prospective study published in 2013 showed that in 21.5% of cases the follow-up skeletal survey helped identify new fractures or provided clarification about concerning findings that were not fractures.[7] Views of the skull, pelvis, and lateral spine may be omitted on follow-up surveys due to the low yield of additional information and the desire to limit further radiation exposure to sensitive organs.[8,9]

The skeletal survey is considered a mandatory study whenever physical abuse is suspected in children younger than 2 years of age and in older children with developmental delay or limited verbal skills where there may be difficulties in detecting fractures clinically. Additionally, skeletal surveys need to be considered in young siblings of those found to have injuries consistent with physical abuse.

Generally speaking, the utility of the skeletal survey decreases in children beyond the age of 2 years, and is felt to provide little value in children older than 5.[1] A recent review of data on the yield of skeletal surveys by age showed a similar rate of detection of fractures in children 24 to 36 months old and those 12 to 24 months old—results supporting a low threshold to obtain a skeletal survey in children up to the age of 3 years.[10] Thus, in children age 2 to 5, it is reasonable to make decisions regarding the type of imaging needed on a case-by-case basis.[1]

A radionuclide bone scan can be used in some cases to complement the skeletal survey. Although it has greater sensitivity than X-ray for detecting rib and subtle long bone shaft fractures, it is less sensitive than X-ray for detecting classic metaphyseal lesions. In addition, a bone scan cannot reliably detect skull fractures; therefore, at least two X-ray views of the skull must always be done. Further evaluation of all areas showing abnormalities on bone scan must be carried out with X-ray. A review of the literature on yield of skeletal survey compared to yield on bone scan showed that neither investigation alone was as good as the two combined; however, the skeletal survey with oblique views of the ribs still remains the gold standard for evaluating occult skeletal trauma.[11]

The use of bedside ultrasound to diagnose skull and long bone fractures in the emergency department has had some recent attention.[12,13] Ultrasound in these cases is used as an extension of the physical examination and as an adjunct to, not replacement for, traditional imaging methods. Intact cortical bone almost completely reflects ultrasound waves, thus fracture planes can be identifiable as breaks in this pattern. Ultrasound examination may be of some value in identifying occult or unsuspected bony injures and periosteal hematoma in child abuse cases.[12] Ultrasound examination must be performed and interpreted by, or under the supervision of, a physician who has had training in this modality. The clinician should be aware that fractures might be missed with ultrasound. For example, in the case of a skull fracture that is not situated under a scalp hematoma, scanning only the area of hematoma may miss the fracture.[13] Appropriate images need to be kept as part of the permanent record both for legal purposes and for quality review. While bedside ultrasound shows some potential as an adjunct to

X-ray and bone scan, it should never be the sole modality for imaging of skeletal trauma in cases of suspected physical abuse.

Imaging intracranial injury

Abusive head trauma is the leading cause of death from head injury in children under 2 years of age, and serious neurological sequelae may be seen in those that survive.[2] When intracranial injury is suspected, the brain and extra-axial spaces should be imaged with computed tomography (CT), magnetic resonance imaging (MRI), or a combination of these. These cross-sectional imaging modalities allow characterization of the extent of injury and facilitate intervention. Serial imaging may be helpful in monitoring the evolution of the injury and dating the age of the abnormalities found.

CT is highly sensitive and specific for the detection of acute intraparenchymal, subarachnoid, subdural, and epidural bleeding and the consequences of these abnormalities (**Figure 4**). Additionally, it can provide information on skull and facial fractures, as well as soft tissue injuries. The ability to reveal such injuries and abnormalities, coupled with the speed and near universal availability of CT, make it the first choice for evaluating acute cases when inflicted head trauma is suspected.

In contrast to the advantages of CT in the acute setting, MRI offers better sensitivity and specificity for detecting subacute and old injury and may miss acute subdural or subarachnoid hemorrhage. MRI is the best modality for overall assessment of intracranial trauma and can provide information on brain edema, contusions, intraparenchymal, and extra-axial hemorrhages. MRI should be used in all cases with head CT findings of abnormalities and may even be useful in some cases where CT findings are normal but a strong clinical suspicion of abusive head injury exists.

Until recently it was accepted that the appearance of subdural hematomas on CT and MRI could provide information about the time of injury. Typically, subdural blood found to be hyperdense or of mixed density on head CT was thought to indicate an acute injury, whereas blood that was found to be hypodense was considered to be several days old. More recently, studies have shown that the appearance of subdural blood can vary widely and the density found on imaging is not sufficient to date a subdural hemorrhage.[14,15] However, the time frame of injury can be established with some reasonable certainty using radiological findings combined with the child's history and information from a physical exam.[15]

In young infants with open fontanelles and sutures, head ultrasound has been considered a modality for the immediate bedside diagnosis of both skull and intracranial injury. There is concern, however, that clinicians using ultrasound findings may not have sufficient skill or experience in infants to reliably detect injury, and there may be limited opportunity for a permanent record of the images to be made for legal purposes and for quality review. Therefore, if this modality is used to assess head trauma, it must be done in conjunction with CT or MRI.

Imaging spinal trauma

While plain films of the cervical, thoracic, and lumbar spine are included as part of the skeletal survey, cross-sectional images of the spine are increasingly being obtained in those found to have evidence of abusive head trauma.[5] This practice reflects a recent study confirming the significant incidence of spinal subdural hemorrhage in patients with abusive head trauma.[16]

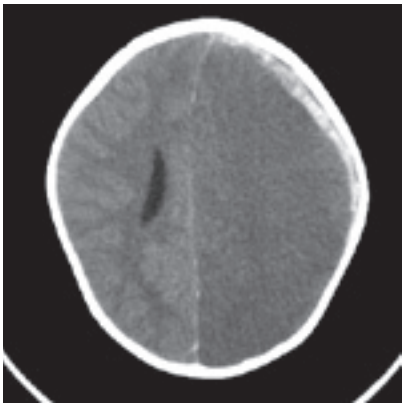

Figure 4. An acute subdural hemorrhage can be seen here along with significant injury to the left cerebral hemisphere associated with midline shift.

Imaging thoracoabdominal trauma

Significant visceral injuries of the chest and abdomen are uncommon in infants, but become increasingly important in toddlers and older children as they are associated with high mortality. Although there may be an initial role for use of ultrasound, the mainstay of imaging is contrast-enhanced CT scanning.[1] While injuries may be similar to those seen in accidental trauma, children who have been subjected to abuse have a higher incidence of pancreatic and duodenal injury, as well as bowel perforation caused by direct blows to the abdomen.[2]

Communication and collaboration

The complex nature of suspected child abuse cases requires detailed and ongoing communication and collaboration between the whole team of health care professionals and community investigators. Primary care physicians and pediatricians who are evaluating children for possible abuse must pro-

Consultation with a pediatric radiologist is of great value in understanding the nature of the injuries seen and in providing guidance about further studies.

vide accurate information about the extent and possible mechanism of injuries seen. As such, direct personal communication with subspecialty clinical and pediatric radiology colleagues who assist with identification of traumatic injuries is mandatory. In cases of trauma identified by diagnostic imaging, consultation with a pediatric radiologist in the local community is of great value in understanding the nature of the injuries seen and in providing guidance about further studies that may be helpful or necessary. Further, it is always possible for physicians and radiologists to review challenging cases with their local Suspected Child Abuse and Neglect (SCAN) team, or the Child Protection Service Unit and pediatric radiologists at BC Children's Hospital.

Conclusions

Diagnostic imaging in cases of suspected child abuse should be performed with the same level of technical excellence used when evaluating accidental trauma and medical conditions. Since physicians may be expected to provide evidence in court, it is mandatory that they work in close collaboration with radiologists experienced in pediatric imaging to ensure that imaging studies are performed to the highest possible standard, and reported in a thorough and informed fashion. A collaborative approach will ensure that abuse is accurately identified and reliably differentiated from both accidental trauma and other unusual medical conditions.

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Competing interests

None declared.

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