

**American College of Radiology  
ACR Appropriateness Criteria®**

**Clinical Condition:**      **Head Trauma — Child**

**Variant 1:**                    **Minor head injury (GCS >13) ≥2 years of age without neurologic signs or high risk factors (eg, altered mental status, clinical evidence of basilar skull fracture). Excluding nonaccidental trauma.**

<b>Radiologic Procedure</b>	<b>Rating</b>	<b>Comments</b>	<b><u>RRL*</u></b>
CT head without contrast	3	This is a known low-yield procedure.	☢☢☢
MRI head without contrast	2		O
X-ray head	1		☢
CT head without and with contrast	1		☢☢☢☢
CT head with contrast	1		☢☢☢
CTA head with contrast	1		☢☢☢☢
MRI head without and with contrast	1		O
MRA head without contrast	1		O
MRA head without and with contrast	1		O
Arteriography cerebral	1		☢☢☢☢
US head	1		O
FDG-PET/CT head	1		☢☢☢☢
Tc-99m HMPAO SPECT head	1		☢☢☢☢
<b><u>Rating Scale:</u> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate</b>			<b>*Relative Radiation Level</b>

**Clinical Condition:** Head Trauma — Child**Variant 2:** Minor head injury (GCS >13), <2 years of age, no neurologic signs or high-risk factors (eg, altered mental status, clinical evidence of basilar skull fracture). Excluding nonaccidental trauma.

Radiologic Procedure	Rating	Comments	<a href="#">RRL*</a>
X-ray head	3	Refer to variant 4 if there is concern for nonaccidental trauma. This procedure is not indicated if CT with reformations is to be performed.	☢
CT head without contrast	3	This procedure has shown to be low yield in the absence of signs or symptoms. It may be considered if clinical assessment, which can be difficult at this age, is uncertain or indeterminate.	☢☢☢
MRI head without contrast	3	Refer to variant 4 if there is concern for nonaccidental trauma.	O
MRA head without contrast	2		O
CTA head with contrast	2		☢☢☢☢
CT head without and with contrast	1		☢☢☢☢
CT head with contrast	1		☢☢☢
MRI head without and with contrast	1		O
MRA head without and with contrast	1		O
Arteriography cerebral	1		☢☢☢☢
US head	1		O
FDG-PET/CT head	1		☢☢☢☢
Tc-99m HMPAO SPECT head	1		☢☢☢☢
<b><u>Rating Scale:</u></b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Clinical Condition:** Head Trauma — Child

**Variant 3:** Moderate or severe head injury (GCS  $\leq 13$ ) or minor head trauma with high-risk factors (eg, altered mental status, clinical evidence of basilar skull fracture). Excluding nonaccidental trauma.

Radiologic Procedure	Rating	Comments	<a href="#">RRL*</a>
CT head without contrast	9		☼☼☼
MRI head without contrast	7		O
MRA head without contrast	4	Consider this procedure if vascular injury is suspected.	O
CTA head with contrast	4	MRA is preferred to this procedure. It may be used for problem solving.	☼☼☼☼
MRA head without and with contrast	3		O
X-ray head	2		☼
CT head without and with contrast	2		☼☼☼☼
CT head with contrast	2		☼☼☼
MRI head without and with contrast	2		O
Arteriography cerebral	2		☼☼☼☼
US head	1		O
FDG-PET/CT head	1		☼☼☼☼
Tc-99m HMPAO SPECT head	1		☼☼☼☼
<b><u>Rating Scale:</u></b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Clinical Condition:** Head Trauma — Child**Variant 4:** Suspected nonaccidental trauma.

Radiologic Procedure	Rating	Comments	RRL*
CT head without contrast	9		☼☼☼
MRI head without contrast	8	SWI and DWI sequences are particularly helpful for axonal shear injury. Consider including cervical spine.	0
X-ray head	7		☼
MRA head without contrast	3	Consider this procedure if vascular injury is suspected. It may be performed in conjunction with neck imaging.	0
US head	3		0
MRI head without and with contrast	2		0
MRA head without and with contrast	2		0
CT head without and with contrast	2		☼☼☼☼
CT head with contrast	2		☼☼☼
Arteriography cerebral	1		☼☼☼☼
CTA head with contrast	1	MRA is preferred to this procedure; it may be used for problem solving.	☼☼☼☼
FDG-PET/CT head	1		☼☼☼☼
Tc-99m HMPAO SPECT head	1		☼☼☼☼
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Variant 5:** Subacute head injury with cognitive and/or neurologic signs.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without contrast	8	MRI is preferred, but imaging should not be delayed if it is not readily available.	0
CT head without contrast	7		☼☼☼
MRA head without contrast	3	Consider this procedure if vascular injury is suspected.	0
MRI head without and with contrast	2	This procedure is not indicated unless there is a concern for infection.	0
MRA head without and with contrast	2		0
CT head without and with contrast	2		☼☼☼☼
CTA head with contrast	2		☼☼☼☼
Arteriography cerebral	2		☼☼☼☼
X-ray head	1		☼
CT head with contrast	1		☼☼☼
US head	1		0
FDG-PET/CT head	1		☼☼☼☼
Tc-99m HMPAO SPECT head	1		☼☼☼☼
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

## HEAD TRAUMA — CHILD

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### **Summary of Literature Review**

#### **Introduction/Background**

Head trauma is a common indication for cranial imaging in children. Although the vast majority of head injuries are mild and do not require intervention [1], traumatic brain injury (TBI) remains a leading cause of death and disability in children [2]. As in adults, the necessity of identifying significant, potentially treatable injury must be weighed against the risks of performing imaging studies and appropriate resource utilization. However, there are several aspects of head trauma in the pediatric population that deserve special attention.

Children are more sensitive to ionizing radiation than adults, thus there is a heightened concern for the effects of computed tomography (CT), which has traditionally been the primary imaging study for suspected TBI. Magnetic resonance imaging (MRI) can detect traumatic lesions without radiation but often requires sedation in children due to the examination length and motion sensitivity. Clinical evaluation can be more difficult, particularly in preverbal children, and some indicators of adult injury, such as emesis, may not be as reliable in children [3,4]. Imaging assessment may also be more challenging in very young children due to the higher water content of incompletely myelinated white matter.

Patterns of injury are different in this population as well. Children are more likely to sustain calvarial fractures due to a larger craniofacial ratio and thinner skull. Abused children may present with trauma from mechanisms not typically encountered in adults, such as repeated rotational forces. Furthermore, radiologic documentation in addition to identification of injuries presents a uniquely important challenge in evaluating children with suspected nonaccidental trauma.

#### **Minor Head Injury**

The precise criteria for minor head injury are not consistent in the literature, but this usually refers to a patient with normal or near-normal postevent mental status and, in pediatric studies, is often defined by a Glasgow Coma Score (GCS) of >13 [5]. Approximately 3%–5% of children with minor head trauma have identifiable abnormalities by imaging, and typically less than 1% require neurosurgical intervention [6–9]. Noncontrast CT has a central role in screening for intracranial traumatic injury due to its wide availability, speed, and ability to detect significant hemorrhage, herniation, hydrocephalus, and fractures. Small hemorrhages may be missed by CT, although the sensitivity can be improved with multiplanar reformations [10]. 3-D reconstructed images can also be particularly helpful in young patients to help distinguish fractures from normal or variant sutures. In the absence of suspected vascular injury, there is little role for contrast-enhanced CT in trauma evaluation since contrast can obscure underlying high-density blood products. The most significant disadvantage of CT is the necessary exposure to ionizing radiation. This is of particular concern in pediatric patients due to the increased radiosensitivity of young tissues, longer lifespan, and overall greater risk of subsequent iatrogenic malignancy [11,12]. The absolute incidence of induced lethal malignancy has not been definitively proven, but the estimated

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risk in children is 1/1000–1/5000 per cranial CT [12]. Dedicated pediatric CT parameters with protocols tailored by patient size should always be used to avoid unnecessarily high radiation doses [13]. See the [Image Gently®](#) website for additional information.

MRI has an equal or higher sensitivity than CT for most intracranial hemorrhage and often demonstrates a greater number of traumatic parenchymal lesions [14,15]. The identification of small bleeds, particularly in the posterior fossa or brainstem, is further increased with newer heme-sensitive techniques such as susceptibility-weighted imaging (SWI) [1,16-18]. Diffusion-weighted imaging (DWI) can be helpful in identifying nonhemorrhagic injuries and associated ischemia as well [15]. However, the use of MRI in the acute traumatic setting is limited by the lack of widespread availability and significantly longer examination times compared with CT. Younger patients often require sedation for adequate imaging, which further complicates rapid assessment, increases resource use, and exposes the patient to potential anesthesia risks. Although MRI may identify prognostically important lesions that are occult by CT, it has not been reported to detect more neurosurgically significant injuries. In a prospective study of over 13,000 children with minor head trauma, no patients with initially negative CT examinations ultimately required neurosurgical intervention [19].

The role of skull radiographs in pediatric head trauma often remains uncertain. Calvarial fractures correlate positively with intracranial injury, and clinical evaluation alone is imprecise [3,6,20]. However, up to 50% of intracranial injuries in children occur in the absence of fracture, and an estimated 21% of fractures detectable by CT may be missed by radiographs [1,21]. Therefore, negative radiographs do not obviate the need for further imaging. In assessing more than 1,500 patients who ranged in age from 1 to 18 years. Reed et al [20] determined that evaluation by clinical history and CT without skull radiographs resulted in neither an increase in undetected intracranial injury nor greater overall radiation, suggesting CT can replace radiographs in many instances.

### **Minor Head Injury in Patients Over 2 Years of Age Without Neurologic Signs or High-Risk Factors**

The probability of significant injury in minor head trauma without neurologic signs or symptoms is very low. The overall incidence of clinically important TBI is estimated to be approximately 0.9% and has been reported to be as low as 0.05% in those without any indications of intracranial abnormality by examination or history [7].

In an effort to avoid unnecessary radiation exposure, there has been much debate regarding which children with minor head injuries can safely forgo CT. A trial evaluating children over the age of 2 by the Pediatric Emergency Care Applied Research Network (PECARN) is the only very large, prospective study conducted exclusively in young patients. This demonstrated a 99.9% negative predictive value and a 96.8% sensitivity for clinically important injury using the criteria of normal mental status and no loss of consciousness, vomiting, severe injury mechanism, signs of basilar skull fracture, or severe headache [7].

Several other clinical algorithms for minor pediatric head trauma have also been proposed from retrospective reviews, including the National Institute for Health and Care Excellence guidelines, Children's Head Injury Algorithm for the Prediction of Important Clinical Events, and Canadian Assessment of Tomography for Childhood Head injury, among others [22-25]. These also provide high sensitivity and negative predictive value but with variable specificity.

It should also be noted that there is some conflicting evidence regarding the importance of several clinical risk factors. There are contradictory reports concerning the probability of traumatic head injury in children with headache, vomiting, loss of consciousness, and severe mechanisms of injury [10,26,27]. Kupperman et al determined a <1% risk of significant TBI in children with these factors, although other studies have reported a higher incidence of injury [3,23,25,28]. The discrepancies are likely due to differences in the degree or duration of headache, number of emesis episodes, and definitions of severe mechanisms. The inconsistencies in the parameters evaluated complicate meta-analysis of these risk factors and likely contribute to the significant variability in CT rates among institutions [28,29]. In the PECARN study, CT imaging or observation was suggested in patients with risk factors other than altered mental status or basilar skull fracture based on physician experience, difficulty of examination, or worsening symptoms. No prediction model can completely replace clinical assessment, and physician judgment still holds a significant role in determining the imaging workup.

### **Minor Head Injury in Patients Under 2 Years of Age Without Neurologic Signs or High Risk Factors**

The reported prevalence of clinically significant brain injury from minor trauma in patients <2 years old is similar to that of older children, with an estimated overall risk of <1% and an increased incidence in the setting of mental status changes (4%) or clinically suspected fracture (3.6%) [7]. In a study of more than 10,000 patients <2 years

old, PECARN demonstrated a 100% negative predictive value and 100% sensitivity for TBI using the assessment criteria of normal mental status, no scalp hematoma except frontal, no loss of consciousness, no severe injury mechanism, no palpable skull fracture, and acting normally according to the parents. However, there remains some uncertainty regarding which clinical findings may constitute mental status changes in very young children. Although some studies have demonstrated acceptable interobserver agreement in assessing clinical variables in patients <2 years old [30], and the GCS system has been modified for infants, there remains concern regarding the accuracy of evaluating very young, preverbal children in settings outside of large, dedicated pediatric centers [31].

Patterns of injury in very young patients also differ from older children. Calvarial fractures are more common. The fracture threshold for an infant is approximately 10% that of a child or adult, and fractures have been reported in 11% of those <2 years old, compared with a prevalence of 2% in all children [3,32]. Axonal injury is also more common in these patients, likely due to the vulnerability of the immature white matter and the greater prevalence of nonaccidental trauma, which is often associated with shear injury and ischemia [1]. Such injuries are frequently occult by CT in infants as the low density of unmyelinated white matter can obscure CT signs of edema. Therefore, MRI may have a greater role in evaluation of the unmyelinated brain of young patients. DWI and heme-sensitive sequences such as gradient echo imaging and SWI are particularly helpful in this age group, as they can reveal signal abnormalities that are otherwise obscured on standard T1-weighted and T2-weighted sequences. However, imaging patients that demonstrate neurologic signs and symptoms should not be delayed, and CT remains the primary modality for evaluating suspected acute intracranial injury in most instances.

### **Minor Head Injury With Neurologic Signs or Symptoms or Moderate to Severe Head Injury**

The risk of intracranial injury from minor trauma is increased in children with mental status changes or clinical signs. In a study of more than 25,000 patients <2 years old with mild head trauma, Kuppermann et al [7] reported a 3.9% incidence of clinically important injury in patients with a GCS of 13–14 and a 7.5% incidence in patients with evidence of basilar skull fracture.

Moderate and severe head injury is typically associated with posttraumatic mental status changes. Despite the lower incidence and fewer numbers of studies addressing more significant injury in children, there is comparatively less debate regarding the need for imaging due to the greater incidence of intracranial injury in patients with decreased GCS [33]. CT is considered the most appropriate initial imaging for children of any age with moderate to severe head injury or neurologic findings in order to rapidly assess for traumatic injury, such as herniation or hemorrhage, which may benefit from prompt intervention.

As with less significant trauma, MRI is unlikely to detect neurosurgically relevant lesions missed by CT. However, patients with more significant trauma and lower GCS are more likely to have sustained shear injury, or ischemia and MRI may have a higher yield for prognosis in this instance. One study of more than 100 pediatric and adult patients reported findings of diffuse axonal injury in 75% of those with moderate to severe trauma [17]. A review of 40 children with moderate or greater trauma reported that 40% of patients with poor outcomes had no CT findings, but all had detectable lesions by MRI. Additionally, the MR lesion burden correlated positively with the degree of disability [34].

Although head ultrasound (US) can provide rapid bedside evaluation in some infants who still have open fontanels, US has limited sensitivity for parenchymal injuries as well as small or peripheral collections and is typically not sufficient for evaluating intracranial trauma [35].

### **Suspected Nonaccidental Trauma**

Nonaccidental trauma is a major public health issue affecting an estimated 144,000 children per year in the United States [36]. The incidence of nonaccidental head trauma (NAHT) is greatest in infants <1 year of age and is associated with a high morbidity and mortality [37]. The goal of imaging in suspected NAHT is twofold: 1) to rapidly identify injuries that may require immediate neurosurgical or medical intervention and 2) to document findings that support the sustained injury was caused by an abusive event.

Nonenhanced head CT should be considered as the initial study in the imaging evaluation of suspected NAHT for rapid and reliable detection of significant acute hemorrhage as well as fracture documentation. However, there is considerable debate regarding which patients should be imaged. NAHT can be an elusive diagnosis, and children may present with symptoms that would not otherwise indicate trauma, such as apneic spells, poor feeding, or irritability. In a series of 173 children with inflicted brain injury, 31% were initially misdiagnosed [38]. Head injury may also be unrecognized even when abuse is suspected. In one study, 37% of children under 2 years of

age with suspected abuse but no overt signs of head injury demonstrated occult head injury by imaging [39]. Another study of patients less than 4 years of age with suspected abuse but no clinical findings of head trauma reported that 29% of those who underwent neuroimaging had evidence of intracranial injury [40]. These findings underscore both the high prevalence of intracranial injury in nonaccidental trauma and the difficulty of clinical diagnosis, which contribute to conflicting imaging recommendations. A retrospective study of 67 patients by Mogbo et al [41] concluded that routine CT scans in infants <2 years of age with suspected abuse and no neurologic findings may not be necessary. Conversely, another review of 74 children with NAHT goes as far as to suggest that if a clinician has sufficient concern to request a skeletal survey, then a head CT should be performed to look for intracranial injury, particularly in younger infants [14].

MRI also has a critical role in assessing these patients. As in any trauma, a negative CT does not preclude the presence of intracranial trauma, and MRI may reveal additional injury. However, the possibility of CT occult lesions has a unique significance in the setting of nonaccidental injury since documentation in addition to treatment is essential. SWI and DWI are particularly helpful in detecting microhemorrhages and axonal shear injury from rotational forces commonly encountered in abuse, and these sequences should be included in any MRI evaluation of suspected NAHT. Multiplanar T1-weighted and T2-weighted imaging can also increase the detection of small subdural collection(s), which is one of the most specific indicators for NAHT. MRI is also helpful in detecting prior or repeated trauma since subacute or chronic blood products may be occult by CT due to a lower density than acute hemorrhage. MRI may help define and record the full extent of injury, and early imaging, if clinically feasible, is recommended in suspected NAHT.

The possibility of cervical spine injury deserves particular attention when imaging suspected NAHT [42]. Significant craniocervical torque and hyperextension forces are common in this setting, and rotational injury to the brainstem and/or upper cervical cord has been proposed as a mechanism of abuse-related hypoxic brain injury and subsequent subdural hematomas [43]. Additional cervical spine imaging should be considered in these infants undergoing cranial MRI, especially those with evidence of neurologic impairment or a mechanism of injury that might result in spinal injury [44]. Soft-tissue injury is more common than fracture, and MRI with fluid-sensitive fat-suppressed sequences can best identify paraspinous muscle edema, ligamentous injury, or spinal cord trauma and may provide evidence that a significant force was sustained [45,46].

Radiographs of the skull are known to have a low predictive value in determining intracranial injury [23]. However, in contrast to accidental head trauma where radiographs have largely been replaced by CT, skull radiographs are still often performed as part of the skeletal survey in evaluation of suspected nonaccidental trauma. It has been generally accepted that skull radiographs and head CT are complementary examinations since fractures in the plane of the transaxial CT image may not be apparent on the head CT examination. Characterization of fracture morphology is particularly important in this setting since some calvarial injuries, such as depressed, wide, or growing skull fractures and involvement of more than one cranial bone, have a significantly greater association with NAHT [47]. A recent study by Prabhu et al [48] reports that 3-D reconstructions can be more accurate in fracture detection and differentiation from accessory sutures. The sensitivity of CT for calvarial fractures and the utility of supplemental plain films is likely highly variable depending on institutional technique and the ability to generate multiplanar reformations.

Head US can easily be performed at the bedside in young infants and can differentiate convexity subdural collections from subarachnoid collections [49]. US is also sensitive in detecting subcortical white-matter tears in the neonate [50]. These typically occur in the frontal and anterior parietal parasagittal regions and represent a shear-type injury that is highly suggestive of NAHT [51]. However, US is insensitive for detecting small acute subdural hematomas, particularly within the interhemispheric fissure and posterior fossa [52], as well as other intracranial injuries, and generally has a limited role in assessing NAHT.

### **Subacute Closed Head Injury With Cognitive and/or Neurological Deficit**

In addition to initial acute intracranial trauma, injury may also be caused by secondary processes such as herniation from worsening parenchymal edema, ischemia, hydrocephalus, and progressive or delayed hemorrhage. During the subacute phase, up to 30% of contusions may cause worsening mass effect with edema from toxic metabolites released into the surrounding tissue and cerebral autoregulation dysfunction [53]. Delayed complications of fractures, such as cerebrospinal fluid leak, leptomeningeal cyst, or meningitis, may also occur.

In an effort to avoid unnecessary radiation exposure and health care costs, it is important to determine which patients would benefit from repeated imaging in the subacute setting. Patients with a significant change in



neurologic status should be reimaged. However, the absence of neurologic changes does not preclude the possibility of secondary or progressive injury. In a retrospective study of 397 pediatric patients diagnosed at time of discharge with intracranial hemorrhage, 2.5% presented with delayed hemorrhage, with only 20% of those exhibiting mental status changes [54]. Hollingworth et al [55] suggested that those who benefit from repeated examination include patients with positive findings on prior CT as well as those with moderate or severe head injury regardless of prior imaging. Using this screening method in a retrospective analysis of more than 250 children, they identified 89% of patients with worsening CT injuries and 100% of patients that proceed to neurosurgical intervention.

MRI is also important in evaluating persistent, unexplained, or new neurological deficits in the subacute setting. The greater sensitivity of MRI for blood products, including small brainstem and infratentorial hemorrhages as well as subacute extraaxial hemorrhage, which becomes less dense on CT over time, and the superior detection of nonhemorrhagic contusions and ischemia may be helpful in the absence of findings on prior CT. However, MRI requires the patient be stable enough to tolerate a lengthier examination. Contrast-enhanced sequences are generally not indicated unless there is a concern for infection such as from penetrating injury or fractures involving the sinuses.

### **Vascular Injuries**

Trauma to the intracranial vessels is infrequently reported and believed to be relatively uncommon in children. Dissection, pseudoaneurysm, and other arterial injuries most often occur extracranially in the cervical region or at the skull base [56] and are typically considered with neck imaging protocols. Still, vascular injuries have been described in pediatric trauma of any severity or mechanism as well as without identifiable antecedent injury. Evaluation is primarily guided by clinical suspicion, and vascular imaging should be considered in patients with evidence of arterial stroke by examination or by imaging, as well as those with fractures extending through the skull base vascular channels [57]. However, there is conflicting data whether pediatric traumatic stroke can be predicted using the same risk factors or clinical signs as adults, leading to the concern that vascular injury may be under-recognized in children [58,59]. Most vascular literature in the pediatric population is confined to small series, and the true incidence and natural history of these injuries in children remains uncertain [60].

Noninvasive imaging with CT angiography (CTA) or magnetic resonance angiography (MRA) is considered the first-line imaging for arterial injury. CTA provides high spatial resolution and rapid assessment but exposes the patient to ionizing radiation, particularly when performed in addition to a necessary noncontrast head CT to assess for acute intracranial injury. MRA can evaluate the intracranial vasculature without radiation and can be performed in conjunction with MRI for assessment of hemorrhage and ischemia; however, it is a lengthier examination and may be difficult to perform emergently. Subtle injuries may be occult on either CTA or MRA, and conventional angiography remains the definitive diagnostic test for vascular injury. However, due to the invasive procedure, radiation, and need for sedation as well as limited availability, conventional angiography is usually reserved for problem solving in cases with uncertain diagnostic imaging and high clinical suspicion.

### **Advanced Imaging**

There has been increasing interest in using higher order imaging techniques, such as positron emission tomography (PET), single-photon emission computed tomography (SPECT) perfusion, functional MRI (fMRI), diffusion tensor imaging (DTI), and proton magnetic resonance spectroscopy (MRS), to assess the functional and microstructural consequences of head trauma [16].

Several small studies suggest that blood flow and perfusion abnormalities on Tc-99m SPECT and decreased metabolic activity on FDG-PET brain imaging can detect subtle traumatic changes in children and often correlate with outcomes, although the prognostic value varies depending on imaging timing [61-65]. fMRI has also shown alterations in language and sensorimotor organization in children with posttraumatic injury, but these studies are confined to small series, and there is a lack of preinjury fMRI data for comparison. Transcranial Doppler ultrasound (TCD) has been used to assess intracranial blood flow in some adult trauma victims. However, the cerebral hemodynamics of young children differ from those of adults, and TCD evaluation for pediatric head trauma is relatively untested at this time. The high radiation doses associated with CT perfusion are typically unwarranted in this population, and MR perfusion has yet to be studied in a substantial pediatric cohort.

Preliminary data suggest that DTI may also visualize injuries not detected by conventional MR sequences, and some studies have shown a strong correlation between decreased fractional anisotropy, particularly in the corpus callosum, and posttraumatic outcomes in children [61,63,66]. MRS may also provide insight into TBI, with

metabolite abnormalities such as increased lactate and decreased N-acetylaspartate correlating with severity of injury and prognosis in small studies, particularly in neonates and infants [62,67,68]. However, although advanced imaging offers future promise for more thorough assessment and understanding of TBI, these modalities remain generally understudied in pediatric head trauma. The small sample sizes, variability in timing, and differences in technique in the literature are particularly problematic in pediatric assessment due to the continuously changing normative values of the developing brain. There are few validated data to support the routine use of these techniques in clinical evaluation at this time.

## Summary

- Noncontrast CT is the primary study for emergent evaluation of suspected intracranial injury in children, although the decision to image should consider the increased risks of ionizing radiation in this population.
- Imaging is typically not indicated in children with minor head trauma and no signs or symptoms. However, neurologic examination can be difficult in younger children, and imaging in this setting may be appropriate if the clinical assessment is uncertain or indeterminate.
- MRI is more sensitive than CT for small parenchymal lesions, ischemia, and shear injury and may be particularly helpful in patients whose clinical status is discordant with negative CT findings, those with moderate or severe injury, and in cases of suspected nonaccidental trauma.
- Advanced imaging techniques may visualize injury occult by standard imaging but remain relatively untested in the pediatric population with few data to support routine clinical use at this time.

## 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, both because of 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 to 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 (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as “Varies”.		

## Supporting Documents

- [ACR Appropriateness Criteria® Overview](#)
- [Procedure Information](#)
- [Evidence Table](#)

## References

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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.