American College of Radiology
ACR Appropriateness Criteria®
Suspected Physical Abuse-Child

Variant: 1 Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
Radiography skeletal survey	Usually Appropriate	☢☢☢
CT head without IV contrast	Usually Appropriate	☢☢☢
Radiography area of interest	May Be Appropriate (Disagreement)	Varies
CT chest without IV contrast	May Be Appropriate	☢☢☢☢
US abdomen	Usually Not Appropriate	O
US abdomen with IV contrast	Usually Not Appropriate	O
US head	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRI head without IV contrast	Usually Not Appropriate	O
MRV head without IV contrast	Usually Not Appropriate	O
Bone scan whole body	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢☢
CT chest with IV contrast	Usually Not Appropriate	☢☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢☢

Variant: 2 Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
Radiography area of interest	Usually Appropriate	Varies
Radiography skeletal survey	May Be Appropriate (Disagreement)	☢☢☢
US abdomen	Usually Not Appropriate	O
US abdomen with IV contrast	Usually Not Appropriate	O
US head	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRI head without IV contrast	Usually Not Appropriate	O
MRV head without IV contrast	Usually Not Appropriate	O
Bone scan whole body	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢☢
CT chest with IV contrast	Usually Not Appropriate	☢☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢☢

CT chest without IV contrast	Usually Not Appropriate	☢☢☢☢
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT head without IV contrast	Usually Not Appropriate	☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢☢

Variant: 3 Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs , symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
Radiography skeletal survey	Usually Appropriate	☢☢☢
CT head without IV contrast	Usually Appropriate	☢☢☢
Radiography area of interest	May Be Appropriate (Disagreement)	Varies
MRI complete spine without IV contrast	May Be Appropriate	O
MRI head without IV contrast	May Be Appropriate	O
MRV head without IV contrast	May Be Appropriate	O
US head	Usually Not Appropriate	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
MRI cervical spine without IV contrast	Usually Not Appropriate	O
MRI complete spine without and with IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
Bone scan whole body	Usually Not Appropriate	☢☢☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT cervical spine without IV contrast	Usually Not Appropriate	☢☢☢☢
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢

Variant: 4 Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
Radiography area of interest	Usually Appropriate	Varies
CT head without IV contrast	Usually Appropriate	☢☢☢
Radiography skeletal survey	May Be Appropriate	☢☢☢
MRI complete spine without IV contrast	May Be Appropriate	O
MRI head without IV contrast	May Be Appropriate	O
MRV head without IV contrast	May Be Appropriate	O
US head	Usually Not Appropriate	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
MRI cervical spine without IV contrast	Usually Not Appropriate	O
MRI complete spine without and with IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O

Bone scan whole body	Usually Not Appropriate	☢☢☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT cervical spine without IV contrast	Usually Not Appropriate	☢☢☢☢
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢

Variant: 5 Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
Radiography skeletal survey	Usually Appropriate	☢☢☢
CT abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢☢
Radiography area of interest	May Be Appropriate (Disagreement)	Varies
CT chest with IV contrast	May Be Appropriate	☢☢☢☢
CT chest without IV contrast	May Be Appropriate	☢☢☢☢
US abdomen	Usually Not Appropriate	O
US abdomen with IV contrast	Usually Not Appropriate	O
Bone scan whole body	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢☢

Variant: 6 Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
Radiography area of interest	Usually Appropriate	Varies
CT abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢☢
Radiography skeletal survey	May Be Appropriate (Disagreement)	☢☢☢
CT chest with IV contrast	May Be Appropriate	☢☢☢☢
CT chest without IV contrast	May Be Appropriate	☢☢☢☢
US abdomen	Usually Not Appropriate	O
US abdomen with IV contrast	Usually Not Appropriate	O
Bone scan whole body	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢☢

Variant: 7 Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.

Procedure	Appropriateness Category	Peds Relative Radiation Level
Radiography skeletal survey	Usually Appropriate	☢☢☢
MRI head without IV contrast	May Be Appropriate (Disagreement)	O
Bone scan whole body	May Be Appropriate	☢☢☢☢

CT chest without IV contrast	May Be Appropriate	☢☢☢☢
US abdomen	Usually Not Appropriate	O
US abdomen with IV contrast	Usually Not Appropriate	O
US head	Usually Not Appropriate	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
MRI cervical spine without IV contrast	Usually Not Appropriate	O
MRI complete spine without and with IV contrast	Usually Not Appropriate	O
MRI complete spine without IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRV head without IV contrast	Usually Not Appropriate	O
CT abdomen and pelvis with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢☢
CT chest with IV contrast	Usually Not Appropriate	☢☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢☢

<u>Variant: 8</u> Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
Radiography skeletal survey	Usually Appropriate	☢☢☢
MRI head without IV contrast	May Be Appropriate (Disagreement)	O
CT head without IV contrast	May Be Appropriate (Disagreement)	☢☢☢
US abdomen	Usually Not Appropriate	O
US abdomen with IV contrast	Usually Not Appropriate	O
US head	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRV head without IV contrast	Usually Not Appropriate	O
Bone scan whole body	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢☢
CT chest with IV contrast	Usually Not Appropriate	☢☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT chest without IV contrast	Usually Not Appropriate	☢☢☢☢
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Not Appropriate	☢☢☢☢☢

Panel Members

David M. Mirsky, MD[a], Dianna M. E. Bardo, MD[b], Ramesh S. Iyer, MD, MBA[c], Sherwin S. Chan, MD, PhD[d], V. Michelle Silvera, MD[e], Andrea G. Asnes, MD, MSW[f], Isabel A. Barata, MD, MS, MBA[g], Richard A. Falcone Jr., MD, MPH[h], Abhaya V. Kulkarni, MD, PhD[i], Terry L. Levin, MD[j], Nirav K. Pandya, MD[k], Judy H. Squires, MD[l], Andrew T. Trout, MD[m], Matthew T. Whitehead, MD[n], Sumit Pruthi, MD, MBBS[o]

Summary of Literature Review

Introduction/Background

Child maltreatment is a global health emergency. The World Health Organization characterizes child maltreatment as "physical and/or emotional ill-treatment, sexual abuse, neglect, negligence, and commercial or other exploitation, which results in actual or potential harm to the child's health, survival, development, or dignity in the context of a relationship of responsibility, trust or power" [1]. According to the United States Children's Bureau of the Health and Human Services' Administration, in 2019, there were 3.5 million investigations of suspected child abuse and neglect in the United States and 656,000 victims of maltreatment. Of those, 61% were neglected, 10.3% were physically abused, 7.2% were sexually abused, and more than 15.5% were victimized in a combination of subtypes [2]. Approximately 28.7% of victims were <3 years of age, and 15.3% of victims <1 year of age. That year, child fatalities related to abuse or neglect were 1,770, equating to 4 to 5 child deaths each day. Of the children that died, more than two-thirds (70.6%) were <3 years of age and almost one-half (46.6%) were <1 year of age. However, the full extent of child abuse and neglect is unknown as the incidence is likely underreported [2]. Factors that place a child at higher risk of physical abuse include pre-existing neurological and psychiatric conditions, physical, or development issues, and caregiver features such as being young, single, and having a history of substance abuse and/or depression. Additionally, a challenging living environment, such as poverty, contributes to the risk [1-3].

Physically abused children may present with neurological injuries, hollow viscus and solid-organ injuries, superficial and deep soft-tissue injuries, thermal injuries, and/or fractures. Imaging plays an important role in the detection and documentation of physical injury. Fractures are a common type of injury diagnosed radiographically in abused infants. Fractures highly suggestive of physical abuse include posterior rib fractures, classic metaphyseal lesions (CMLs), fractures that are unsuspected or inconsistent with the provided history or unusual for the child's age, multiple fractures involving more than one skeletal area, and fractures of differing ages [4-6]. Head injury is also common in young abused children [7] and is among the leading causes of child maltreatment fatalities. On imaging, subdural hematomas (SDHs), skull fractures, and injured bridging veins are common. The type and extent of imaging performed in a child who is a suspected victim of abuse depends on the child's age, signs, symptoms, and other social considerations, such as being the sibling of a physically abused infant [8,9]. Diagnosing child abuse requires differentiating anatomical and developmental variants from pathology [10], as well as considering possible underlying metabolic [6] and genetic conditions [11]. No single injury is diagnostic of child abuse. Instead, the combination, severity, and/or age of injuries along with inconsistencies or lack of credibility in the provided clinical history, provide indications of the diagnosis. Ultimately, a thorough clinical evaluation by a multidisciplinary team is required to make the determination of abuse.

Special Imaging Considerations

Identifying imaging abnormalities suggestive of child abuse can raise complex medical, social, and legal issues. Diagnosing these abnormalities is often critical in supporting or ruling out the diagnosis of abuse and impacts decisions made in nonmedical settings such as safety planning and legal investigations. Therefore, it is paramount that diagnostic imaging adheres to the highest quality standards for examination techniques, particularly concerning the specifics of anatomic

coverage and the number of skeletal survey radiographic views required for diagnosing known or suspected physical child abuse, as defined by professional multisociety recommendations. See the "ACR-SPR Practice Parameter For The Performance And Interpretation Of Skeletal Surveys In Children" [12], Society for Pediatric Radiology (SPR), American Society of Pediatric Neuroradiology, and the Consensus Statement on Abusive Head Trauma (AHT) in Infants and Young Children [13] recommendations for further guidance.

The role of focused assessment with ultrasonography for trauma (FAST) (or extended-FAST or chest abdominal-FAST in evaluating chest injury) is primarily one of triage; a positive FAST and signs of hemodynamic instability may lead to immediate surgical intervention rather than CT [14,15]. Ultrasound (US) may be able to diagnose certain thoracic and abdominal injuries, but it is an insufficient test to fully exclude injuries to these areas because it has a relatively lower specificity compared with CT [16].

A FAST examination is a US technique used in the emergency department setting to evaluate for free intraperitoneal fluid, pericardial fluid, pleural effusion, and pneumothorax in patients who have suffered abdominal trauma, as a manner of differentiating patients who require further advanced imaging such as contrast-enhanced CT of the abdomen and pelvis [17,18]. FAST is an established practice in adult trauma care but is not established as a standard of care in children [19]. Studies to support the use of FAST examinations in infants and children suffering abdominal trauma as the result of physical child abuse have not been published.

In a study of 925 hemodynamically stable children suffering accidental abdominal trauma, 465 patients underwent FAST examinations. Study results revealed that FAST did not improve clinical care by means of reduction of emergency department length of stay, missed injuries, or length of hospital stay, and therefore did not support the use of FAST in children suffering abdominal trauma. Of note, children included in this study were a mean age of 9.7 years (SD 5.3 years), and were not suspected to have suffered nonaccidental injury [20]. The value of FAST in children suffering nonaccidental abdominal trauma is not known and may be of future research interest.

Whole body MRI (WB-MRI) has been investigated in comparison with skeletal survey and bone scintigraphy for detection of fractures and soft tissue injuries in patients with suspected physical child abuse. The radiographic skeletal survey has been determined to be the optimal diagnostic imaging modality for diagnosing CMLs and rib fractures compared with WB-MRI.

In a study of 21 infants undergoing imaging investigation for physical child abuse, a key determinant of the superiority of radiographs was the ability of the radiologist to detect the presence of healing fractures and to determine differences in the age of detected fractures [21]. In a study of 170 children up to 3 years of age comparing WB-MRI with radiographic skeletal survey and bone scintigraphy, the radiographic skeletal survey was determined to have the greatest sensitivity (88.4%) and specificity (99.7%) as an independent imaging modality. In comparison, bone scintigraphy had a sensitivity of 54.8% and a specificity of 99.7%, whereas WB-MRI had a sensitivity of 54.8% and a specificity of 99.7%. The diagnostic sensitivity and specificity for the presence of fractures was increased to 95.9% and the sensitivity was maintained at 99.2% when the skeletal survey was combined with WB-MRI [22]. Both studies report that muscle and subcutaneous edema, as well as other soft tissue abnormalities, are more readily identified on WB-MRI. These findings may be present even in the absence of fractures [21,22].

Fast MRI is an abbreviated examination that uses rapid, motion-tolerant sequences, avoids the need for sedation, and does not involve ionizing radiation. It is known by various names, including shunt series MRI, quick MRI, QuickBrain MRI, rapid MRI, ultra-rapid MRI, ultra-fast MRI, one bang MRI, and vent check MRI. This technique has been used for decades in a variety of clinical settings. The most widely studied indication for fast MRI in pediatrics is in assessing shunted hydrocephalus. More recently, there has been interest in using fast MRI for trauma, particularly AHT.

In a prospective study of 223 children <6 years of age, all of whom underwent both CT head and fast MRI during emergency care for suspected trauma, fast MRI was found to have a sensitivity of 93% and a specificity of 96% for the diagnosis of traumatic brain injury, including skull fracture, intracranial hemorrhage, and parenchymal injury, when compared with CT head [23]. In a separate prospective study of patients with trauma <15 years of age with suspected traumatic brain injury, a total of 73 patients underwent both CT and QuickBrain MRI. QuickBrain MRI had a sensitivity of 95% for detecting clinically important traumatic brain injury [24]. Lastly, in a study investigating the implementation of a brain injury screening MRI for infants at risk of AHT, 98% of the 158 enrolled subjects successfully underwent the MRI brain injury screening examination [25]. The authors concluded that using an MRI brain injury screen instead of a head CT is feasible and could potentially decrease head CT usage by more than 90% in this patient population.

Of note, there is a significant variation in the number of sequences and image detail included in fast MRI protocols across different institutions. To that end, MRI protocols lacking a gradient echo sequence are less sensitive for the detection of blood products. In addition, a fast MRI does not replace the need for a standard brain MRI to ensure complete assessment and documentation of central nervous system (CNS) injuries.

For purposes of this document, FAST examinations are only discussed in the Special Imaging Considerations section.

Initial Imaging Definition

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously wherein each procedure provides unique clinical information to effectively manage the patient's care).

Discussion of Procedures by Variant

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

The imaging evaluation for physical abuse depends on the age of the child. In children <2 years of age without obvious injury, the suspicion for physical abuse may be raised based on discrepancies between the clinical presentation and the caregiver's reported history. When this circumstance is encountered in patients without obvious or suspected injuries concerning for physical child abuse such as bruising, limb deformity, oral injuries, and burns, among others, occult injuries may be diagnosed on radiologic examinations.

In the following discussion, an area of interest can refer to the following: skull, cervical, thoracic, lumbar lumbosacral, complete spine or any combination of spinal levels, chest, ribs, shoulder, humerus, elbow, radius or ulna, wrist, hand, hip, femur, knee, tibia or fibula, ankle or foot.

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

A. Bone scan whole body

There is no relevant literature to support the use of bone scintigraphy or PET imaging as the initial imaging modality when there is concern for physical abuse. Bone scintigraphy, typically performed with Tc-99m methylene diophosphate (MDP), has been used as an adjunct to the radiographic skeletal survey [26-28]. As reported by Conway et al [27], bone scintigraphy has a 25% to 50% increased sensitivity for detection of rib fractures, bowing diaphyseal fractures, periosteal reaction, and even soft tissue injury.

In young children, normal physiologic activity at the growth plates of long bones and throughout the spine, pelvis, and small bones of the hands and feet is also detected on bone scans. This physiologic activity may obscure evidence of metaphyseal fractures, which are characteristic fractures of physical child abuse. For this reason, the sensitivity of bone scintigraphy for detecting CMLs is limited compared with skeletal survey, with a reported sensitivity range of 31% to 67% [26,29].

Skull fractures are also difficult to detect with confidence on bone scintigraphy examinations, as fractures that occur parallel to and in proximity to calvarial sutures, as well as those in the occipital bone (which has complex variations in suture development), may not be distinguishable from normal sutural physiologic tracer activity [30,31]. Bone scintigraphy, therefore, is considered a complementary examination, used in conjunction with radiographic skeletal surveys, to identify radiographically occult fractures, enabling a more complete analysis of fractures in abused children [32,33].

F-18 sodium fluoride (NaF) for PET imaging has a similar distribution in bone as MDP. Both tracers reveal physiologic changes in bone, as increased uptake of radiotracer that occurs due to fracture or other pathology. The concentration of F-18 NaF in the blood is greater than that of MDP, resulting in images with higher spatial resolution, which enables the depiction of subtle fractures that are common in physical child abuse. PET scan has been found to have greater sensitivity (85%) and nearly equivalent specificity (97%) for detection of all but posterior rib fractures in physical child abuse, compared with a baseline skeletal survey, which has a sensitivity of 72% for detection of any fractures and a specificity of 99% for the detection of posterior rib fractures [29].

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent.

Initial imaging.
B. CT abdomen and pelvis with IV contrast

There is no relevant literature to support the use of CT abdomen and pelvis with intravenous (IV) contrast as an initial diagnostic examination in the setting of suspected abusive trauma when visceral injuries are not clinically apparent. Abdominal injury is seen in only 2% to 11.4% of cases of physical child abuse in infants. However, it is the second leading cause of death after head injury. Clinical and laboratory findings, such as abdominal bruising, distention, pain or tenderness, hypoactive bowel sounds, and abnormal liver function tests (>2 times the upper limit of normal), may be used to inform the decision to perform an abdomen and pelvis CT [34,35]. Based on the results of a study of 1,272 abused children between 0 and 5 years of age, there was a sensitivity of 77% and a specificity of 82% for identification of occult intraabdominal trauma. The authors recommended using liver transaminase levels >80 IU/L as an indication for performing a contrast-enhanced abdomen and pelvis CT [36]. Although the study did not separately report the sensitivity and specificity for children up to 24 months of age, it found that abdominal injury was identified in infants 0 to 6 months of age (25.9%), 6 to 12 months of age (13%), and 12 to 24 months of age (24.1%) [36]. When CT abdomen and pelvis is performed, IV contrast should be administered in order to detect and assess the severity of solid organ and vascular injury [37-39].

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
C. CT abdomen and pelvis without and with IV contrast

There is no relevant literature to support the use of CT abdomen and pelvis with IV contrast as an initial diagnostic examination in the setting of suspected abusive trauma when visceral injuries are not clinically apparent. When CT abdomen and pelvis is performed, IV contrast should be administered to detect and assess the severity of solid organ and vascular injury [37-39]. CT without IV contrast may be helpful for diagnosing hollow viscus injury, but it does not reveal findings of solid visceral laceration, perfusion defects, or vascular injury, which are readily diagnosed on CT with IV contrast [39]. There is no existing literature to support the use of CT abdomen and pelvis, both with and without IV contrast, as an initial diagnostic examination in the setting of suspected abusive trauma.

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
D. CT abdomen and pelvis without IV contrast

CT abdomen and pelvis without IV contrast may be helpful for diagnosing hollow viscus injury, but it does not reveal solid visceral laceration, perfusion defects, or vascular injury, which may be more readily diagnosed on CT with IV contrast [39]. There is no existing literature to support the use of CT abdomen and pelvis without IV contrast as an effective diagnostic examination in the setting of suspected abusive trauma.

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
E. CT chest with IV contrast

Identification of rib fractures is of great importance because they are highly suggestive of abuse. The presence of rib fractures increases the probability of abuse to 71% to 98% in infants and

children up to 48 months of age (positive predictive value [PPV] of 66% to 71%), when there is not a recognized accidental explanation for the injury [40,41]. In 2 small retrospective studies of 16 infants over a 4-year period [42] and 12 infants over a 6-year period, chest CT was found to be more sensitive for the detection of early subacute, subacute, and old rib fractures than chest radiography, detecting an additional 18 and 52 additional rib fractures, respectively [42,43]. Additionally, in a retrospective autopsy study paired with postmortem chest radiographs and CT, 3 times as many rib fractures were detected on chest CT compared with chest radiographs (sensitivity 44.9% [95% confidence interval {CI} 31.7-58.9] versus 13.5% [95% CI, 8.1-21.5]; difference 31.4% [95% CI, 23.3-37.8; P < .001]) [44].

Low-dose chest CT without IV contrast has also been shown to have value in the diagnosis of scapular and vertebral fractures [42,45]. Although no specific medical literature in the investigation of other thoracic pathology secondary to abusive trauma, studies of contrast-enhanced chest CT after accidental blunt chest trauma have shown its usefulness in diagnosing pneumothorax, pneumomediastinum, esophageal, and aortic injury [46]. Currently, there is no relevant literature to support the use of IV contrast with chest CT in a child suspected abusive truma when visceral injuries are not clinically apparent.

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
F. CT chest without and with IV contrast

Although no specific medical literature exists in the investigation of other thoracic pathology secondary to abusive trauma, studies of contrast-enhanced chest CT after accidental blunt chest trauma have shown its usefulness in diagnosing pneumothorax, pneumomediastinum, esophageal, and aortic injury [46]. Although low-dose chest CT without IV contrast has been shown to have value in the diagnosis of occult rib, scapular, and vertebral fractures after abusive trauma, there is no relevant literature to support the use of a chest CT without and with IV contrast [42,45].

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
G. CT chest without IV contrast

Identification of rib fractures is of great importance because they are highly suggestive of abuse. The presence of rib fractures increases the probability of abuse to 71% to 98% in infants and children up to 48 months of age (PPV of 66% to 71%) when there is not a recognized accidental explanation for the injury [40,41]. In 2 small retrospective studies of 16 infants over a 4-year period [42] and 12 infants over a 6-year period, chest CT was found to be more sensitive for the detection of early subacute, subacute, and old rib fractures than chest radiography, detecting an additional 18 and 52 additional rib fractures, respectively [42,43]. Additionally, in a retrospective autopsy study paired with postmortem chest radiographs and CT, 3 times as many rib fractures were detected on chest CT compared with chest radiographs (sensitivity 44.9% [95% CI, 31.7-58.9] versus 13.5% [95% CI, 8.1-21.5]; difference 31.4% [95% CI, 23.3-37.8; P < .001]) [44].

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
H. CT head with IV contrast

Multiple studies have demonstrated high rates of occult head injury (19%-37%) in children <2 years of age with concern for physical abuse, even in the absence of neurological symptoms [47-51]. SDH is the most commonly seen intracranial abnormality (multiple, convexity, parafalcine, and posterior fossa) [13,52,53]. Mixed-attenuation SDHs occur more frequently in AHT. SDH with parafalcine extension was the most common intracranial lesion in children <24 months of age, observed in 97 patients suffering AHT (92%), in a study of 105 infants by Bradford et al [52]. Estimating the age of an SDH on head CT in a child with abusive head injury is challenging and often unreliable. Attenuation values of subdural fluid cannot accurately determine the age of blood products in most cases. Therefore, it is recommended that radiologists do not date SDHs in their radiology report. Instead, using descriptive terminology to describe an SDH is more appropriate and recommended [52,54]. Additional craniocerebral injuries that may be seen include subarachnoid hemorrhage, epidural hemorrhage, bridging vein injury, parenchymal ischemic injury, parenchymal laceration, shear injury, and retinal hemorrhages [13,55-60].

CT acquisition is fast and generally does not require sedation for imaging of young children. As such, CT is typically considered the most useful imaging modality in AHT. CT head should be performed with multiplanar reconstructions and 3-D reformations [57,61-64], as these reconstructions increase the sensitivity of CT for the detection of intracranial hemorrhage and fractures. For example, Orman et al [63] reported that head CT with 3-D reconstructions increased the sensitivity and specificity for detection of linear skull fractures in children <2 years of age to 83.9% and 97.1%, respectively, compared with 2-D CT alone (78.2% and 92.8%, respectively; $P < .05$). The presence of skull fracture and/or intracranial injury such as SDH has been shown to be more common in infants suffering AHT (75%) compared with those suffering accidental head trauma (29%), in a study including 205 infants under 24 months of age [65].

There is no relevant literature to support the need for IV contrast administration. If the noncontrast CT scan does not detect significant lesions that require rapid neurosurgical intervention, and the clinical presentation warrants further assessment, an MRI of the head is typically performed [66].

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

I. CT head without and with IV contrast

There is no relevant literature to support the need for IV contrast administration. If the noncontrast CT scan does not detect significant lesions that require rapid neurosurgical intervention, and the clinical presentation warrants further assessment, an MRI of the head is typically performed [66].

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

J. CT head without IV contrast

Multiple studies have demonstrated high rates of occult head injury (19%-37%) in children <2 years of age with concern for physical abuse, even in the absence of neurological symptoms [47-51]. SDH is the most commonly seen intracranial abnormality (multiple, convexity, parafalcine, and posterior fossa) [13,52,53]. Mixed-attenuation SDHs occur more frequently in AHT. SDH with parafalcine extension was the most common intracranial lesion in children <24 months of age, observed in 97 patients suffering AHT (92%) in a study of 105 infants by Bradford et al [52]. Estimating the age of an SDH on head CT in a child with abusive head injury is challenging and

often unreliable. Attenuation values of subdural fluid cannot accurately determine the age of blood products in most cases. Therefore, it is recommended that radiologists do not date SDHs in their radiology report. Instead, using descriptive terminology to describe an SDH is more appropriate and recommended [52,54]. Additional craniocerebral injuries that may be seen include subarachnoid hemorrhage, epidural hemorrhage, bridging vein injury, parenchymal ischemic injury, parenchymal laceration, shear injury, and retinal hemorrhages [13,55-60].

CT acquisition is fast and generally does not require sedation for imaging of young children. As such, CT is typically considered the most useful imaging modality in AHT. CT head should be performed with multiplanar reconstructions and 3-D reformations [57,61-64], as these reconstructions increase the sensitivity of CT for the detection of intracranial hemorrhage and fractures. For example, Orman et al [63] reported that CT with 3-D reconstructions increased the sensitivity and specificity for detection of linear skull fractures in children <2 years of age to 83.9% and 97.1%, respectively, compared with 2-D CT alone (78.2% and 92.8%, respectively; $P < .05$). The presence of skull fracture and/or intracranial injury such as SDH has been shown to be more common in infants suffering AHT (75%) compared with those suffering accidental head trauma (29%) in a study including 205 infants under 24 months of age [65].

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

K. MRI head without and with IV contrast

Occult head injury in children <2 years of age with concern for physical abuse is common. There have been several recent studies assessing the usefulness of MRI as an initial imaging modality in the workup of suspected abuse. Compared with CT, MRI has been shown to have similar detection rates of extraaxial collections (MRI versus CT: 95% versus 87%) and often higher detection rates of intraparenchymal injury (MRI versus CT: 43% versus 11%) [23,66,67]. Furthermore, the use of a black bone MRI sequence shows promising results as an alternative to CT for the detection of skull fractures in AHT, although it is still less accurate than CT in the detection of linear fractures and fractures of aerated bone [68,69]. MRI is useful in characterizing extraaxial hemorrhage, documenting cerebral contusions, lacerations, and other parenchymal brain injuries, as well as defining injured bridging veins [55,56,58,70-72]. Currently, MRI head with and without IV contrast is not used as an initial imaging modality for patients in whom abuse is suspected. MRI is typically reserved for further evaluation of children with abnormal initial CT examinations and in cases of high clinical suspicion with a normal CT head [59,73]. IV contrast material is not routinely administered, although it may increase the accuracy of assessing septations or loculations in extraaxial collections in some patients [7,74].

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

L. MRI head without IV contrast

Occult head injury in children <2 years of age with concern for physical abuse is common. There have been several recent studies assessing the usefulness of MRI as an initial imaging modality in the workup of suspected abuse. Compared with CT, MRI has been shown to have similar detection rates of extraaxial collections (MRI versus CT: 95% versus 87%) and often higher detection rates of intraparenchymal injury (MRI versus CT: 43% versus 11%) [23,66,67]. Furthermore, the use of a black bone MRI sequence shows promising results as an alternative to CT for the detection of skull

fractures in AHT, although it is still less accurate than CT in the detection of linear fractures and fractures of aerated bone [68,69]. MRI is useful in characterizing extraaxial hemorrhage, documenting cerebral contusions, lacerations, and other parenchymal brain injuries, as well as defining injured bridging veins [55,56,58,70-72]. Currently, MRI head without IV contrast is not used as an initial imaging modality for patients in whom abuse is suspected. It is typically reserved for further evaluation of children with abnormal initial CT examinations and in cases of high clinical suspicion with a normal CT head [59,73].

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
M. MRV head without IV contrast

Injury to the bridging veins has been shown to be highly associated with AHT and is considered one of the primary sources of SDHs. It is commonly seen at the junction of the bridging vein and superior sagittal sinus complex [13,55,75]. Choudhary et al [55] found that nearly 70% of children with AHT had some form of venous abnormality. Although much less common than injury to the bridging veins, cerebral sinovenous thrombosis can occur in the setting of AHT. Burtard et al [76] found that in a large population of children with AHT (n = 243), 7% had intracranial venous thrombosis. Currently MRI head along with MR venography (MRV) of the head without IV contrast is not used as an initial modality for patients in whom abuse is suspected. It is typically reserved for further evaluation of children with abnormal initial CT examinations and in cases of high clinical suspicion with a normal CT head [59,73].

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
N. Radiography area of interest

The radiographic appearance of a fracture may raise concern for abusive injury, including CMLs, posteromedial rib fractures, scapular fractures, spinous process fractures, and sternal fractures, which are highly specific for abusive trauma. The presence of multiple and bilateral fractures, fractures of varied states of healing, epiphyseal fractures, vertebral fractures or subluxations, complex skull fractures, and fractures of the digits are moderately specific for physical child abuse in infants and toddlers [5,77-79]. CMLs are highly specific for abusive trauma in infants at high risk of abusive traumatic injury, with a prevalence of 50%, whereas a prevalence of 0% was noted in infants at low risk of abusive traumatic injury [80]. A review of rib fractures in young children, revealed a high prevalence (67%-82%) of rib fractures in abused infants in the first year of life, 29% prevalence in children 12 to 23 months of age, and 28% prevalence of rib fractures in abused children between 24 to 35 months of age [81]. The presence of rib fractures has been shown to be associated with other skeletal injuries in 65% of infants [82]. In the absence of an appropriate history of direct impact, it is believed that very rarely diagnosed fractures of the scapula, spinous process, and sternum are highly suggestive of abusive traumatic injury, although prevalence is not available [83,84].

In addition to identifying a fracture in an area of suspicion in an infant, the presentation and history of the mechanism of injury are important considerations. It is important to consider whether the mechanism of trauma is appropriate for the age or developmental stage of the child and if it is consistently reported, whether the presentation for medical care is timely, and if other injuries are apparent. Inconsistencies in these points and/or diagnosis of moderate- or high-risk

fractures usually warrant further diagnostic workup with a complete radiographic skeletal survey [4].

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
O. Radiography skeletal survey

A radiographic skeletal survey examination is the imaging procedure of choice for the detection of fractures in all children <2 years of age in whom there is a concern for physical child abuse, according to the SPR and the American Academy of Pediatrics (AAP) [4,5,37,85]. A skeletal survey is typically performed for all children <2 years of age with obvious abusive injuries, suspicious injuries, or injuries not consistent with the history provided [37].

The use of radiographic skeletal surveys for suspected physical child abuse varies among infants and young children up to 2 years of age, reported at 85% to 100% in infants and 77% to 90% in 1-year-olds [86]. The yield of radiographic skeletal surveys in infants, as measured by the discovery of occult fractures, is 13% to 26%. Specific injuries are associated with the detection of occult fractures: head injury (23%-34%), skull fracture without intracranial hemorrhage (1%-6%), and all types of fracture (47%) [82,87]. Fractures commonly discovered in infants in whom physical child abuse is suspected and their prevalence is as follows: rib 14%, skull 24%, long bones (shaft 19%, CML 8%, Salter Harris type II 2%), and clavicle 4%. Less common fractures discovered in infants include: hand or foot 2%, scapula 1%, spine 1%, and pelvis 0.2% [82]. After a skeletal survey, or as a supplement to the standard views of a skeletal survey, additional radiographic views of a particular area of interest to confirm or refute the presence of fracture may increase diagnostic confidence in findings of a normal skeletal survey [88]. Similarly, a follow-up skeletal survey in 10 to 14 days might be helpful to evaluate the progression of known injuries or identify any additional occult injuries.

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
P. US abdomen

Abdominal US performed to detect visceral injury or hemoperitoneum after blunt abdominal trauma is not useful in hemodynamically stable children suffering trauma [89]. Grayscale US imaging is not sufficiently sensitive or specific for detecting solid organ injury in children. The sensitivity of grayscale US relative to contrast-enhanced CT for fluid detection ranges from 59% to 79% and for fluid and solid organ injury from 65% to 71% for 2 observers. The specificity for fluid detection is 79%. For fluid and solid organ injury, the specificity ranges from 71% to 79% for 2 observers [20].

For the purpose of this document, we are rating the diagnostic US abdomen procedure performed and read by a radiologist, not the FAST examination. For additional information regarding FAST examination, see the Special Imaging Considerations section.

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
Q. US abdomen with IV contrast

Contrast-enhanced US (CEUS) of the abdomen has become a reliable tool in the initial diagnosis and in follow-up imaging of visceral injuries in children who have suffered low- to moderate-energy blunt abdominal trauma, such as can be seen in physical child abuse. The sensitivity and specificity of CEUS can reach up to 95%, although this was not specifically investigated in children suspected of physical child abuse [90]. A prospective study of 21 children and adolescents between 7 and 18 years of age with known diagnoses of abdominal solid organ injury, underwent conventional grayscale and power Doppler US and CEUS within 48 hours of their injuries. The sensitivity and specificity of CEUS was 85.7% and 98.6%, respectively, compared with 45.2% and 96.4% for conventional US [91].

There is no relevant literature to support the use of CEUS as initial modality in the setting of abusive trauma when visceral injuries are not clinically apparent. A role for CEUS may become established in the future for evaluating clinically occult abdominal visceral injury in children suffering physical child abuse in the future. The benefits of US and CEUS include greater accessibility for unstable patients in the emergency department or intensive care unit and the potential for administering intravascular hemostatic agents when necessary [91,92].

CEUS may also play a role in follow-up of hemodynamically stable children suffering low-energy abdominal trauma as is found in abusive injury [93].

Variant 1: Child. 24 months of age or younger. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

R. US head

In infants, head US is a neuroimaging option because of their open fontanel. Head US is commonly used in determining the presence and extent of germinal matrix hemorrhage, intraventricular hemorrhage, and ventriculomegaly in premature infants, but it has not been studied extensively for other indications—specifically abusive trauma. In a retrospective study of infants <2 years of age who had a US of the head performed for the evaluation of potential intracranial hemorrhage, the authors found the overall sensitivity and specificity for detection of hemorrhage to be 67% and 99%, respectively. They concluded that the sensitivity of head US was inadequate to justify its use as a screening tool for the detection of intracranial hemorrhage in young infants [94]. More recently, a retrospective study analyzed head US in infants (<12 months) after minor head trauma in its ability to detect skull fracture and/or intracranial hemorrhage. Although the authors found a higher sensitivity of 93% and specificity of 98%, the majority of patients did not have cross-sectional imaging to corroborate their results. They primarily relied on clinical outcomes as to whether the head US results were valid [95].

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

The imaging evaluation for physical abuse depends on the age of the child. Children >24 months of age are often able to verbalize the area(s) of injury or pain; discrepancies between their reported injury, clinical presentation, and caregiver reports of pertinent history may raise concerns for physical abuse. When a child can verbalize or otherwise indicate a site of injury, initial imaging should focus on the areas of clinical concern.

In the following discussion, the area of interest can refer to the following: skull, cervical, thoracic,

lumbar lumbosacral, complete spine or any combination of spinal levels, chest, ribs, shoulder, humerus, elbow, radius or ulna, wrist, hand, hip, femur, knee, tibia or fibula, ankle or foot.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
A. Bone scan whole body

Bone scan is an adjunctive examination for detecting bone injuries. Although some authors describe usefulness of bone scan for diagnosing additional bone and soft tissue injury, it is not the first imaging modality for this indication (see Variant 1 in the previous section). There is no relevant literature to support the use of bone scintigraphy as the initial imaging modality if concerned for physical abuse in a child >24 months of age.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
B. CT abdomen and pelvis with IV contrast

In older children, unless developmentally delayed, in which the physical examination is often more reliable, there is no relevant literature to support the use of CT abdomen and pelvis with IV contrast in the initial evaluation of abdominal trauma in a patient without clinically apparent visceral injury in a child >24 months of age.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
C. CT abdomen and pelvis without and with IV contrast

In older children, unless developmentally delayed, in which the physical examination is often more reliable, there is no relevant literature to support the use of CT abdomen and pelvis without and with IV contrast in the initial evaluation of abdominal trauma in a patient without clinically apparent visceral injury in a child >24 months of age.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
D. CT abdomen and pelvis without IV contrast

In older children, unless developmentally delayed, in which the physical examination is often more reliable, there is no relevant literature to support the use of CT abdomen and pelvis without IV contrast in the initial evaluation of abdominal trauma in a patient without clinically apparent visceral injury in a child >24 months of age.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
E. CT chest with IV contrast

In older children, unless developmentally delayed, in which the physical examination is often more reliable, there is no relevant literature to support the use of CT chest with IV contrast in the initial evaluation of rib fractures.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent.

Initial imaging.
F. CT chest without and with IV contrast

In older children, unless developmentally delayed, in which the physical examination is often more reliable, there is no relevant literature to support the use of CT chest without and with IV contrast in the initial evaluation of rib fractures.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
G. CT chest without IV contrast

In older children, unless developmentally delayed, in which the physical examination is often more reliable, there is no relevant literature to support the use of CT chest without IV contrast in the initial evaluation of rib fractures.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
H. CT head with IV contrast

In older children, unless developmentally delayed, in which the neurological examination is often more reliable, there is no relevant literature to support the use of CT head with IV contrast in the initial evaluation of children with concern for abuse but no neurological symptoms or clinical concern for neurologic injury.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
I. CT head without and with IV contrast

In older children, unless developmentally delayed, in which the neurological examination is often more reliable, there is no relevant literature to support the use of CT head without and with IV contrast in the initial evaluation of children with concern for abuse but no neurological symptoms or clinical concern for neurologic injury.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
J. CT head without IV contrast

In older children, unless developmentally delayed, in which the neurological examination is often more reliable, there is no relevant literature to support the use of CT head without IV contrast in the initial evaluation of children with concern for abuse but no neurological symptoms or clinical concern for neurologic injury.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
K. MRI head without and with IV contrast

In older children, in which the neurological examination is often more reliable, there is no relevant literature to support the use of MRI head without and with IV contrast in the initial evaluation of children with concern for abuse but no neurological symptoms or clinical concern for neurologic injury.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

L. MRI head without IV contrast

In older children, in which the neurological examination is often more reliable, there is no relevant literature to support the use of MRI head without IV contrast in the initial evaluation of children with concern for abuse but no neurological symptoms or clinical concern for neurologic injury.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

M. MRV head without IV contrast

In older children, in which the neurological examination is often more reliable, there is no relevant literature to support the use of MRV head without IV contrast in the initial evaluation of children with concern for abuse but no neurological symptoms or clinical concern for neurologic injury.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

N. Radiography area of interest

Children >24 months of age are typically able to comply with a physical examination and can verbalize or otherwise indicate the site of injury or pain. Therefore, if a child can communicate, and when appropriate, a directed radiographic examination of a specific area(s) of interest can be performed rather than performing a complete skeletal survey [85]. Additionally, a strong inverse relationship between the presence of numerous and/or occult fractures versus isolated fractures due to abusive trauma is found related to the age of the child. Numerous investigators and epidemiological data report marked disparities in the incidence of positive skeletal surveys based age. For example, Belfer et al reported a 6% positive skeletal survey in children >24 months of age of age, compared with a 31% positive rate in younger children [40,41,96].

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.

O. Radiography skeletal survey

A radiographic skeletal survey examination may not be more useful than a radiographic examination of a specific area of interest in children >24 months of age. However, a skeletal survey may be helpful when a child is unable to communicate a specific site of injury, he or she has multiple unexplained fractures, or occult fractures are discovered, thereby increasing the concern for physical child abuse [85,97]. The type and number of fractures resulting from abusive trauma vary by age group, with children >24 months of age of age having fewer fractures overall and more often experiencing isolated fractures [40]. A review of data from 32 articles published between 1990 and 2016, which examined the usefulness of radiographic skeletal surveys in 64,983 children <60 months of age, concluded that standardization and uniform implementation of skeletal surveys is warranted. The review also found that occult fractures were detected in up to 44% of children ≥24 months with abusive head injury [86]. Another study of 96 children at a single institution reported that skeletal surveys were positive in 31% of children <24 months of age, but positive in only 6% of children >24 months of age of age [85]. A recent retrospective review of 325 skeletal surveys in children >24 months of age found that occult fractures were diagnosed in only

6 examinations (1.8%) [98].

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
P. US abdomen

There is no relevant literature to support the role of US abdomen as the initial imaging modality in suspected cases of physical abuse in children >24 months of age.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
Q. US abdomen with IV contrast

There is no relevant literature to support the role of US abdomen with IV contrast as the initial imaging modality in suspected cases of physical abuse in children >24 months of age.

Variant 2: Child. Greater than 24 months of age. Concern for physical abuse based on clinical presentation or history. Neurological, skeletal, or visceral injuries not clinically apparent. Initial imaging.
R. US head

In a child >24 months of age, there is no role for head US as a neuroimaging modality because their fontanelles are closed.

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

CNS injuries may occur in children with AHT from various mechanisms. Imaging can be used to detect these injuries, to follow their evolution, and to evaluate the development of secondary complications. AHT is among the leading causes of child maltreatment fatalities and early identification through imaging may be lifesaving.

In the following discussion, the area of interest can refer to the following: skull, cervical, thoracic, lumbar, lumbosacral, complete spine, or any combination of spinal levels.

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.
A. Bone scan whole body

Bone scan is an adjunctive examination for detecting bone injuries. Although some authors describe usefulness of bone scan for the diagnosis of soft tissue injury, it is not the first imaging modality for this indication [26,28] (see Variant 1 previously discussed). There is no relevant literature to support the use of bone scintigraphy as the initial imaging modality with clinical suspicion for CNS injury.

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

B. CT cervical spine with IV contrast

Victims of AHT often suffer spinal injury, such as ligamentous injury, trauma to the paraspinal soft tissues, extraaxial hemorrhage, and/or spinal cord injury [82,99-102]. Spinal fractures are relatively uncommon in physical abuse [102-105]. When they do occur, they are typically in the form of compression fractures. Most cervical spine injuries in abused infants are ligamentous [99,100], for which CT cervical spine with IV contrast has little usefulness.

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

C. CT cervical spine without and with IV contrast

There is no relevant literature to support the use of CT cervical spine with and without IV contrast in the initial evaluation of children with a clinical suspicion for CNS injury.

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

D. CT cervical spine without IV contrast

Victims of AHT often suffer spinal injury, such as ligamentous injury, trauma to the paraspinal soft tissues, extraaxial hemorrhage, and/or spinal cord injury [82,99-102]. Spinal fractures are relatively uncommon in physical abuse [102-105]. When they occur, they are typically in the form of compression fractures for which spine imaging may be helpful. Most cervical spine injuries in abused infants are ligamentous [99,100], for which CT cervical spine without IV contrast has little usefulness.

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

E. CT head with IV contrast

There is no relevant literature to support the need for IV contrast administration. If the noncontrast CT scan does not detect significant lesions that require rapid neurosurgical intervention, and the clinical presentation warrants further assessment, an MRI of the head is typically performed [66].

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

F. CT head without and with IV contrast

There is no relevant literature to support the need for IV contrast administration. If the noncontrast CT scan does not detect significant lesions that require rapid neurosurgical intervention, and the clinical presentation warrants further assessment, an MRI of the head is typically performed [66].

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

G. CT head without IV contrast

Neuroimaging is typically performed in children in whom AHT is suspected [37]. The goal in the acute setting is the rapid detection of treatable conditions. SDH is the most commonly seen intracranial abnormality (multiple, convexity, parafalcine, and posterior fossa) [13,52,53]. Mixed-attenuation SDHs occur more frequently in AHT. SDH with parafalcine extension was the most common intracranial lesion seen in children <24 months of age, observed in 97 patients suffering AHT (92%), in a study of 105 infants by Bradford et al [52]. Estimating the age of an SDH on head CT in a child with abusive head injury is challenging and often unreliable. Attenuation values of subdural fluid cannot accurately determine the age of blood products in most cases. Therefore, it is recommended that radiologists do not date SDHs in their radiology report. Instead, using descriptive terminology to describe an SDH is more appropriate and recommended [52,54]. Additional craniocerebral injuries that may be seen include subarachnoid hemorrhage, epidural hemorrhage, bridging vein injury, parenchymal ischemic injury, parenchymal laceration, shear injury, and retinal hemorrhages [13,55-60].

CT acquisition is fast, and generally does not require sedation for imaging of young children. As such, CT is typically considered the most useful imaging modality in AHT. CT head should be performed with multiplanar reconstructions and 3-D reformations [57,61-64], as these reconstructions increase the sensitivity of CT for the detection of intracranial hemorrhage and fractures. The presence of skull fracture and/or intracranial injury such as SDH has been shown to be more common in infants suffering AHT (75%) compared with those suffering accidental head trauma (29%), in a study including 205 infants under 24 months of age [65].

There is no relevant literature to support the need for IV contrast administration. If the CT scan does not detect significant lesions that require rapid neurosurgical intervention, and the clinical presentation warrants further assessment, an MRI of the head is typically performed.

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

H. MRI cervical spine without and with IV contrast

Victims of AHT often suffer spinal injury, such as ligamentous injury, trauma to the paraspinal soft tissues, extraaxial hemorrhage, and/or spinal cord injury [82,99-102]. Most cervical spine injuries detected by MRI are ligamentous [99-102]. Cervical spine injury, particularly at the craniocervical junction, is associated with bilateral hypoxic-ischemic injury [100]. However, spinal cord injury detected on MRI is rare. There is no relevant literature to support the need for IV contrast administration.

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

I. MRI cervical spine without IV contrast

Victims of AHT often suffer spinal injury, such as ligamentous injury, trauma to the paraspinal soft tissues, extraaxial hemorrhage, and/or spinal cord injury [82,99-102]. Most cervical spine injuries detected by MRI are ligamentous [99-102]. Cervical spine injury, particularly at the craniocervical junction, is associated with bilateral hypoxic-ischemic injury [100]. However, spinal cord injury

detected on MRI is rare. MRI of the spine without IV contrast is typically performed when the brain MRI is obtained and should be performed as part of the complete spine MRI. There is no added usefulness to performing the study with IV contrast. An MRI of the spine without IV contrast is typically performed when a brain MRI is obtained. Based on recent literature available, many pediatric and radiology guidelines recommend entire spine imaging in the context of AHT, particularly in cases with neurological symptoms or when the mechanism of injury suggests potential for spinal trauma [106]. These guidelines recognize that cervical spine imaging alone may be insufficient to rule out all potential injuries in these cases.

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

J. MRI complete spine without and with IV contrast

A frequent spinal finding in AHT is the presence of spinal SDH. MRI of the entire spine may show thoracolumbar SDH that would be missed by imaging the cervical spine only. In a recent retrospective study of 256 children <3 years of age who underwent skeletal survey and head MRI for suspected child abuse, the authors found that 23% of examinations showed injuries localized to the thoracolumbar spine. Specifically, 23 of 34 spinal SDHs were isolated to the thoracolumbar regions [107]. In a separate study assessing children <5 years of age evaluated for AHT (median age of 4 months), children with imaging of the entire spine were more likely to have an SDH as well as epidural hemorrhage compared with those with imaging of the cervical spine alone [102]. The authors found that spinal SDH was associated with a combination of retinal hemorrhages, noncontact head injuries, and a diagnosis of AHT. In a retrospective study, which investigated the presence of spinal SDH on spinal MRI in infants, spinal canal SDH was found in 62 of 67 (93%) of those with AHT and in only 1 of 70 (<1%) infants suffering accidental head trauma [100]. Although spinal SDHs rarely result in cord compression or alter clinical management, they do impact the determination of whether injuries are a result of abuse. SDHs of the spine are highly specific for AHT [99,100,102]. As such, MRI of the complete spine without IV contrast is typically considered, particularly for cases where the distinction between abusive and accidental trauma is not clear. There is no added usefulness to perform the study with IV contrast. MRI of the spine without IV contrast is typically performed when obtaining the brain MRI.

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

K. MRI complete spine without IV contrast

A frequent spinal finding in AHT is the presence of spinal SDH. MRI of the entire spine may show thoracolumbar SDH that would be missed by imaging the cervical spine only. In a recent retrospective study of 256 children <3 years of age who underwent skeletal survey and head MRI for suspected child abuse, the authors found 23% of examinations showed injuries localized to the thoracolumbar spine. Specifically, 23 of 34 spinal SDHs were isolated to the thoracolumbar regions [107]. In a separate study assessing children <5 years of age evaluated for AHT (median age of 4 months), children with imaging of the entire spine were more likely to have an SDH as well as epidural hemorrhage compared with those with imaging of the cervical spine alone [102]. The authors found that spinal SDH was associated with a combination of retinal hemorrhages, noncontact head injuries, and a diagnosis of AHT. In a retrospective study, which investigated the

presence of spinal SDH on spinal MRI in infants, spinal canal SDH was found in 62 of 67 (93%) of those with AHT and in only 1 of 70 (<1%) infants suffering accidental head trauma [100]. Although spinal SDHs rarely result in cord compression or alter clinical management, they do impact the determination of whether injuries are a result of abuse. SDHs of the spine are highly specific for AHT [99,100,102]. As such, MRI of the complete spine without IV contrast is typically considered, particularly for cases where the distinction between abusive and accidental trauma is not clear. There is no added usefulness to perform the study with IV contrast. MRI of the spine without IV contrast is typically performed at the time of obtaining the brain MRI.

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

L. MRI head without and with IV contrast

There have been several recent studies assessing the usefulness of MRI in the context of trauma evaluation. Compared with CT, MRI has been shown to have similar detection rates of extraaxial collections (MRI versus CT: 95% versus 87%) and often higher detection rates of parenchymal injury (MRI versus CT: 43% versus 11%) [23,66,67]. Furthermore, supplementing the MRI protocol with a black bone MRI sequence may provide high sensitivity and specificity for the detection of skull fractures in AHT in certain instances compared with routine or conventional MRI [68,69]. MRI is useful in characterizing extraaxial hemorrhage, documenting cerebral contusions, lacerations, and other parenchymal brain injuries, as well as defining injured bridging veins [55,56,58,70-72].

Presently, MRI head is not used as a screening examination in children in whom abuse is clinically suspected; it is typically reserved for further evaluation of all abnormal initial examinations and cases of high clinical suspicion with a normal CT head [59,73]. Additional diagnostic information will be found on MRI over CT in approximately 25% of patients [59,73], and MRI head can also contribute to prognosis. In a child with an abnormal CT, additional assessment with MRI is useful to further assess the extent of posttraumatic injury. IV contrast material is not routinely administered, although it may increase the accuracy of assessing septations or loculations in extraaxial collections in some patients [7,74].

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

M. MRI head without IV contrast

There have been several recent studies assessing the usefulness of MRI in the context of trauma evaluation. Compared with CT, MRI has been shown to have similar detection rates of extraaxial collections (MRI versus CT: 95% versus 87%) and often higher detection rates of parenchymal injury (MRI versus CT: 43% versus 11%) [23,66,67]. Furthermore, supplementing the MRI protocol with a black bone MRI sequence may provide high sensitivity and specificity for the detection of skull fractures in AHT in certain instances compared with routine or conventional MRI [68,69]. MRI is useful in characterizing extraaxial hemorrhage, documenting cerebral contusions, lacerations, and other parenchymal brain injuries, as well as defining injured bridging veins [55,56,58,70-72].

Presently, MRI head is not used as a screening examination in children in whom abuse is clinically suspected; it is typically reserved for further evaluation of all abnormal initial examinations and

cases of high clinical suspicion with a normal CT head [59,73]. Additional diagnostic information will be found on MRI over CT in approximately 25% of patients [59,73], and MRI head can also contribute to prognosis. In a child with an abnormal CT, additional assessment with MRI is useful to further assess the extent of posttraumatic injury. IV contrast material is not routinely administered, although it may increase the accuracy of assessing septations or loculations in extraaxial collections in some patients [7,74].

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

N. MRV head without IV contrast

Injury to the bridging veins has been shown to be highly associated with AHT and is considered one of the primary sources of SDHs. It is commonly seen at the junction of the bridging vein and superior sagittal sinus complex [13,55,75]. Choudhary et al [55] found that nearly 70% of children with AHT had some form of venous abnormality. Although much less common than injury to the bridging veins, cerebral sinovenous thrombosis can occur in the setting of AHT. Burtard et al [76] found that in a large population of children with AHT (n = 243), 7% had intracranial venous thrombosis.

Presently, MRI with MRV head without IV contrast is not used as a screening examination in children in whom abuse is clinically suspected. It is typically reserved for further evaluation of all abnormal initial CT examinations and cases of high clinical suspicion with a normal CT head [59,73].

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

O. Radiography area of interest

For infants with skull fractures not associated with intracranial hemorrhage, the radiographic skeletal survey reveals additional noncalvarial fractures in only 1% to 6% of cases, but the presence of additional fractures on radiographic skeletal surveys increases to 23% to 34% in infants with more significant head injury. The use of skull radiographs are best used within a skeletal survey [82,86,108].

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

P. Radiography skeletal survey

A skeletal survey is typically performed for all children <2 years of age with obvious abusive injuries, suspicious injuries, or injuries not consistent with the history provided [37]. Cutaneous injuries, in particular bruises, are the most common type of physical abuse injury seen in infants and children of any age and are considered to be highly indicative for abusive injury in premobile infants [109]. The distribution of bruises differs with age, showing a distinctly different pattern in nonambulatory infants than in children who are able to walk [110].

The use of radiographic skeletal surveys for suspected physical child abuse varies in infants and

young children up to 2 years of age, reported between 85% to 100% in infants and 77% to 90% in 1-year-olds [86]. The yield of radiographic skeletal surveys in infants, as measured by the discovery of occult fractures, is 13% to 26%. Specific injuries are associated with detection of occult fractures: head injury (23%-34%), skull fracture without intracranial hemorrhage (1%-6%), and all types of fracture (47%) [82,87]. Fractures commonly discovered in infants in whom physical child abuse is suspected and their prevalence is as follows: rib (14%), skull (24%), long bones (shaft 19%), CML (8%), Salter Harris type II (2%), and clavicle (4%). Less common fractures discovered in infants include hand or foot (2%), scapula (1%), spine (1%), and pelvis (0.2%) [82].

Variant 3: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs, symptoms, or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

Q. US head

In infants, head US is a neuroimaging option because of their open fontanel. Head US is commonly used in determining the presence and extent of germinal matrix hemorrhage, intraventricular hemorrhage, and ventriculomegaly in premature infants, but it has not been studied extensively for other indications—specifically trauma. In a retrospective study of infants <2 years of age who had a US of the head performed for the evaluation of potential intracranial hemorrhage, the authors found the overall sensitivity and specificity for detection of hemorrhage to be 67% and 99%, respectively. They concluded that the sensitivity of head US was inadequate to justify its use as a screening tool for the detection of intracranial hemorrhage in young infants [94]. More recently, a retrospective study analyzed head US in infants (<12 months) after minor head trauma in the ability to detect skull fracture and/or intracranial hemorrhage. Although they had a higher sensitivity of 93% and specificity of 98%, the majority of patients did not have cross-sectional imaging to corroborate their results. They primarily relied on clinical outcome as to whether the head US results were valid [95].

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

CNS injuries may occur in children with AHT from various mechanisms. Imaging can be used to detect these injuries, to follow their evolution, and to evaluate the development of secondary complications. AHT is among the leading causes of child maltreatment fatalities and early identification through imaging may be lifesaving.

In the following discussion, the area of interest can refer to the following: skull, cervical, thoracic, lumbar, lumbosacral, complete spine, or any combination of spinal levels.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

A. Bone scan whole body

Bone scan is an adjunctive examination for detecting bone injuries. Although some authors describe the usefulness of bone scans for diagnosing soft tissue injuries, it is not the first imaging modality for this indication [26,28] (see Variant 1 previously discussed). There is no relevant

literature to support the use of bone scintigraphy as the initial imaging modality when there is concern for physical abuse.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.
B. CT cervical spine with IV contrast

Victims of AHT often suffer spinal injury, such as ligamentous injury, trauma to the paraspinal soft tissues, extraaxial hemorrhage, and/or spinal cord injury [82,99-102]. Spinal fractures are relatively uncommon in physical abuse [102-105]. When they do occur, they are typically in the form of compression fractures. Most cervical spine injuries in abused infants are ligamentous [99,100], for which CT cervical spine with IV contrast has little usefulness.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.
C. CT cervical spine without and with IV contrast

Victims of AHT often suffer spinal injury, such as ligamentous injury, trauma to the paraspinal soft tissues, extraaxial hemorrhage, and/or spinal cord injury [82,99-102]. Spinal fractures are relatively uncommon in physical abuse [102-105]. When they do occur, they are typically in the form of compression fractures. Most cervical spine injuries in abused infants are ligamentous [99,100], for which CT cervical spine without and with IV contrast has little usefulness.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.
D. CT cervical spine without IV contrast

Victims of AHT often suffer spinal injury, such as ligamentous injury, trauma to the paraspinal soft tissues, extraaxial hemorrhage, and/or spinal cord injury [82,99-102]. Spinal fractures are relatively uncommon in physical abuse [102-105]. When they occur, they are typically in the form of compression fractures, for which spine imaging may be helpful. Most cervical spine injuries in abused infants are ligamentous [99,100], for which CT cervical spine without IV contrast has little usefulness.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.
E. CT head with IV contrast

There is no relevant literature to support the need for IV contrast administration. If the CT head without IV contrast does not reveal significant lesions that require rapid neurosurgical intervention, and the clinical presentation warrants further assessment, an MRI of the head is typically performed.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or

symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

F. CT head without and with IV contrast

There is no relevant literature to support the need for CT head both with and without IV contrast administration in this clinical scenario. If the noncontrast CT head does not reveal significant lesions that require rapid neurosurgical intervention, and the clinical presentation warrants further assessment, an MRI of the head is typically performed.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

G. CT head without IV contrast

Neuroimaging is typically performed in children in whom AHT is suspected [37]. The goal of imaging in the acute setting is the rapid detection of treatable conditions. In children >24 months of age of age, the type of intracranial injury typically differs from those found in children up to 24 months of age, with cerebral contusions and edema more common than SDHs [13,52,53]. Estimating the age of an SDH on head CT in a child with abusive head injury is challenging and often unreliable. Attenuation values of subdural fluid cannot accurately determine the age of blood products in most cases. Therefore, it is recommended that radiologists do not date SDHs in their radiology report. Instead, using descriptive terminology to describe an SDH is more appropriate and recommended [52,54]. Additional craniocerebral injuries that may be seen include subarachnoid hemorrhage, epidural hemorrhage, bridging vein injury, parenchymal ischemic injury, parenchymal laceration, shear injury, and retinal hemorrhages [13,55-60].

CT acquisition is fast and generally does not require sedation for imaging of young children. As such, CT head without IV contrast is typically considered the most useful imaging modality in AHT. CT head should be performed with multiplanar reconstructions and 3-D reformations [57,61-64], as these reconstructions increase the sensitivity of CT for the detection of intracranial hemorrhage and fractures. The presence of a skull fracture and/or intracranial injury has been shown to be not significantly different in those suffering AHT (55%) compared with those suffering accidental head trauma (45%) in a study including 47 children >24 months of age of age [65].

There is no relevant literature to support the need for IV contrast administration. If the CT head without IV contrast does not reveal significant lesions that require rapid neurosurgical intervention, and the clinical presentation warrants further assessment, an MRI of the head is typically performed.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

H. MRI cervical spine without and with IV contrast

There is limited relevant literature comparing the pattern of injuries seen on MRI in abusive spinal trauma for children >24 months of age of age compared with those <24 months of age. MRI of the cervical spine is typically performed at the time of obtaining the brain MRI. There is no added usefulness to performing the study with IV contrast.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

I. MRI cervical spine without IV contrast

There is limited relevant literature comparing the pattern of injuries seen on MRI in abusive spinal trauma for children >24 months of age of age compared with those <24 months of age.

Victims of AHT often suffer spinal injury, such as ligamentous injury, trauma to the paraspinal soft tissues, extraaxial hemorrhage, and/or spinal cord injury [82,99-102]. Most cervical spine injuries detected by MRI are ligamentous [99-102]. Cervical spine injury, particularly at the craniocervical junction, is associated with bilateral hypoxic-ischemic injury [100]. However, spinal cord injury detected on MRI is rare. MRI of the cervical spine without IV contrast is typically performed at the time of obtaining the brain MRI and should be performed as part of the complete spine MRI. There is no added usefulness to performing the study with IV contrast. An MRI of the spine without IV contrast is typically performed when a brain MRI is obtained. Based on recent literature available, many pediatric and radiology guidelines recommend entire spine imaging in the context of AHT, particularly in cases with neurological symptoms or when the mechanism of injury suggests potential for spinal trauma [106]. These guidelines recognize that cervical spine imaging alone may be insufficient to rule out all potential injuries in these cases.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

J. MRI complete spine without and with IV contrast

There is limited relevant literature comparing the pattern of injuries seen on MRI in abusive spinal trauma for children >24 months of age of age compared with those <24 months of age.

A frequent spinal finding in AHT is the presence of spinal SDH. MRI of the entire spine may show thoracolumbar SDH that would be missed by imaging the cervical spine only. In a recent retrospective study of 256 children <3 years of age who underwent skeletal survey and head MRI for suspected child abuse, the authors found that 23% of examinations showed injuries localized to the thoracolumbar spine. Specifically, 23 of 34 spinal SDHs were isolated to the thoracolumbar regions [107]. In a separate study assessing children <5 years of age evaluated for AHT (median age of 4 months), children with imaging of the entire spine were more likely to have an SDH as well as epidural hemorrhage compared with those with imaging of the cervical spine alone [102]. The authors found that spinal SDH was associated with a combination of retinal hemorrhages, noncontact head injuries, and a diagnosis of AHT. In a retrospective study, which investigated the presence of spinal SDH on spinal MRI in infants, spinal canal SDH was found in 62 of 67 (93%) of those with AHT and in only 1 of 70 (<1%) infants suffering accidental head trauma [100]. Although spinal SDHs rarely result in cord compression or alter clinical management, they do impact the determination of whether injuries are a result of abuse. SDHs of the spine are highly specific for AHT [99,100,102]. As such, MRI of the complete spine without IV contrast is typically considered, particularly for cases in which the distinction between abusive and accidental trauma is not clear. There is no added usefulness to perform the study with IV contrast. MRI of the spine without IV contrast is typically performed at the time of obtaining the brain MRI.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

K. MRI complete spine without IV contrast

There is limited relevant literature comparing the pattern of injuries seen on MRI in abusive spinal trauma for children >24 months of age of age compared with those <24 months of age.

A frequent spinal finding in AHT is the presence of a spinal SDH. MRI of the entire spine may show thoracolumbar SDH that would be missed by imaging the cervical spine only. In a recent retrospective study of 256 children <3 years of age who underwent skeletal survey and head MRI for suspected child abuse, the authors found that 23% of examinations showed injuries localized to the thoracolumbar spine. Specifically, 23 of 34 spinal SDHs were isolated to the thoracolumbar regions [107]. In a separate study assessing children <5 years of age evaluated for AHT (median age of 4 months), children with imaging of the entire spine were more likely to have an SDH as well as epidural hemorrhage compared with those with imaging of the cervical spine alone [102]. The authors found that spinal subdural blood was associated with a combination of retinal hemorrhages, noncontact head injuries, and a diagnosis of AHT. In a retrospective study, which investigated the presence of spinal subdural blood on spinal MRI in infants, spinal canal subdural blood was found in 62 of 67 (93%) of those with AHT and in only 1 of 70 (<1%) infants suffering accidental head trauma [100]. Although spinal SDHs rarely result in cord compression or alter clinical management, they do impact the determination of whether injuries are a result of abuse. SDHs of the spine are highly specific for AHT [99,100,102]. As such, MRI of the complete spine without IV contrast is typically considered, particularly for cases in which the distinction between abusive and accidental trauma is not clear. There is no added usefulness to performing the study with IV contrast. MRI of the spine without IV contrast is typically performed at the time of obtaining the brain MRI.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.

L. MRI head without and with IV contrast

There is limited relevant literature comparing the pattern of injuries seen on MRI in AHT for children >24 months of age compared with those <24 months of age.

There have been several recent studies assessing the usefulness of MRI in the context of trauma evaluation. Compared with CT, MRI has been shown to have similar detection rates of extraaxial collections (MRI versus CT: 95% versus 87%) and often higher detection rates of parenchymal injury (MRI versus CT: 43% versus 11%) [23,66,67]. Furthermore, the use of a black bone MRI sequence may provide high sensitivity and specificity for the detection of skull fractures in AHT in certain instances compared with conventional MRI alone [68,69]. MRI is useful in characterizing extraaxial blood, documenting cerebral contusions, lacerations, and other parenchymal brain injuries, as well as defining injured bridging veins [55,56,58,70-72].

Presently, an MRI head is not used as an initial examination in children in whom abuse is clinically suspected; it is typically reserved for further evaluation of all abnormal initial examinations and

cases of high clinical suspicion with a normal CT head [59,73]. Additional diagnostic information will be found on MRI over CT in approximately 25% of patients [59,73], and MRI can also contribute to the prognosis. In a child with an abnormal CT, additional assessment with MRI is useful to further assess the extent of traumatic injury. IV contrast material is not routinely administered, although it may increase the accuracy of assessing septations or loculations in extraaxial collections in some patients [7,74].

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.
M. MRI head without IV contrast

There is limited relevant literature comparing the pattern of injuries seen on MRI in AHT for children >24 months of age compared with those <24 months of age.

There have been several recent studies assessing the usefulness of MRI in the context of trauma evaluation. Compared with CT, MRI has been shown to have similar detection rates of extraaxial collections (MRI versus CT: 95% versus 87%) and often higher detection rates of intraparenchymal injury (MRI versus CT: 43% versus 11%) [23,66,67]. Furthermore, supplementing the MRI protocol with a black bone MRI sequence may provide high sensitivity and specificity for the detection of skull fractures in AHT in certain instances compared with routine and conventional MRI [68,69]. MRI is useful in characterizing extraaxial blood, documenting cerebral contusions, lacerations, and other parenchymal brain injuries, as well as defining injured bridging veins [55,56,58,70-72].

Presently, MRI head is not used as a screening examination in children in whom abuse is clinically suspected; it is typically reserved for further evaluation of abnormal initial CT examinations and cases of high clinical suspicion with a normal CT head [59,73]. Additional diagnostic information will be found on MRI over CT in approximately 25% of patients [59,73] and MRI can also contribute to the prognosis. In a child with an abnormal CT, additional assessment with MRI head without IV contrast is useful to further assess the extent of traumatic injury.

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.
N. MRV head without IV contrast

Presently, MRI head and MRV head without IV contrast is not used as a screening examination in children in whom abuse is clinically suspected, it is typically reserved for further evaluation of abnormal initial CT examinations and cases of high clinical suspicion with a normal CT head [59,73].

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.
O. Radiography area of interest

Children >24 months of age are typically able to comply with a physical examination and can verbalize or otherwise indicate the site of injury or pain. Therefore, if a child can communicate, and when appropriate, a directed radiographic examination of a specific area(s) of interest can be

performed rather than performing a complete skeletal survey [85]. The use of skull radiographs are best used within a skeletal survey [82,86,108].

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.
P. Radiography skeletal survey

Cutaneous injuries, particularly bruises, are a common type of physical abusive injury [109]. The distribution of bruises varies with age, showing a distinctly different pattern in nonambulatory infants compared with children who are able to walk [110]. The yield of a complete radiographic skeletal survey is significantly diminished in children >24 months of age, unless they are not able to communicate effectively with examining medical personnel or have multiple unexplained or occult fractures [96,97].

Variant 4: Child. Greater than 24 months of age of age. One or more physical examinations or clinical findings suspicious for CNS injury due to physical abuse: neurologic signs or symptoms or other injuries (scalp bruises, hematoma, or skin injury to the head, neck, or spine). Initial imaging.
Q. US head

In a child, >24 months of age, there is no role for head US as a neuroimaging modality because their fontanelles are closed.

Variant 5: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.

The most serious injuries generally guide the choice of the initial imaging examination selection when numerous suspicious injuries are found on physical examination. A 2020 study of the United States National Trauma Databank reviewed 678,503 children admitted to the hospital with traumatic injury and determined that 19,149 (3%) children were victims of physical child abuse. The study also found that 13,529 (71%) of patients admitted to the hospital and 63% of fatalities occurred in children <1 year of age [111]. Further, the investigators determined that victims of physical child abuse frequently presented with multiple injuries. Specifically, children with traumatic brain injury often had thoracic injuries (57%) and solid organ injuries (38%), whereas children with coexisting rib and extremity fractures also suffered solid organ injuries (36%) [111]. In this study and others, after neurological injuries, skin abnormalities including bruises, contusions, superficial wounds, and burns were found to be the most common injuries in infants suffering physical child abuse. These findings may warrant laboratory investigation to guide further radiological examination [39].

In the following discussion, the area of interest can refer to the following:chest, abdomen and pelvis.

.

Note that children 24 months or younger with suspected physical abuse due to potential visceral injury may also have neurologic injuries. Based on their signs, symptoms, or clinical examination, refer to Variants 1 and 3 for guidance on neuroimaging.

Variant 5: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries

(bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
A. Bone scan whole body

There is no relevant literature to support the use of bone scan as the initial imaging modality in abused children with suspected visceral injury. In young children, nuclear medicine and molecular imaging studies can increase the sensitivity for the detection of fractures, periosteal reaction, and tissue injury associated with orthopedic findings, but not visceral findings [26-28].

Variant 5: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
B. CT abdomen and pelvis with IV contrast

Abdominal injury is seen in only 2% to 11.4% of cases of physical child abuse in infants but it is the second leading cause of death after head injury. Clinical and laboratory findings, such as abdominal bruising, distention, pain or tenderness, hypoactive bowel sounds, and abnormal liver function tests (>2 times the upper limit of normal), may be used to inform the decision to perform an abdomen and pelvis CT [34,35]. Based on the results of a study of 1,272 abused children between 0 and 5 years of age, there was 77% sensitivity and 82% specificity for identification of occult intraabdominal trauma. The authors recommended using liver transaminase levels >80 IU/L as an indication for performing a contrast-enhanced abdomen and pelvis CT [36]. Although the study did not separately report the sensitivity and specificity for children up to 24 months of age, it found that abdominal injury was identified in infants 0 to 6 months of age (25.9%), 6 to 12 months of age (13%), and 12 to 24 months of age (24.1%) [36]. At this time, even though laboratory results may be 1 factor by which clinical suspicion of intraabdominal trauma may be suspected, performance of CT abdomen and pelvis should not be denied solely based on normal laboratory results [32]. When CT abdomen and pelvis is performed, IV contrast should be administered in order to detect and assess the severity of solid organ and vascular injury [37-39].

Variant 5: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
C. CT abdomen and pelvis without and with IV contrast

CT abdomen and pelvis with IV contrast can help detect visceral and vascular injury as stated previously. There is no relevant literature to support the use of CT abdomen and pelvis without and with IV contrast.

Variant 5: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
D. CT abdomen and pelvis without IV contrast

CT abdomen and pelvis with IV contrast can help detect visceral and vascular injury as stated previously. There is no relevant literature to support the use of CT abdomen and pelvis without IV contrast.

Variant 5: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
E. CT chest with IV contrast

Identification of rib fractures is of great importance because they are highly suggestive of abuse.

The presence of rib fractures increases the probability of abuse to 71% to 98% in infants and children up to 48 months of age (PPV of 66% to 71%) when there is not a recognized accidental explanation for the injury [40,41]. In 2 small retrospective studies of 16 infants over a 4-year period [42], and 12 infants over a 6-year period [43], chest CT was found to be more sensitive for the detection of early subacute, subacute, and old rib fractures, than was chest radiography, detecting an additional 18 and 52 additional rib fractures, respectively [42,43].

No specific medical literature exists in the investigation of thoracic pathology secondary to abusive trauma. Studies of contrast-enhanced chest CT after accidental blunt chest trauma have shown its usefulness in diagnosing mediastinal hematoma, pulmonary hemorrhage, pneumothorax, pneumomediastinum, esophageal, and aortic injury. In a study of 127 patients <15 years of age, chest CT findings differed or added information over chest radiograph findings in 45 patients (37%), but in 39 (87%) of these patients, the chest CT findings would not have changed management [46]. Advances in CT technology that enable very low-dose chest CT scan techniques described in recent literature, report that chest CT without IV contrast may be an important adjunctive imaging modality for identification of acute and healing rib fractures in children of all ages with suspected abusive trauma [42,112].

Variant 5: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
F. CT chest without and with IV contrast

There is no relevant literature to support the use of CT chest without and with IV contrast in this clinical scenario.

Variant 5: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
G. CT chest without IV contrast

Identification of rib fractures is of great importance because they are highly suggestive of abuse. The presence of rib fractures increases the probability of abuse to 71% to 98% in infants and children up to 48 months of age (PPV of 66% to 71%) when there is not a recognized accidental explanation for the injury [40,41]. In 2 small retrospective studies of 16 infants over a 4-year period [42], and 12 infants over a 6-year period [43], chest CT was found to be more sensitive for the detection of early subacute, subacute, and old rib fractures, than was chest radiography, detecting an additional 18 and 52 additional rib fractures, respectively [42,43].

No specific medical literature exists in the investigation of thoracic pathology secondary to abusive trauma. Studies of contrast-enhanced chest CT after accidental blunt chest trauma have shown its usefulness in diagnosing mediastinal hematoma, pulmonary hemorrhage, pneumothorax, pneumomediastinum, esophageal, and aortic injury. In a study of 127 patients <15 years of age, chest CT findings differed or added information over chest radiograph findings in 45 patients (37%), but in 39 (87%) of these patients, the chest CT findings would not have changed management [46].

Variant 5: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
H. Radiography area of interest

The presentation and history of the mechanism of injury are important considerations. Key elements include whether the mechanism of trauma is appropriate for the child's age or developmental stage and whether it is consistently reported. Additionally, it is important to assess whether the presentation for medical care is timely and if other injuries are apparent. Inconsistencies in these points and/or the diagnosis of moderate- or high-risk fractures, usually warrant further diagnostic workup with a complete radiographic skeletal survey [4].

Radiography of the chest, abdomen, or pelvis for investigation of visceral injury is insensitive and even if findings of pneumothorax, free air in the peritoneal cavity, or abnormal bowel gas pattern are discovered, the presence of these findings are not specific for the type injury.

Variant 5: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
I. Radiography skeletal survey

A radiographic skeletal survey is typically performed for all children <2 years of age with obvious abusive injuries, suspicious injuries, or injuries not consistent with the history provided [37]. When the physical examination or clinical findings are suspicious for visceral trauma due to physical abuse, a skeletal survey may be warranted in an infant <24 months of age because they are unable to participate in the physical examination or localize the site of injury [85].

Variant 5: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
J. US abdomen

Abdominal US performed to detect visceral injury or hemoperitoneum after a blunt abdominal trauma is not useful in hemodynamically stable children suffering trauma [89]. Grayscale US imaging is not sufficiently sensitive or specific for detecting solid organ injury in children. The sensitivity of grayscale US relative to contrast-enhanced CT for fluid detection ranges from 59% to 79% and for fluid and solid organ injury from 65% to 71% for 2 observers. The specificity for fluid detection is 79% and for fluid and solid organ injury is and specificity ranges from 71% to 79% for 2 observers [20]. FAST US has not been shown to improve length of stay in the emergency department, or other potential benefits of earlier diagnosis and may result in delay in performing contrast enhanced abdomen and pelvis CT [20,113].

For the purpose of this document, we are rating the diagnostic US abdomen procedure performed and read by a radiologist, not the FAST examination. For additional information regarding FAST examination, see the Special Imaging Considerations section.

Variant 5: Child. 24 months of age or younger. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
K. US abdomen with IV contrast

CEUS of the abdomen has become a reliable tool in the initial diagnosis and in follow-up imaging of visceral injuries in children who have suffered low- to moderate-energy blunt abdominal trauma, such as can be seen in physical child abuse. The sensitivity and specificity of CEUS can reach up to 95%, although this was not specifically investigated in children suspected of physical child abuse [90]. A prospective study of 21 children and adolescents between 7 and 18 years of age

with known diagnoses of abdominal solid organ injury, underwent conventional grayscale and power Doppler US and CEUS within 48 hours of their injuries. The sensitivity and specificity of CEUS was 85.7% and 98.6%, respectively, compared with 45.2% and 96.4% for conventional US, respectively [91].

A role for CEUS may become established for the evaluation of clinically occult abdominal visceral injury in children suffering physical child abuse in the future. The benefits of US and CEUS include greater accessibility for unstable patients in the emergency department or intensive care unit and the potential for administering intravascular hemostatic agents when necessary [91,92,113].

Variant 6: Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.

The most serious injuries generally guide the choice of the initial imaging examination selection when numerous suspicious injuries are found on physical examination. Clinical skin abnormalities including bruises, contusions, superficial wounds, and burns—the most common nonorthopedic injuries in children suffering physical child abuse—warrant investigation [3].

A 2020 study of the United States National Trauma Databank reviewed 678,503 children admitted to the hospital with traumatic injuries and determined that 19,149 (3%) children were victims of physical child abuse. The study found that 5,620 (29%) of patients admitted to the hospital and 27% of fatalities occurred in children >1 year of age [111]. Further, investigators determined that victims of physical child abuse frequently presented with multiple injuries. Specifically, children with traumatic brain injury often had thoracic injuries (57%) and solid organ injuries (38%), whereas children with coexisting rib and extremity fractures also suffered solid organ injuries (36%) [111]. In this study and others, after neurological injuries, skin abnormalities such as bruises, contusions, superficial wounds, and burns were found to be the most common injuries in infants suffering physical child abuse and may warrant laboratory investigation to guide further radiological examination [39].

Data from a 2,000-child inpatient database confirm that infants and young children are the most vulnerable to abuse. However, the data also reveal that 18% of abused children in the study cohort were 3 to 12 years of age and 14% were 13 to 20 years of age. Approximately one-third of these older children required hospitalization for their injuries. Comorbid conditions, most commonly neurological and psychiatric conditions, were present in every age group, but were most common in children 3 to 12 years of age (34.8%) and 13 to 20 years of age (60.8%) [3]. These data support the widely held view that child abuse is a complex problem with many contributing social, economic, and health-related factors, and that children of all ages are vulnerable [1-3,111].

In the following discussion, the area of interest can refer to the following: chest, abdomen and pelvis.

Variant 6: Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.

A. Bone scan whole body

There is no relevant literature to support the use of bone scan as the initial imaging modality in abused children with suspected visceral injury. In young children, nuclear medicine and molecular

imaging studies can increase the sensitivity for the detection of fractures, periosteal reaction, and tissue injury associated with orthopedic findings, but not visceral findings [26-28].

Variant 6: Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging. B. CT abdomen and pelvis with IV contrast

Abusive abdominal injury is rare, seen in only 2% to 11.4% of cases of physical child abuse, but is important because it is the second leading cause of death in abused children, after head injury. Clinical and laboratory findings, such as abdominal bruising, distention, pain or tenderness, hypoactive bowel sounds, and abnormal liver function tests (>2 times the upper limit of normal), may be used to inform the decision to perform an abdomen and pelvis CT [34,35]. Based on the results of a study of 1,272 abused children between 0 and 5 years of age, there was a sensitivity of 77% and a specificity of 82% for identification of occult intraabdominal trauma. The authors recommended using liver transaminase levels >80 IU/L as an indication for performing a contrast-enhanced abdomen and pelvis CT [36]. Although the study did not separately report the sensitivity and specificity for children up to 24 months of age, it found that abdominal injury was identified in infants 0 to 6 months of age (25.9%), 6 to 12 months of age (13%), and 12 to 24 months of age (24.1%) [36]. When CT abdomen and pelvis is performed, IV contrast should be administered in order to detect and assess the severity of solid organ and vascular injury [37-39].

Variant 6: Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging. C. CT abdomen and pelvis without and with IV contrast

CT abdomen and pelvis with IV contrast can help detect visceral and vascular injury as stated previously. There is no relevant literature to support the use of CT abdomen and pelvis without and with IV contrast.

Variant 6: Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging. D. CT abdomen and pelvis without IV contrast

CT abdomen and pelvis with IV contrast can help detect visceral and vascular injury as stated previously. There is no relevant literature to support the use of CT abdomen and pelvis without IV contrast.

Variant 6: Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging. E. CT chest with IV contrast

Identification of rib fractures is of great importance because they are highly suggestive of abuse. The presence of rib fractures increases the probability of abuse to 71% to 98% in infants and children up to 48 months of age (PPV of 66% to 71%) when there is not a recognized accidental explanation for the injury [40,41].

No specific medical literature exists in the investigation of thoracic pathology secondary to abusive trauma. Studies of contrast-enhanced chest CT after accidental blunt chest trauma have shown its usefulness in diagnosing mediastinal hematoma, pulmonary hemorrhage, pneumothorax,

pneumomediastinum, esophageal, and aortic injury. In a study of 127 patients <15 years of age, chest CT findings differed or added information over chest radiograph findings in 45 patients (37%), but in 39 (87%) of these patients, the chest CT findings would not have changed management [46].

Variant 6: Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging. F. CT chest without and with IV contrast

There is no relevant literature to support the use of CT chest without and with IV contrast in this clinical scenario.

Variant 6: Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging. G. CT chest without IV contrast

Identification of rib fractures is of great importance because they are highly suggestive of abuse. The presence of rib fractures increases the probability of abuse to 71% to 98% in infants and children up to 48 months of age (PPV of 66% to 71%) when there is not a recognized accidental explanation for the injury [40,41].

No specific medical literature exists in the investigation of thoracic pathology secondary to abusive trauma. Studies of contrast-enhanced chest CT after accidental blunt chest trauma have shown its usefulness in diagnosing mediastinal hematoma, pulmonary hemorrhage, pneumothorax, pneumomediastinum, esophageal, and aortic injury. In a study of 127 patients <15 years of age, chest CT findings differed or added information over chest radiograph findings in 45 patients (37%), but in 39 (87%) of these patients, the chest CT findings would not have changed management [46].

Variant 6: Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging. H. Radiography area of interest

Children >24 months of age are typically able to comply with a physical examination and verbalize or otherwise indicate the site of injury or pain following trauma. It is reasonable for an examiner to determine a child's ability to communicate and, when appropriate, direct a targeted radiographic examination of specific area(s) of interest rather than performing a complete skeletal survey [85].

Radiography of the chest, abdomen, or pelvis for investigation of visceral injury is insensitive and even if findings of pneumothorax, free air in the peritoneal cavity, or abnormal bowel gas pattern are discovered, the presence of these findings are not specific for the type injury.

Variant 6: Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging. I. Radiography skeletal survey

When the physical examination or clinical findings are suspicious for physical abuse, a skeletal survey may be warranted if the child is unable to participate in the physical examination or localize the site of injury [85].

Variant 6: Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
J. US abdomen

Abdominal US performed to detect visceral injury or hemoperitoneum after a blunt abdominal trauma is not useful in hemodynamically stable children suffering trauma [89]. Grayscale US imaging is not sufficiently sensitive or specific for detecting solid organ injury in children. The sensitivity of grayscale US relative to contrast-enhanced CT for fluid detection ranges from 59% to 79% and for fluid and solid organ injury from 65% to 71% for 2 observers. The specificity for fluid detection is 79%. For fluid and solid organ injury, the specificity ranges from 71% to 79% for 2 observers [20].

For the purpose of this document, we are rating the diagnostic US abdomen procedure performed and read by a radiologist, not the FAST examination. For additional information regarding FAST examination, see the Special Imaging Considerations section.

Variant 6: Child. Greater than 24 months of age. One or more physical examinations or clinical findings suspicious for visceral injury due to physical abuse: abdominal pain or other injuries (bruising, hematoma, or skin injury to the chest wall or trunk). Initial imaging.
K. US abdomen with IV contrast

CEUS of the abdomen has become a reliable tool in the initial diagnosis and in follow-up imaging of visceral injuries in children who have suffered low- to moderate-energy blunt abdominal trauma, such as in cases of physical child abuse. The sensitivity and specificity of CEUS can reach up to 95%, although this was not specifically investigated in children suspected of physical child abuse [90]. A prospective study of 21 children and adolescents between 7 and 18 years of age with known diagnoses of abdominal solid organ injury, underwent conventional grayscale and power Doppler US and CEUS within 48 hours of their injuries. The sensitivity and specificity of CEUS was 85.7% and 98.6%, respectively, compared with 45.2% and 96.4% for conventional US, respectively [91].

A role for CEUS may become established for evaluation of clinically occult abdominal visceral injury in children suffering physical child abuse in the future. The benefits of US and CEUS include greater accessibility for unstable patients in the emergency department or intensive care unit and the potential for administering intravascular hemostatic agents when necessary [91,92,113].

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
A. Bone scan whole body

Bone scintigraphy, when used as an adjunct to the radiographic skeletal survey, can increase the sensitivity for detecting fractures, periosteal reaction, and even soft tissue injury when an anatomic abnormality is present radiographically [26-28].

In young children, normal physiologic activity at the growth plates of long bones and throughout the spine, pelvis, and small bones of the hands and feet, is also detected on bone scans. This physiologic activity may obscure evidence of metaphyseal fractures, which are characteristic

fractures of physical child abuse. For this reason, the sensitivity of bone scintigraphy for detecting CMLs is limited compared with skeletal survey, with a reported range of 31% to 67% [26,29].

Skull fractures are also difficult to detect with confidence on bone scintigraphy examinations, as fractures that occur parallel to and in proximity to calvarial sutures, as well as those in the occipital bone (which has complex variations in suture development), may not be distinguishable from normal sutural physiologic tracer activity [30,31]. Bone scintigraphy, therefore, is considered a complementary examination, used in conjunction with radiographic skeletal surveys, to identify radiographically occult fractures, enabling a more complete analysis of fractures in abused children [32,33].

Bone scintigraphy can be used to identify acute and healing fractures in children suffering from abuse. Although it is highly sensitive for identifying bone abnormalities, bone scintigraphy is not specific for the type of abnormality and often does not reveal CMLs, a fracture type that is often seen in abused infants. This is because normal tracer activity at the metaphysis may obscure abnormal tracer activity related to a CML [28]. When a bone scan is performed, correlative radiographs are required to investigate any abnormality [114].

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
B. CT abdomen and pelvis with IV contrast

Injuries to organs of the abdomen and pelvis resulting from abusive trauma may be occult. Hollow viscus or solid visceral injury are the most likely to require CT imaging. Although these injuries are more likely to present acutely, presentation may be delayed by up to 2 weeks after the initial insult. It has been shown that CT of the abdomen and pelvis, even in the acute phase after trauma, is positive in <20% of patients and alters patient management in only 2% of patients [34]. Presumably, in a delayed time frame, these percentages would diminish further.

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
C. CT abdomen and pelvis without and with IV contrast

CT abdomen and pelvis with IV contrast can help detect visceral and vascular injury as stated previously. There is no relevant literature to support the use of CT abdomen and pelvis without and with IV contrast for follow-up imaging of the abdomen within 10 to 14 days after an initially negative workup.

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
D. CT abdomen and pelvis without IV contrast

CT abdomen and pelvis with IV contrast can help detect visceral and vascular injury as stated previously. There is no relevant literature to support the use of CT abdomen and pelvis without IV contrast for follow-up imaging after an initially negative workup.

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
E. CT chest with IV contrast

Chest CT may be beneficial as a follow-up examination if persistent physical examination findings suggest thoracic pathology, such as point tenderness over a rib, scapula, or sternum that raise

concern for an occult fracture. There is no relevant literature to support follow-up chest CT to diagnose abusive fractures of the scapula or sternum. Chest CT has been shown to be more sensitive in detecting early subacute, subacute, and late rib fractures in abused infants [43]. Chest CT may be beneficial for evaluating chest pain concerning for mediastinal, pulmonary, or pleural abnormalities following abusive trauma. This view is based on studies that have shown the usefulness of contrast-enhanced chest CT after accidental blunt chest trauma for the diagnosis of pneumothorax, pneumomediastinum, esophageal, and aortic injury, although typically these symptoms present within 10 days of the traumatic event [46]. CT chest with IV contrast is not helpful as a follow-up imaging technique for all patients and may be better used to confirm new radiographic findings concerning for pulmonary or mediastinal injury [42].

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
F. CT chest without and with IV contrast

There is no relevant literature to support the use of CT chest without and with IV contrast for follow-up imaging after an initially negative workup.

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
G. CT chest without IV contrast

The presence of rib fractures increases the probability of abuse to 71% to 98% in infants and children up to 48 months of age (PPV of 66% to 71%) when there is not a recognized accidental explanation for the injury [40,41]. Chest CT may be beneficial as a follow-up examination if persistent physical examination findings suggest thoracic pathology, such as point tenderness over a rib, scapula, or sternum that raise concern for an occult fracture. It can serve as an adjunct imaging tool for skeletal surveys. Although no relevant literature supports using follow-up chest CT to diagnose abusive fractures of the scapula or sternum, chest CT has been shown to be more sensitive in detecting early subacute, subacute, and late rib fractures in abused infants [43]. Chest CT may be beneficial for evaluating chest pain concerning for mediastinal, pulmonary, or pleural abnormalities following abusive trauma. This view is based on studies that have shown the usefulness of contrast-enhanced chest CT after accidental blunt chest trauma for the diagnosis of pneumothorax, pneumomediastinum, esophageal, and aortic injury, although typically these symptoms present within 10 days of the traumatic event [46].

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
H. MRI cervical spine without and with IV contrast

There is no relevant literature to support the use of MRI cervical spine without and with IV contrast for follow-up imaging of the spine within 10 to 14 days after an initially negative workup.

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
I. MRI cervical spine without IV contrast

There is no relevant literature to support the use of MRI cervical spine without IV contrast for follow-up imaging of the spine within 10 to 14 days after an initially negative workup. Spine imaging may be beneficial when performed as a follow-up or alongside an abnormal brain MRI.

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.

J. MRI complete spine without and with IV contrast

There is no relevant literature to support the use of MRI complete spine without and with IV contrast for follow-up imaging of the spine within 10 to 14 days after an initially negative workup.

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
K. MRI complete spine without IV contrast

There is no relevant literature to support the use of MRI complete spine without IV contrast for follow-up imaging of the spine within 10 to 14 days after an initially negative workup. Spine imaging may be beneficial when performed as a follow-up or alongside an abnormal brain MRI.

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
L. MRI head without and with IV contrast

If there is persistent suspicion for injury as evident by a persistent abnormal neurologic examination or signs after an initial negative evaluation, neuroimaging is typically considered. MRI brain examinations may be helpful in cases where the initial head CT imaging is normal. For example, in a small series of abused infants by Morad et al [115], MRI performed 3 to 7 days after normal head CT examinations revealed SDH in 4 of 8 infants. Moreover, because MRI has been shown to reveal additional traumatic injury over abnormal CT examinations in approximately 25% of cases, and can also contribute to prognosis, MRI may be useful when a normal CT and high clinical suspicion for AHT are discordant [59,73]. IV contrast material is not routinely administered, although it may increase the accuracy of assessing septations or loculations in extraaxial collections in some patients [7,74].

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
M. MRI head without IV contrast

If there is persistent suspicion for injury as evident by a persistent abnormal neurologic examination or signs after an initial negative evaluation, neuroimaging is typically considered. Brain MRI may be helpful in cases in which the initial head CT imaging is normal. For example, in a small series of abused infants by Morad et al [115], MRI performed 3 to 7 days after normal head CT examinations revealed SDH in 4 of 8 infants. Moreover, because MRI has been shown to reveal additional traumatic injury over abnormal CT examinations in approximately 25% of cases, and can also contribute to prognosis, MRI may be useful when a normal CT and high clinical suspicion for AHT are discordant [59,73].

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
N. MRV head without IV contrast

Injury to the bridging veins has been shown to be highly associated with AHT and is considered one of the primary sources of SDHs. It is commonly seen at the junction of the bridging vein and superior sagittal sinus complex [13,55,75]. Choudhary et al [55] found that nearly 70% of children with AHT had some form of venous abnormality. Although much less common than injury to the bridging veins, cerebral sinovenous thrombosis can occur in the setting of AHT. Burtard et al [76] found that in a large population of children with AHT (n = 243), 7% had intracranial venous thrombosis. If there is persistent suspicion for injury as evident by a persistent abnormal neurologic examination or signs after an initial negative evaluation, neuroimaging is typically

considered. An MRV may be obtained along with MRI head and may be useful in further defining the injured bridging veins and venous sinus thombosis [55,56,58,70-72].

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
O. Radiography skeletal survey

Follow-up skeletal survey for patients <24 months of age suspected of suffering physical child abuse is recommended by numerous professional organizations, including the AAP, ACR, and SPR [12,37]. Follow-up examinations are important not only for confirming or discovering traumatic injuries, but also for ruling out their presence [116]. Studies have shown that new information related to abuse is discovered in 21.5% of patients, and at least 1 new fracture is discovered in 15.6% to 28% of patients undergoing follow-up skeletal surveys [117,118]. In infants with normal radiographic findings on the initial skeletal survey, new findings indicative of abusive injury, including rib fractures, have appeared on follow-up skeletal surveys in 8.5% of patients [119]. In addition to detecting new fractures, follow-up skeletal surveys are also useful for confirming or clarifying findings noted on the initial skeletal survey. In a study of 48 patients by Zimmerman et al [120], 46% of patients showed additional findings important to making the diagnosis of physical child abuse, with 27 fractures identified in 11 patients on the follow-up examination.

Using a selective or limited approach to follow-up radiographic skeletal surveys, excluding views of the spine, pelvis, skull, and possibly hands, has been investigated with varied results documented in small numbers of patients. In a study of 534 study participants by Hansen et al [121], new fractures of the spine were found in 5 of 14 patients with spine fractures diagnosed on the initial skeletal survey. However, Sonik et al [122], in a study of 22 patients, did not discover additional spine fractures on follow-up examinations. Neither study showed additional pelvic fractures on the follow-up examinations. On this basis, a limited follow-up skeletal survey could be considered if there is no clinical concern for injuries localized to low yield anatomic areas such as the pelvis, spine, hands, or skull [120-122].

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
P. US abdomen

Abdominal US performed to detect visceral injury or hemoperitoneum after blunt abdominal trauma is not useful in hemodynamically stable children suffering trauma [89]. In children with known visceral injury, US may be used to follow solid organ or hollow visceral injury and fluid collections, but there is no relevant literature to support follow-up imaging in children without known or suspected complications [39,123].

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
Q. US abdomen with IV contrast

There is no relevant literature to support the use of US abdomen with IV contrast for follow-up imaging of the abdomen within 10 to 14 days after an initially negative workup.

Variant 7: Child. 24 months of age or younger. Suspected physical abuse. Negative initial skeletal survey and CT head. Follow-up imaging within 10 to 14 days.
R. US head

In infants, head US is a neuroimaging option because of their open fontanel. Head US is commonly

used in determining the presence and extent of germinal matrix hemorrhage, intraventricular hemorrhage, and ventriculomegaly in premature infants, but it has not been studied extensively for other indications—specifically trauma. In a retrospective study of infants <2 years of age who had a US of the head performed for the evaluation of potential intracranial hemorrhage, the authors found the overall sensitivity and specificity for detection of hemorrhage to be 67% and 99%, respectively. They concluded that the sensitivity of head US was inadequate to justify its use as a screening tool for the detection of intracranial hemorrhage in young infants [94]. More recently, a retrospective study analyzed head US in infants (<12 months) after minor head trauma in the ability to detect skull fracture and/or intracranial hemorrhage. Although they had a higher sensitivity of 93% and specificity of 98%, the majority of patients did not have cross-sectional imaging to corroborate their results. They primarily relied on clinical outcome as to whether the head US results were valid [95].

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.

Evaluation of all children currently sharing a household with an abused child is critical. Child maltreatment of children living in the same household as a severely abused child has been reported in up to 72% of siblings [9,124,125].

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
A. Bone scan whole body

There is no relevant literature to support the use of whole body bone scan as the initial imaging modality for children who share a home with a child with suspected or known physical abuse.

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
B. CT abdomen and pelvis with IV contrast

There is no relevant literature to support the use of CT of the abdomen and pelvis with IV contrast as the initial imaging modality for children who share a home with a child with suspected or known physical abuse.

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
C. CT abdomen and pelvis without and with IV contrast

There is no relevant literature to support the use of CT of the abdomen and pelvis without and with IV contrast as the initial imaging modality for children who share a home with a child with suspected or known physical abuse.

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
D. CT abdomen and pelvis without IV contrast

There is no relevant literature to support the use of CT of the abdomen and pelvis without IV contrast as the initial imaging modality for children who share a home with a child with suspected or known physical abuse.

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
E. CT chest with IV contrast

There is no relevant literature to support the use of CT of the chest with IV contrast as the initial imaging modality for children who share a home with a child with suspected or known physical abuse.

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
F. CT chest without and with IV contrast

There is no relevant literature to support the use of CT of the chest without and with IV contrast as the initial imaging modality for children who share a home with a child with suspected or known physical abuse.

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
G. CT chest without IV contrast

There is no relevant literature to support the use of CT of the chest without IV contrast as the initial imaging modality for children who share a home with a child with suspected or known physical abuse.

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
H. CT head with IV contrast

There is no relevant literature to support the use of CT head with IV contrast as the initial imaging modality for children who share a home with a child with suspected or known physical abuse.

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
I. CT head without and with IV contrast

There is no relevant literature to support the use of CT head without and with IV contrast as the initial imaging modality for children who share a home with a child with suspected or known physical abuse.

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
J. CT head without IV contrast

Children who share a home with a child with suspected or known physical abuse are at increased risk for physical abuse based on their exposure [126]. Multiple studies have demonstrated high rates of occult head injury (19%-37%) in children <2 years of age with concern for physical abuse, even in the absence of neurological symptoms [47-51]. Head CT has the advantage of rapid acquisition and excellent sensitivity for traumatic injuries such as hemorrhage. For trauma evaluation, head CT may be performed without IV contrast, as the presence of contrast may obscure subtle hemorrhages. Multiplanar and 3-D reconstructed CT images increase the sensitivity of CT for detecting small hemorrhages and fractures, making them particularly useful [13,62-64,127,128].

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
K. MRI head without and with IV contrast

Presently, an MRI head is not used as an initial examination in children with clinically suspected abuse. It is typically reserved for further evaluation of abnormal initial examinations and for cases

in which there is a high clinical suspicion for AHT but a normal CT head. IV contrast material is not routinely administered, although it may increase the accuracy of assessing septations or loculations in extraaxial collections in some patients [7,74].

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
L. MRI head without IV contrast

Presently, an MRI head is not used as an initial examination in children with clinically suspected abuse. It is typically reserved for further evaluation of abnormal initial examinations and for cases in which there is a high clinical suspicion for AHT but a normal CT head. However, there is growing expert consensus that MRI may be beneficial in this scenario [13].

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
M. MRV head without IV contrast

Presently, an MRV head is not used as an initial examination in children with clinically suspected abuse; it is typically reserved for further evaluation of abnormal initial examinations and for cases in which there is a high clinical suspicion for AHT but a normal CT head.

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
N. Radiography skeletal survey

Siblings and household contacts <2 years of age of abused children are typically examined for abusive injuries and may undergo a skeletal survey [129].

A radiographic skeletal survey is useful as a first imaging modality in children <24 months of age, even when asymptomatic, if they live in the same home as another child who is suspected or known to be a victim of child abuse [37]. Occult fractures have been diagnosed in more than 10% of children <2 years of age who are siblings of children known to have suffered abusive trauma [9]. In a study of 870 pairs of adult siblings, in which one sibling was known to have suffered abusive trauma as a child, 59% of the associated siblings also reported experiencing abuse [130].

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
O. US abdomen

There is no relevant literature to support the use of US abdomen as the initial imaging modality for children who share a home with a child with suspected or known physical abuse.

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
P. US abdomen with IV contrast

There is no relevant literature to support the use of abdominal US with IV contrast as the initial imaging modality for children who share a home with a child with suspected or known physical abuse.

Variant 8: Child. 24 months of age or younger. Asymptomatic, who shares a home with a child with suspected or known physical abuse. Initial imaging.
Q. US head

In a child >24 months of age, there is no role for head US as a neuroimaging modality because

their fontanelles are closed.

Summary of Highlights

This is a summary of the key recommendations from the variant tables. Refer to the complete narrative document for more information.

- **Variants 1 and 2**: For children ≤24 months of age with concern for physical abuse and no clinically apparent neurological, skeletal, or visceral injuries, initial imaging should include a skeletal survey and noncontrast head CT, as these examinations are complementary. Additional radiographs of symptomatic areas and/or a noncontrast chest CT may be considered to clarify findings on the initial radiographs. Similarly, a follow-up skeletal survey in 10 to 14 days could be helpful to evaluate how known injuries are evolving or to detect additional occult injuries. In children >24 months of age who can verbalize or localize pain, a targeted radiographic examination of the area of concern is typically sufficient. Routine head CT is not recommended in these older children unless there is a developmental delay, or additional clinical scenarios in which neurological examinatons may be deemed less reliable.
- **Variants 3 and 4**: For any child exhibiting clinical signs of CNS injury due to abuse, initial neuroimaging should include a noncontrast head CT. MRI and MRV of the head and MRI of the total spine (without IV contrast) may be performed simultaneously or afterward to evaluate suspicious or inconclusive CT findings, or in cases of high suspicion for abuse with a normal CT of the head. For initial body imaging in this clinical setting, a radiographic skeletal survey is recommended for children ≤24 months of age. In children >24 months of age, who are usually able to cooperate with a physical examination and identify or describe the site of injury or pain, a targeted radiographic examination of specific areas is advised. Radiographs of the suspected site and a complete skeletal survey can be used to evaluate abnormal initial findings in Variants 3 and 4, respectively. Of note, CT head and skeletal survey and targeted radiographs are complementary examinatons.
- **Variants 5 and 6:** In children with suspected visceral injury from abuse, imaging recommendations again depend on age. The recommended initial radiographs are a complete skeletal survey for children ≤24 months of age and radiographs of the area of concern for those >24 months of age. Regardless of age, a CT of the abdomen and pelvis with IV contrast is always recommended. A chest CT (with or without IV contrast) may be appropriate depending on findings and clinical suspicion. Of note, skeletal survey and targeted radiographs and CT abdomen and pelvis with IV contrast are complementary examinations. Additionally, for children suspected of physical abuse due to visceral injury, they may also have concurrent neurologic injuries. Depending on the signs, symptoms, or clinical examination findings, please refer to Variants 1, 3, and 4 for guidance on appropriate neuroimaging.
- **Variant 7**: For a child ≤24 months of age with suspected abuse but a negative initial skeletal survey and head CT, a repeat skeletal survey is recommended within 10 to 14 days. A chest CT and/or whole body bone scan may be appropriate in certain cases. An MRI of the head without IV contrast can help detect subtle injuries not seen on CT.
- **Variant 8**: For asymptomatic children ≤24 months of age who are household contacts of a physically abused child, a complete skeletal survey is recommended. Neuroimaging may include either a noncontrast head CT or noncontrast head MRI, based on clinical judgment.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents, please go to the ACR website at https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria.

Gender Equality and Inclusivity Clause

The ACR acknowledges the limitations in applying inclusive language when citing research studies that predates the use of the current understanding of language inclusive of diversity in sex, intersex, gender, and gender-diverse people. The data variables regarding sex and gender used in the cited literature will not be changed. However, this guideline will use the terminology and definitions as proposed by the National Institutes of Health.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

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 (RRL) indication has been included for each imaging examination. The RRLs 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, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation

dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document.

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv

*RRL 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 (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

References

1. World Health Organization. Violence against children. Available at: https://www.who.int/health-topics/violence-against-children#tab=tab_1.
2. U.S. Department of Health & Human Services, Administration for Children and Families, Administration on Children, Youth and Families, Children's Bureau. (2021). Child Maltreatment 2019. Available at: https://www.acf.hhs.gov/cb/report/child-maltreatment-2019.
3. Loder RT, Feinberg JR. Orthopaedic injuries in children with nonaccidental trauma: demographics and incidence from the 2000 kids' inpatient database. J Pediatr Orthop 2007;27:421-6.
4. Berthold O, Frericks B, John T, Clemens V, Fegert JM, Moers AV. Abuse as a Cause of Childhood Fractures. [Review]. Deutsches Arzteblatt International. 115(46):769-775, 2018 11 16.
5. Flaherty EG, Perez-Rossello JM, Levine MA, et al. Evaluating children with fractures for child physical abuse. Pediatrics 2014;133:e477-89.
6. Servaes S, Brown SD, Choudhary AK, et al. The etiology and significance of fractures in infants and young children: a critical multidisciplinary review. [Review]. Pediatric Radiology. 46(5):591-600, 2016 May.
7. Wright JN.. CNS Injuries in Abusive Head Trauma. [Review]. AJR. American Journal of Roentgenology. 208(5):991-1001, 2017 May.
8. Becker JC, Liersch R, Tautz C, Schlueter B, Andler W. Shaken baby syndrome: report on four pairs of twins. Child Abuse Negl. 1998; 22(9):931-937.
9. Lindberg DM, Shapiro RA, Laskey AL, Pallin DJ, Blood EA, Berger RP. Prevalence of abusive injuries in siblings and household contacts of physically abused children. Pediatrics. 2012;130(2):193-201.
10. Quigley AJ, Stafrace S. Skeletal survey normal variants, artefacts and commonly misinterpreted findings not to be confused with non-accidental injury. Pediatr Radiol. 2014;44(1):82-93; quiz 79-81.

11. Pfeifer CM, Henry MK, Care MM, et al. Debunking Fringe Beliefs in Child Abuse Imaging: AJR Expert Panel Narrative Review. [Review]. AJR. American Journal of Roentgenology. 217(3):529-540, 2021 Sep.

12. American College of Radiology. ACR-SPR Practice Parameter For The Performance And Interpretation Of Skeletal Surveys In Children. Available at: https://gravitas.acr.org/PPTS/GetDocumentView?docId=186+&releaseId=2

13. Choudhary AK, Servaes S, Slovis TL, et al. Consensus statement on abusive head trauma in infants and young children. [Review]. Pediatric Radiology. 48(8):1048-1065, 2018 08.

14. Akoglu H, Celik OF, Celik A, Ergelen R, Onur O, Denizbasi A. Diagnostic accuracy of the Extended Focused Abdominal Sonography for Trauma (E-FAST) performed by emergency physicians compared to CT. American Journal of Emergency Medicine. 36(6):1014-1017, 2018 Jun.Am J Emerg Med. 36(6):1014-1017, 2018 Jun.

15. Becker A, Lin G, McKenney MG, Marttos A, Schulman CI. Is the FAST exam reliable in severely injured patients?. Injury. 41(5):479-83, 2010 May.

16. Laselle BT, Byyny RL, Haukoos JS, et al. False-negative FAST examination: associations with injury characteristics and patient outcomes. Ann Emerg Med. 60(3):326-34.e3, 2012 Sep.

17. Allen CJ, Tashiro J, Sola JE. Role of FAST or Abdominal Ultrasound to Limit CT Imaging in Evaluation of the Pediatric Abdominal Trauma Patient. Current Surgery Reports 2014;2:56.

18. Menaker J, Blumberg S, Wisner DH, et al. Use of the focused assessment with sonography for trauma (FAST) examination and its impact on abdominal computed tomography use in hemodynamically stable children with blunt torso trauma. J Trauma Acute Care Surg 2014;77:427-32.

19. Le Coz J, Orlandini S, Titomanlio L, Rinaldi VE. Point of care ultrasonography in the pediatric emergency department. [Review]. Italian Journal of Pediatrics. 44(1):87, 2018 Jul 27.Ital. J. Pediatr.. 44(1):87, 2018 Jul 27.

20. Holmes JF, Kelley KM, Wootton-Gorges SL, et al. Effect of Abdominal Ultrasound on Clinical Care, Outcomes, and Resource Use Among Children With Blunt Torso Trauma: A Randomized Clinical Trial. JAMA 2017;317:2290-96.

21. Perez-Rossello JM, Connolly SA, Newton AW, Zou KH, Kleinman PK. Whole-body MRI in suspected infant abuse. AJR Am J Roentgenol 2010;195:744-50.

22. Proisy M, Vivier PH, Morel B, et al. Whole-body MR imaging in suspected physical child abuse: comparison with skeletal survey and bone scintigraphy findings from the PEDIMA prospective multicentre study. European Radiology. 31(11):8069-8080, 2021 Nov.

23. Lindberg DM, Stence NV, Grubenhoff JA, et al. Feasibility and Accuracy of Fast MRI Versus CT for Traumatic Brain Injury in Young Children. Pediatrics 2019;144.

24. Sheridan DC, Pettersson D, Newgard CD, et al. Can QuickBrain MRI replace CT as first-line imaging for select pediatric head trauma? J Am Coll Emerg Physicians Open 2020;1:965-73.

25. Berger RP, Furtado AD, Flom LL, Fromkin JB, Panigrahy A. Implementation of a brain injury screen MRI for infants at risk for abusive head trauma. Pediatric Radiology. 50(1):75-82, 2020 Jan.

26. Bainbridge JK, Huey BM, Harrison SK. Should bone scintigraphy be used as a routine adjunct to skeletal survey in the imaging of non-accidental injury? A 10 year review of

reports in a single centre. Clinical Radiology. 70(8):e83-9, 2015 Aug.

27. Conway JJ, Collins M, Tanz RR, et al. The role of bone scintigraphy in detecting child abuse. Semin Nucl Med. 1993; 23(4):321-333.

28. Drubach LA. Nuclear Medicine Techniques in Pediatric Bone Imaging. Semin Nucl Med 2017;47:190-203.

29. Drubach LA, Johnston PR, Newton AW, Perez-Rossello JM, Grant FD, Kleinman PK. Skeletal trauma in child abuse: detection with 18F-NaF PET. Radiology 2010;255:173-81.

30. Muroi A, Enomoto T, Ihara S, Ishikawa E, Inagaki T, Matsumura A. Developmental changes in the occipital cranial sutures of children less than 2 years of age. Childs Nerv Syst 2020.

31. Sidpra J, Jeelani NUO, Ong J, Birch W, Mankad K. Skull fractures in abusive head trauma: a single centre experience and review of the literature. Childs Nerv Syst 2020.

32. Mandelstam SA, Cook D, Fitzgerald M, Ditchfield MR. Complementary use of radiological skeletal survey and bone scintigraphy in detection of bony injuries in suspected child abuse. Arch Dis Child. 2003; 88(5):387-390; discussion 387-390.

33. Fernandes AR, Faria MT, Oliveira A, Barata P, Pereira J. Child Abuse: Bone Scintigraphy for the Evaluation of Non-Accidental Lesions. Acta Radiol Portusguesa 2019;31:7-10.

34. Trout AT, Strouse PJ, Mohr BA, Khalatbari S, Myles JD. Abdominal and pelvic CT in cases of suspected abuse: can clinical and laboratory findings guide its use? Pediatr Radiol. 2011; 41(1):92-98.

35. Karaduman D, Sarioglu-Buke A, Kilic I, Gurses E. The role of elevated liver transaminase levels in children with blunt abdominal trauma. Injury 2003;34:249-52.

36. Lindberg D, Makoroff K, Harper N, et al. Utility of hepatic transaminases to recognize abuse in children. Pediatrics. 2009; 124(2):509-516.

37. Christian CW, Committee on Child Abuse and Neglect, American Academy of Pediatrics. The evaluation of suspected child physical abuse. Pediatrics. 135(5):e1337-54, 2015 May.

38. Goodwin SJ, Flanagan SG, McDonald K. Imaging of Chest and Abdominal Trauma in Children. [Review]. Current Pediatric Review. 11(4):251-61, 2015.Curr. Pediatr. Rev.. 11(4):251-61, 2015.

39. Raissaki M, Veyrac C, Blondiaux E, Hadjigeorgi C. Abdominal imaging in child abuse. Pediatr Radiol 2011;41:4-16; quiz 137-8.

40. Pomeranz CB, Barrera CA, Servaes SE. Value of chest CT over skeletal surveys in detection of rib fractures in pediatric patients. Clinical Imaging. 82:103-109, 2022 Feb.

41. Sanchez TR, Lee JS, Coulter KP, Seibert JA, Stein-Wexler R. CT of the chest in suspected child abuse using submillisievert radiation dose. Pediatric Radiology. 45(7):1072-6, 2015 Jul.Pediatr Radiol. 45(7):1072-6, 2015 Jul.

42. Holl EM, Marek AP, Nygaard RM, Richardson CJ, Hess DJ. Use of Chest Computed Tomography for Blunt Pediatric Chest Trauma: Does It Change Clinical Course?. Pediatric Emergency Care. 36(2):81-86, 2020 Feb.Pediatr Emerg Care. 36(2):81-86, 2020 Feb.

43. Kemp AM, Dunstan F, Harrison S, et al. Patterns of skeletal fractures in child abuse: systematic review. BMJ 2008;337:a1518.

44. Maguire S, Cowley L, Mann M, Kemp A. What does the recent literature add to the

identification and investigation of fractures in child abuse: an overview of review updates 2005-2013. Evidence-Based Child Health: A Cochrane Review Journal 2013;8:2044-57.

45. Wootton-Gorges SL, Stein-Wexler R, Walton JW, Rosas AJ, Coulter KP, Rogers KK. Comparison of computed tomography and chest radiography in the detection of rib fractures in abused infants. Child Abuse Negl. 2008;32(6):659-663.

46. Shelmerdine SC, Langan D, Hutchinson JC, et al. Chest radiographs versus CT for the detection of rib fractures in children (DRIFT): a diagnostic accuracy observational study. The Lancet Child & Adolescent Health. 2(11):802-811, 2018 11.

47. Boehnke M, Mirsky D, Stence N, Stanley RM, Lindberg DM. Occult head injury is common in children with concern for physical abuse. Pediatric Radiology. 48(8):1123-1129, 2018 08.

48. Fickenscher KA, Dean JS, Mena DC, Green BA, Lowe LH. Occult cranial injuries found with neuroimaging in clinically asymptomatic young children due to abusive compared to accidental head trauma. South Med J 2010;103:121-5.

49. Harper NS, Feldman KW, Sugar NF, Anderst JD, Lindberg DM. Additional injuries in young infants with concern for abuse and apparently isolated bruises. J Pediatr. 2014;165(2):383-388 e381.

50. Laskey AL, Holsti M, Runyan DK, Socolar RR. Occult head trauma in young suspected victims of physical abuse. J Pediatr. 2004;144(6):719-722.

51. Rubin DM, Christian CW, Bilaniuk LT, Zazyczny KA, Durbin DR. Occult head injury in high-risk abused children. Pediatrics. 2003;111(6 Pt 1):1382-1386.

52. Bradford R, Choudhary AK, Dias MS. Serial neuroimaging in infants with abusive head trauma: timing abusive injuries. J Neurosurg Pediatrics. 12(2):110-9, 2013 Aug.

53. Wittschieber D, Karger B, Pfeiffer H, Hahnemann ML. Understanding Subdural Collections in Pediatric Abusive Head Trauma. [Review]. Ajnr: American Journal of Neuroradiology. 40(3):388-395, 2019 03.

54. Sieswerda-Hoogendoorn T, Postema FA, Verbaan D, Majoie CB, van Rijn RR. Age determination of subdural hematomas with CT and MRI: a systematic review. Eur J Radiol. 2014;83(7):1257-1268.

55. Choudhary AK, Bradford R, Dias MS, Thamburaj K, Boal DK. Venous injury in abusive head trauma. Pediatric Radiology. 45(12):1803-13, 2015 Nov.

56. Palifka LA, Frasier LD, Metzger RR, Hedlund GL. Parenchymal Brain Laceration as a Predictor of Abusive Head Trauma. Ajnr: American Journal of Neuroradiology. 37(1):163-8, 2016 Jan.

57. Ronning MM, Carolan PL, Cutler GJ, Patterson RJ. Parasagittal vertex clots on head CT in infants with subdural hemorrhage as a predictor for abusive head trauma. Pediatric Radiology. 48(13):1915-1923, 2018 12.

58. Teixeira SR, Goncalves FG, Servin CA, Mankad K, Zuccoli G. Ocular and Intracranial MR Imaging Findings in Abusive Head Trauma. [Review]. Topics in Magnetic Resonance Imaging. 27(6):503-514, 2018 Dec.

59. Vazquez E, Delgado I, Sanchez-Montanez A, Fabrega A, Cano P, Martin N. Imaging abusive head trauma: why use both computed tomography and magnetic resonance imaging?. [Review]. Pediatr Radiol. 44 Suppl 4:S589-603, 2014 Dec.

60. Zimmerman RA, Bilaniuk LT, Farina L. Non-accidental brain trauma in infants: diffusion imaging, contributions to understanding the injury process. J Neuroradiol 2007;34:109-14.

61. Choudhary AK, Jha B, Boal DK, Dias M. Occipital sutures and its variations: the value of 3D-CT and how to differentiate it from fractures using 3D-CT? Surg Radiol Anat 2010;32:807-16.

62. Langford S, Panigrahy A, Narayanan S, et al. Multiplanar reconstructed CT images increased depiction of intracranial hemorrhages in pediatric head trauma. Neuroradiology. 57(12):1263-8, 2015 Dec.

63. Orman G, Wagner MW, Seeburg D, et al. Pediatric skull fracture diagnosis: should 3D CT reconstructions be added as routine imaging? J Neurosurg Pediatr 2015;16:426-31.

64. Prabhu SP, Newton AW, Perez-Rossello JM, Kleinman PK. Three-dimensional skull models as a problem-solving tool in suspected child abuse. Pediatr Radiol. 2013;43(5):575-581.

65. Kelly P, John S, Vincent AL, Reed P. Abusive head trauma and accidental head injury: a 20-year comparative study of referrals to a hospital child protection team. Archives of Disease in Childhood. 100(12):1123-30, 2015 Dec.

66. Buttram SD, Garcia-Filion P, Miller J, et al. Computed tomography vs magnetic resonance imaging for identifying acute lesions in pediatric traumatic brain injury. Hosp. pediatr.. 5(2):79-84, 2015 Feb.

67. Roguski M, Morel B, Sweeney M, et al. Magnetic resonance imaging as an alternative to computed tomography in select patients with traumatic brain injury: a retrospective comparison. J Neurosurg Pediatrics. 15(5):529-34, 2015 May.

68. Dremmen MHG, Wagner MW, Bosemani T, et al. Does the Addition of a "Black Bone" Sequence to a Fast Multisequence Trauma MR Protocol Allow MRI to Replace CT after Traumatic Brain Injury in Children? AJNR Am J Neuroradiol 2017;38:2187-92.

69. Kralik SF, Supakul N, Wu IC, et al. Black bone MRI with 3D reconstruction for the detection of skull fractures in children with suspected abusive head trauma. Neuroradiology. 61(1):81-87, 2019 Jan.

70. Hahnemann ML, Kinner S, Schweiger B, et al. Imaging of bridging vein thrombosis in infants with abusive head trauma: the "Tadpole Sign". European Radiology. 25(2):299-305, 2015 Feb.

71. Orru' E, Huisman TAGM, Izbudak I. Prevalence, Patterns, and Clinical Relevance of Hypoxic-Ischemic Injuries in Children Exposed to Abusive Head Trauma. J Neuroimaging. 28(6):608-614, 2018 11.

72. Rambaud C.. Bridging veins and autopsy findings in abusive head trauma. [Review]. Pediatric Radiology. 45(8):1126-31, 2015 Jul.

73. Kemp AM, Rajaram S, Mann M, et al. What neuroimaging should be performed in children in whom inflicted brain injury (iBI) is suspected? A systematic review. Clin Radiol. 2009; 64(5):473-483.

74. Porto L, Bartels MB, Zwaschka J, et al. Abusive head trauma: experience improves diagnosis. Neuroradiology 2021;63:417-30.

75. Vilanilam GK, Jayappa S, Desai S, Zuccoli G, Ramakrishnaiah RH, Choudhary AK. Venous injury in pediatric abusive head trauma: a pictorial review. Pediatr Radiol 2021;51:918-26.

76. Burtard C, Panks J, Silverman LB, et al. Prevalence of cerebral sinovenous thrombosis in abusive head trauma. Pediatr Radiol 2023;53:78-85.

77. Murphy R, Kelly DM, Moisan A, et al. Transverse fractures of the femoral shaft are a better predictor of nonaccidental trauma in young children than spiral fractures are. Journal of Bone & Joint Surgery - American Volume. 97(2):106-11, 2015 Jan 21.

78. Rosado N, Ryznar E, Flaherty EG. Understanding humerus fractures in young children: Abuse or not abuse?. Child Abuse & Neglect. 73:1-7, 2017 Nov.

79. Ryznar E, Rosado N, Flaherty EG. Understanding forearm fractures in young children: Abuse or not abuse?. Child Abuse & Neglect. 47:132-9, 2015 Sep.

80. Kleinman PK, Perez-Rossello JM, Newton AW, Feldman HA, Kleinman PL. Prevalence of the classic metaphyseal lesion in infants at low versus high risk for abuse. AJR Am J Roentgenol 2011;197:1005-8.

81. Paine CW, Fakeye O, Christian CW, Wood JN. Prevalence of Abuse Among Young Children With Rib Fractures: A Systematic Review. Pediatric Emergency Care. 35(2):96-103, 2019 Feb.

82. Barber I, Perez-Rossello JM, Wilson CR, Silvera MV, Kleinman PK. Prevalence and relevance of pediatric spinal fractures in suspected child abuse. Pediatr Radiol. 43(11):1507-15, 2013 Nov.

83. Kogutt MS, Swischuk LE, Fagan CJ. Patterns of injury and significance of uncommon fractures in the battered child syndrome. Am J Roentgenol Radium Ther Nucl Med 1974;121:143-9.

84. Shaw J, Simonton K. Pediatric Fractures: Identifying and Managing Physical Abuse. Clinical Pediatric Emergency Medicine 2020:[In Press].

85. Lindberg DM, Berger RP, Reynolds MS, Alwan RM, Harper NS. Yield of skeletal survey by age in children referred to abuse specialists. J Pediatr. 2014;164(6):1268-1273 e1261.

86. Paine CW, Wood JN. Skeletal surveys in young, injured children: A systematic review. Child Abuse & Neglect. 76:237-249, 2018 02.

87. Ravichandiran N, Schuh S, Bejuk M, et al. Delayed identification of pediatric abuse-related fractures. Pediatrics 2010;125:60-6.

88. Meshaka R, Garbera DM, Arthurs OJ, Shelmerdine SC. Value of additional lateral radiographs in paediatric skeletal surveys for suspected physical abuse. Clinical Radiology. 77(1):e40-e47, 2022 01.

89. Benya EC, Lim-Dunham JE, Landrum O, Statter M. Abdominal sonography in examination of children with blunt abdominal trauma. AJR Am J Roentgenol 2000;174:1613-6.

90. Trinci M, Piccolo CL, Ferrari R, Galluzzo M, Ianniello S, Miele V. Contrast-enhanced ultrasound (CEUS) in pediatric blunt abdominal trauma. J Ultrasound 2019;22:27-40.

91. Armstrong LB, Mooney DP, Paltiel H, et al. Contrast enhanced ultrasound for the evaluation of blunt pediatric abdominal trauma. J Pediatr Surg 2018;53:548-52.

92. Paltiel HJ, Barth RA, Bruno C, et al. Contrast-enhanced ultrasound of blunt abdominal trauma in children. Pediatr Radiol 2021;51:2253-69.

93. Pinto F, Valentino M, Romanini L, Basilico R, Miele V. The role of CEUS in the assessment of

haemodynamically stable patients with blunt abdominal trauma. [Review]. Radiol Med (Torino). 120(1):3-11, 2015 Jan.

94. Elkhunovich M, Sirody J, McCormick T, Goodarzian F, Claudius I. The Utility of Cranial Ultrasound for Detection of Intracranial Hemorrhage in Infants. Pediatr Emerg Care 2018;34:96-101.

95. Peter C, Stranzinger E, Heverhagen JT, et al. Minor head trauma in infants - how accurate is cranial ultrasound performed by trained radiologists? Eur J Pediatr 2023;182:3113-20.

96. Belfer RA, Klein BL, Orr L. Use of the skeletal survey in the evaluation of child maltreatment. Am J Emerg Med 2001;19:122-4.

97. Kemp AM. Fractures in physical child abuse. Paediatrics and Child Health 2008;18:550-53.

98. McNamara CR, Panigrahy A, Sheetz M, Berger RP. The Likelihood of an Occult Fracture in Skeletal Surveys Obtained in Children More Than 2 Years Old With Concerns of Physical Abuse. Pediatric Emergency Care. 38(2):e488-e492, 2022 Feb 01.

99. Choudhary AK, Bradford RK, Dias MS, Moore GJ, Boal DK. Spinal subdural hemorrhage in abusive head trauma: a retrospective study. Radiology. 2012;262(1):216-223.

100. Choudhary AK, Ishak R, Zacharia TT, Dias MS. Imaging of spinal injury in abusive head trauma: a retrospective study.[Erratum appears in Pediatr Radiol. 2015 Apr;45(5):784; PMID: 25794487]. Pediatr Radiol. 44(9):1130-40, 2014 Sep.

101. Kadom N, Khademian Z, Vezina G, Shalaby-Rana E, Rice A, Hinds T. Usefulness of MRI detection of cervical spine and brain injuries in the evaluation of abusive head trauma. Pediatr Radiol. 44(7):839-48, 2014 Jul.

102. Rabbitt AL, Kelly TG, Yan K, Zhang J, Bretl DA, Quijano CV. Characteristics associated with spine injury on magnetic resonance imaging in children evaluated for abusive head trauma. Pediatric Radiology. 50(1):83-97, 2020 Jan.

103. Karmazyn B, Lewis ME, Jennings SG, Hibbard RA, Hicks RA. The prevalence of uncommon fractures on skeletal surveys performed to evaluate for suspected abuse in 930 children: should practice guidelines change? AJR Am J Roentgenol. 2011;197(1):W159-163.

104. Kleinman PK, Morris NB, Makris J, Moles RL, Kleinman PL. Yield of radiographic skeletal surveys for detection of hand, foot, and spine fractures in suspected child abuse. AJR Am J Roentgenol. 200(3):641-4, 2013 Mar.

105. Lindberg DM, Harper NS, Laskey AL, Berger RP, ExSTRA Investigators. Prevalence of abusive fractures of the hands, feet, spine, or pelvis on skeletal survey: perhaps "uncommon" is more common than suggested. Pediatr Emerg Care. 29(1):26-9, 2013 Jan.

106. Canty KW, Feldman KW, Bartnik-Olson B, Choudhary AK, Shiroishi MS, Group ECAW. Current issues and controversies surrounding spine imaging and the significance of spinal subdural hemorrhage in suspected abusive head trauma. Pediatr Radiol 2022;52:2445-49.

107. Karmazyn B, Reher TA, Supakul N, et al. Whole-Spine MRI in Children With Suspected Abusive Head Trauma. AJR Am J Roentgenol 2022;218:1074-87.

108. Deye KP, Berger RP, Lindberg DM, Ex SI. Occult abusive injuries in infants with apparently isolated skull fractures. J Trauma Acute Care Surg 2013;74:1553-8.

109. Feldman KW, Tayama TM, Strickler LE, et al. A Prospective Study of the Causes of Bruises in

Premobile Infants. Pediatr Emerg Care 2020;36:e43-e49.

110. Kemp AM, Dunstan F, Nuttall D, Hamilton M, Collins P, Maguire S. Patterns of bruising in preschool children--a longitudinal study. Archives of Disease in Childhood. 100(5):426-31, 2015 May.

111. Rosenfeld EH, Johnson B, Wesson DE, Shah SR, Vogel AM, Naik-Mathuria B. Understanding non-accidental trauma in the United States: A national trauma databank study. J Pediatr Surg 2020;55:693-97.

112. Forbes-Amrhein MM, Dillman JR, Trout AT, et al. Frequency and Severity of Acute Allergic-Like Reactions to Intravenously Administered Gadolinium-Based Contrast Media in Children. Invest Radiol 2018;53:313-18.

113. Henry MK, Bennett CE, Wood JN, Servaes S. Evaluation of the abdomen in the setting of suspected child abuse. Pediatr Radiol 2021;51:1044-50.

114. Section on Radiology. American Academy of Pediatrics. Diagnostic imaging of child abuse. Pediatrics 2009;123:1430-5.

115. Morad Y, Avni I, Benton SA, et al. Normal computerized tomography of brain in children with shaken baby syndrome. J AAPOS 2004;8:445-50.

116. Anilkumar A, Fender LJ, Broderick NJ, Somers JM, Halliday KE. The role of the follow-up chest radiograph in suspected non-accidental injury. Pediatr Radiol 2006;36:216-8.

117. Harper NS, Eddleman S, Lindberg DM. The utility of follow-up skeletal surveys in child abuse. Pediatrics. 2013;131(3):e672-678.

118. Harper NS, Lewis T, Eddleman S, Lindberg DM, ExSTRA Investigators. Follow-up skeletal survey use by child abuse pediatricians. Child Abuse & Neglect. 51:336-42, 2016 Jan.

119. Bennett BL, Chua MS, Care M, Kachelmeyer A, Mahabee-Gittens M. Retrospective review to determine the utility of follow-up skeletal surveys in child abuse evaluations when the initial skeletal survey is normal. BMC Res Notes. 2011;4:354.

120. Zimmerman S, Makoroff K, Care M, Thomas A, Shapiro R. Utility of follow-up skeletal surveys in suspected child physical abuse evaluations. Child Abuse Negl 2005; 29(10):1075-1083..

121. Hansen KK, Keeshin BR, Flaherty E, et al. Sensitivity of the limited view follow-up skeletal survey. Pediatrics. 2014;134(2):242-248.

122. Sonik A, Stein-Wexler R, Rogers KK, Coulter KP, Wootton-Gorges SL. Follow-up skeletal surveys for suspected non-accidental trauma: can a more limited survey be performed without compromising diagnostic information? Child Abuse Negl. 2010;34(10):804-806.

123. Navarro O, Babyn PS, Pearl RH. The value of routine follow-up imaging in pediatric blunt liver trauma. Pediatr Radiol 2000;30:546-50.

124. Baldwin JA, Oliver JE. Epidemiology and family characteristics of severely-abused children. Br J Prev Soc Med 1975;29:205-21.

125. Hamilton-Giachritsis CE, Browne KD. A retrospective study of risk to siblings in abusing families. J Fam Psychol 2005;19:619-24.

126. Mankad K, Sidpra J, Mirsky DM, et al. International Consensus Statement on the Radiological Screening of Contact Children in the Context of Suspected Child Physical

Abuse. [Review]. JAMA Pediatrics. 177(5):526-533, 2023 05 01.

127. Wei SC, Ulmer S, Lev MH, Pomerantz SR, Gonzalez RG, Henson JW. Value of coronal reformations in the CT evaluation of acute head trauma. AJNR. 2010;31(2):334-339.

128. Zacharia TT, Nguyen DT. Subtle pathology detection with multidetector row coronal and sagittal CT reformations in acute head trauma. Emerg Radiol. 2010;17(2):97-102.

129. Halstead S, Scott G, Thust S, Hann G. Review of the new RCR guidelines (2017): The radiological investigation of suspected physical abuse in children. Arch Dis Child Educ Pract Ed 2019;104:309-12.

130. Witte S, Fegert JM, Walper S. Risk of maltreatment for siblings: Factors associated with similar and different childhood experiences in a dyadic sample of adult siblings. Child Abuse Negl 2018;76:321-33.

131. Measuring Sex, Gender Identity, and Sexual Orientation.

132. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: https://edge.sitecorecloud.io/americancoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/Clinical/Appropriateness-Criteria/ACR-Appropriateness-Criteria-Radiation-Dose-Assessment-Introduction.pdf.

Disclaimer

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). 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 evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent 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 or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, 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.

[a]Children's Hospital Colorado, Aurora, Colorado. [b]Ann & Robert H. Lurie Children's Hospital of Chicago, Chicago, Illinois. [c]Secondary Panel Chair, Seattle Children's Hospital, Seattle, Washington. [d]Panel Vice-Chair, Children's Mercy Hospital, Kansas City, Missouri. [e]Panel Vice-Chair, Mayo Clinic Hospital, Rochester, Minnesota. [f]Yale School of Medicine, New Haven, Connecticut; American Academy of Pediatrics. [g]Donald and Barbara Zucker School of Medicine at Hofstra/Northwell, Hempstead, New York; American College of Emergency Physicians. [h]Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio; American Pediatric Surgical Association. [i]Hospital for Sick Children, Toronto, Ontario, Canada; American Association of Neurological Surgeons/Congress of Neurological Surgeons. [j]The Children's Hospital at Montefiore, Albert Einstein College of Medicine, Bronx, New York. [k]University of California San Francisco Benioff Children's Hospital, San Francisco, California; American Academy of Orthopaedic Surgeons. [l]UPMC Children's Hospital of Pittsburgh, Pittsburgh,

Pennsylvania. [m]Cincinnati Children’s Hospital Medical Center, Cincinnati, Ohio; Commission on Nuclear Medicine and Molecular Imaging. [n]Children's Hospital of Philadelphia, Philadelphia, Pennsylvania. [o]Specialty Chair, Vanderbilt Children's Hospital, Nashville, Tennessee.