New 2019

American College of Radiology
ACR Appropriateness Criteria®
Head Trauma-Child

Variant: 1 Child. Minor acute blunt head trauma. Very low risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
Radiography skull	Usually Not Appropriate	☢☢
Arteriography cerebral	Usually Not Appropriate	☢☢☢☢
MRA head without and with IV contrast	Usually Not Appropriate	O
MRA head without IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRI head without IV contrast	Usually Not Appropriate	O
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	☢☢☢
CTA head with IV contrast	Usually Not Appropriate	☢☢☢☢

Variant: 2 Child. Minor acute blunt head trauma. Intermediate risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
CT head without IV contrast	May Be Appropriate	☢☢☢
Radiography skull	Usually Not Appropriate	☢☢
Arteriography cerebral	Usually Not Appropriate	☢☢☢☢
MRA head without and with IV contrast	Usually Not Appropriate	O
MRA head without IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRI head without IV contrast	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CTA head with IV contrast	Usually Not Appropriate	☢☢☢☢

Variant: 3 Child. Minor acute blunt head trauma. High risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
CT head without IV contrast	Usually Appropriate	☢☢☢
Radiography skull	Usually Not Appropriate	☢☢
Arteriography cerebral	Usually Not Appropriate	☢☢☢☢
MRA head without and with IV contrast	Usually Not Appropriate	O
MRA head without IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRI head without IV contrast	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢

CTA head with IV contrast	Usually Not Appropriate	☢☢☢☢

Variant: 4 Child. Moderate or severe acute blunt head trauma (GCS less than or equal to 13). Excluding suspected abusive head trauma. Initial imaging.

Procedure	Appropriateness Category	Peds Relative Radiation Level
CT head without IV contrast	Usually Appropriate	☢☢☢
Radiography skull	Usually Not Appropriate	☢☢
Arteriography cerebral	Usually Not Appropriate	☢☢☢☢
MRA head without and with IV contrast	Usually Not Appropriate	O
MRA head without IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRI head without IV contrast	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CTA head with IV contrast	Usually Not Appropriate	☢☢☢☢

Variant: 5 Child. Subacute blunt head trauma with cognitive or neurologic signs.

Procedure	Appropriateness Category	Peds Relative Radiation Level
MRI head without IV contrast	Usually Appropriate	O
CT head without IV contrast	Usually Appropriate	☢☢☢
Radiography skull	Usually Not Appropriate	☢☢
Arteriography cerebral	Usually Not Appropriate	☢☢☢☢
MRA head without and with IV contrast	Usually Not Appropriate	O
MRA head without IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢
CTA head with IV contrast	Usually Not Appropriate	☢☢☢☢

Variant: 6 Child. Chronic blunt head trauma with new or progressive cognitive or neurologic deficits. Excluding suspected abusive head trauma and post-traumatic seizure.

Procedure	Appropriateness Category	Peds Relative Radiation Level
MRI head without IV contrast	Usually Appropriate	O
MRA head without IV contrast	May Be Appropriate (Disagreement)	O
MRI head without and with IV contrast	May Be Appropriate (Disagreement)	O
MRI head without IV contrast with DTI	May Be Appropriate (Disagreement)	O
CT head without IV contrast	May Be Appropriate (Disagreement)	☢☢☢
Radiography skull	Usually Not Appropriate	☢☢
Arteriography cerebral	Usually Not Appropriate	☢☢☢☢
MR spectroscopy head without IV contrast	Usually Not Appropriate	O
MRA head without and with IV contrast	Usually Not Appropriate	O
MRI functional (fMRI) head without IV contrast	Usually Not Appropriate	O
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢☢

CTA head with IV contrast	Usually Not Appropriate	☢☢☢☢
FDG-PET/CT brain	Usually Not Appropriate	☢☢☢☢

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Summary of Literature Review

Introduction/Background

Head trauma is a common indication for cranial imaging in children. Although traumatic brain injury is a leading cause of death and disability in children [1], the vast majority of head injuries are uncomplicated, transient, and do not require intervention [2]. The necessity of identifying clinically relevant, potentially treatable injury must be weighed against the risks of performing unwarranted imaging studies, possible unnecessary sedation, and inappropriate resource utilization.

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 is often defined by a Glasgow Coma Scale (GCS) of 14 or 15 [3]. The probability of significant anatomic injury in minor head trauma is low. Approximately 3% to 5% of children with minor head trauma have identifiable abnormalities by imaging but typically less than 1% requires neurosurgical intervention [4-7].

In an effort to avoid unnecessary testing, there has been debate regarding which children with minor head trauma can safely forgo imaging. Several clinical decision rules and algorithms for acute minor pediatric head trauma have been proposed. The majority of these, including the National Institute for Health and Care Excellence (NICE) guidelines, the Children's Head Injury Algorithm for the Prediction of Important Clinical Events (CHALICE), the Canadian Assessment of Tomography for Childhood Head Injury (CATCH), and the National Emergency X-Radiography Utilization Study (NEXUS), have been derived from retrospective review [8-11]. The largest prospective dedicated pediatric trial, which included more than 40,000 children, was conducted by the Pediatric Emergency Care Applied Research Network (PECARN) in 2009 [5]. The initial PECARN study investigated children both <2 years of age and those ≥2 years of age and identified clinical criteria to stratify those with very low, intermediate, and relatively high risk for clinically important acute traumatic brain injury in the setting of minor blunt head trauma (see Appendix 1). This clinical decision rule identified children at very low risk for clinically important traumatic brain injury with a 99.9% negative predictive value (NPV) and a 96.8% sensitivity in those ≥2 years of age and a 100% NPV and sensitivity in those <2 years of age [5].

Several subsequent studies have independently validated these clinical decision rules. A large prospective trial in Australia and New Zealand demonstrated the PECARN criteria for very low risk of clinically significant brain injury to have a 100% NPV and 99% sensitivity in children ≥2 years of age and a 100% NPV and sensitivity in children <2 years of age [12]. The sensitivities of the CATCH and CHALICE criteria in this study were 95% and 92%, respectively, and the CATCH algorithm resulted in a greater number of CT scans performed. A large prospective validation study of the NEXUS II criteria in children demonstrated 95% sensitivity for intracranial injury but resulted in a relatively high rate of CTs [13]. Additional smaller validation trials in the United States and abroad have also determined the PECARN criteria for very low risk criteria to be 100% sensitive [14-17].

Although precise comparison among the clinical decision rules is limited by differences in methodology and outcomes, the PECARN criteria remain the most widely validated, particularly for very young children, because of the high sensitivity and strong validation; the PECARN guidelines have been incorporated into the clinical variants for acute minor pediatric head trauma imaging. The PECARN criteria are summarized in Appendix 1.

Note that evaluation in the setting of possible nonaccidental trauma is considered separately under the ACR Appropriateness Criteria® topic on "Suspected Physical Abuse – Child" [18]. Additionally, the PECARN clinical decision rules, as well as this document, address blunt head trauma. Penetrating injury of the head and neck is largely beyond the scope of this document. Trauma to the intracranial vessels is infrequently reported and believed to be relatively uncommon in children, although 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 [19]. Still, vascular injuries have been described in pediatric trauma of any severity or mechanism as well as without identifiable antecedent trauma. Initial evaluation is primarily guided by clinical suspicion, such as the presence of focal deficits. Dissection, pseudoaneurysm, and other arterial injuries most often occur extracranially in the cervical region or at the skull base [20] and are typically considered with neck imaging protocols.

Special Imaging Considerations

CT

Initial head CT for acute trauma evaluation should be performed without intravenous (IV) contrast because the presence of contrast may obscure subtle hemorrhages. Dedicated pediatric head CT parameters with protocols tailored to patient size should always be used [21] (see the Image Gently website for additional information). Multiplanar and 3-D–reconstructed CT images increase the sensitivity of CT for fractures and small hemorrhages and ideally should be performed [22,23].

MRI

The identification of small bleeds, particularly in the posterior fossa or brainstem, is further increased with hemesensitive techniques such as susceptibility-weighted imaging [2,24-26]. Diffusion-weighted imaging can be helpful in identifying nonhemorrhagic injuries and associated ischemia as well [27]. Standard MRI sequences have a low sensitivity for skull fractures.

In recent years, limited rapid brain MRI techniques have been investigated as a means to evaluate pediatric head trauma without the need for sedation. Preliminary data suggest variations of this method may be helpful in following known intracranial hemorrhage documented by CT, but the sensitivity of rapid MRI in lieu of CT remains uncertain [28-31]. Additionally, there is no single uniform definition for rapid brain MRI techniques, and protocols vary among institutions. This is a rapidly evolving area of investigation but, at this time, there is no distinct procedural assignment for fast brain MRI in the ACR lexicon.

Ultrasound

A few recent studies in children have suggested ultrasound (US) can detect calvarial fractures with a sensitivity close to that of CT [32]. However, even in infants with open fontanelles, in which US imaging of the brain is possible, US lacks sensitivity for small subdural hematomas, particularly in the posterior fossa, as well as other small extra-axial hemorrhages. Because intracranial injury can occur with or without fractures and US does not have a high sensitivity for hemorrhages, it does not currently have a significant role in head trauma imaging and as such is not considered in these variant procedures.

Discussion of Procedures by Variant

Variant 1: Child. Minor acute blunt head trauma. Very low risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.

Variant 1: Child. Minor acute blunt head trauma. Very low risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.
A. Radiography skull

Not all skull fractures are evident by radiographs, and up to 50% of intracranial injuries in children occur in the absence of fracture [2,33]. Therefore, radiographs are not sufficient to evaluate for traumatic injury [9].

Variant 1: Child. Minor acute blunt head trauma. Very low risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.
B. CT head with IV contrast

In the setting of acute head trauma (<24 hours), very low risk was defined by PECARN for children ≥2 years of age as those with a GCS of 15, a normal mental status, no clinical signs of basilar skull fracture, no loss of consciousness, no vomiting, no severe injury mechanism, or severe headache. The original PECARN trial by Kuppermann et al [5] analyzed more than 25,000 children ≥2 years of age and demonstrated >96% sensitivity and 99.9% NPV for significant head injury using these decision rules with an estimated risk of clinically important traumatic brain injury of <0.05%.

There have been several subsequent studies providing external validation in a setting outside the initial derivation population. A multicenter trial conducted in Australia and New Zealand in more than 11,000 children ≥2 years of age demonstrated a 99% sensitivity and 100% NPV for the very low-risk PECARN criteria [12]. Several smaller studies of 1,000 to 2,400 children evaluating the PECARN criteria for very low risk all demonstrated a sensitivity of 100% [14-16,31]. Given the robustly validated data confirming near perfect sensitivity, children meeting PECARN criteria for very low risk can safely forgo CT evaluation for acute head trauma.

In children <2 years of age, very low risk was defined by the PECARN study as those with a GCS of 15 and none of the following: other signs of altered mental status, palpable skull fracture, nonfrontal scalp hematoma, loss of consciousness ≥5 seconds, severe mechanism of injury, or not acting normally per parents. The original large prospective trial of more than 14,000 children <2 years of age by Kuppermann et al [5] demonstrated >99% sensitivity and 100% NPV using these decision criteria. Subsequent external validation by Babl et al [12] in 2014 derived from over 4,000 children <2 years of age demonstrated 100% sensitivity and 100% NPV for these very low-risk criteria, with an estimated risk of clinically important traumatic brain injury of <0.02%. Children meeting these criteria may safely forgo CT evaluation for acute head trauma.

Variant 1: Child. Minor acute blunt head trauma. Very low risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.
C. CTA head

There is no relevant literature or expert consensus supporting the use of CT angiography (CTA) in the initial evaluation of children with minor trauma and very low risk for intracranial injury.

Variant 1: Child. Minor acute blunt head trauma. Very low risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.
D. MRI head

There is no relevant literature or expert consensus supporting the use of MRI in the initial evaluation of children with minor trauma and very low risk for intracranial injury.

Variant 1: Child. Minor acute blunt head trauma. Very low risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.
E. MRA head

There is no relevant literature or expert consensus supporting the use of MR angiography (MRA) in the initial evaluation of children with minor trauma and very low risk for intracranial injury.

Variant 1: Child. Minor acute blunt head trauma. Very low risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.
F. Arteriography cerebral

There is no relevant literature or expert consensus supporting the use of conventional cerebral angiography in the initial evaluation of children with minor trauma and very low risk for intracranial injury.

Variant 2: Child. Minor acute blunt head trauma. Intermediate risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.

Variant 2: Child. Minor acute blunt head trauma. Intermediate risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.
A. Radiography skull

Not all skull fractures are evident by radiographs, and up to 50% of intracranial injuries in children occur in the absence of fracture [2,33]. Therefore, radiographs are not sufficient to evaluate for traumatic injury [9].

Variant 2: Child. Minor acute blunt head trauma. Intermediate risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.
B. CT head

Children ≥2 years of age with acute minor head trauma considered to be at intermediate risk per PECARN criteria are those with a GCS of 15, normal mental status, and no evidence of basilar skull fracture but who may have a history of loss of consciousness, vomiting, severe mechanism of injury, or severe headache. The likelihood of significant injury in these children is still quite low, estimated at approximately 0.8% [5].

Children <2 years of age with acute minor head trauma considered to be at intermediate risk by PECARN criteria are those with a GCS of 15, normal mental status, and no evidence of palpable skull fracture but may have a history of loss of consciousness ≥5 seconds, severe mechanism of injury, or not acting normally per parent. The likelihood of significant injury in these children is also still low, estimated at approximately 0.9% [5].

CT may be considered in lieu of careful clinical observation in instances of parental preference, multiple risk factors, worsening clinical symptoms or signs during observation, and in young infants in which observational assessment is more challenging.

Variant 2: Child. Minor acute blunt head trauma. Intermediate risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging. C. CTA head

There is no relevant literature or expert consensus supporting the use of CTA in the initial evaluation of children with minor head injury and intermediate risk for intracranial injury.

Variant 2: Child. Minor acute blunt head trauma. Intermediate risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging. D. MRI head

MRI is sensitive for acute intracranial hemorrhage and other intracranial traumatic injury. However, MRI in the acute setting is frequently impractical. The examination requires preimaging safety screening, is significantly longer than CT, and younger children often need sedation to compete the examination, further delaying time to imaging. IV contrast is typically of little use in evaluation of acute trauma.

Variant 2: Child. Minor acute blunt head trauma. Intermediate risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging. E. MRA head

There is no relevant literature or expert consensus supporting the use of MRA in the initial evaluation of children with minor head injury and intermediate risk for intracranial injury.

Variant 2: Child. Minor acute blunt head trauma. Intermediate risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging. F. Arteriography cerebral

There is no relevant literature or expert consensus supporting the use of conventional cerebral angiography in the initial evaluation of children with minor head injury and intermediate risk for intracranial injury.

Variant 3: Child. Minor acute blunt head trauma. High risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.

Variant 3: Child. Minor acute blunt head trauma. High risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging. A. Radiography skull

Not all skull fractures are evident by radiographs, and up to 50% of intracranial injuries in children occur in the absence of fracture [2,33]. Therefore, radiographs are not sufficient to evaluate for traumatic injury [9].

Variant 3: Child. Minor acute blunt head trauma. High risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging. B. CT head

Children ≥2 years of age considered at high risk for clinically important TBI by PECARN criteria include those with a GCS of 14, other signs of altered mental status, or signs of a basilar skull fracture. The risk of clinically important intracranial injury in these patients is estimated at approximately 4.3% [5].

High-risk factors for intracranial injury from minor head trauma in children <2 years of age by PECARN criteria include those with a GCS of 14, other signs of altered mental status, or signs of any palpable skull fracture. The risk of clinically significant intracranial injury in these patients is estimated at approximately 4.4% [5].

Although still relatively uncommon, the risk of interveneable injury is substantial enough that imaging is strongly recommended. CT has the advantage of rapid acquisition and excellent sensitivity for acute intracranial hemorrhage and fractures.

Variant 3: Child. Minor acute blunt head trauma. High risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.
C. CTA head

Most vascular injuries in children are cervical, and there remains a relative paucity of evidence-based literature regarding the prevalence and nature of isolated intracranial vascular injury in pediatric head trauma. Intracranial vascular injuries have been reported in children with minor head trauma but are likely uncommon [19,34,35]. Vascular imaging is usually not a standard component of initial first-line imaging evaluation in patients with minor head trauma. However, if there are clinical symptoms or signs on other imaging raising suspicion for vascular injury, such as basilar fracture through a vascular canal, CTA may be considered for rapid assessment in the acute setting.

Variant 3: Child. Minor acute blunt head trauma. High risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.
D. MRI head

MRI is sensitive for acute intracranial hemorrhage and other intracranial traumatic injuries. However, MRI in the emergent setting is frequently impractical. The examination is typically significantly longer than CT, requires safety screening, results take longer to obtain, and younger children often need sedation to complete the examination, further delaying assessment. IV contrast is typically of little use in evaluation of acute trauma.

Variant 3: Child. Minor acute blunt head trauma. High risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.
E. MRA head

There remains a relative paucity of evidence-based literature regarding the prevalence and nature of vascular injury in minor pediatric head trauma. Vascular injuries have been reported in children with minor head trauma but are likely uncommon [19,34,35]. Vascular imaging is generally not a standard component of initial first-line imaging evaluation in patients with minor head trauma. If there are clinical or other imaging signs suggestive of vascular injury, MRA could be considered. MRA can be performed without IV contrast using time-of-flight sequences, although IV contrast may be helpful for clarification in some instances, particularly when imaging is limited by tortuosity or flow artifact.

Variant 3: Child. Minor acute blunt head trauma. High risk for clinically important brain injury per PECARN criteria. Excluding suspected abusive head trauma. Initial imaging.
F. Arteriography cerebral

There is no relevant literature or expert consensus regarding the use of conventional cerebral angiography in the initial evaluation of children ≥2 years of age with minor head injury and intermediate risk for intracranial injury.

Variant 4: Child. Moderate or severe acute blunt head trauma (GCS less than or equal to 13). Excluding suspected abusive head trauma. Initial imaging.

Variant 4: Child. Moderate or severe acute blunt head trauma (GCS less than or equal to 13). Excluding suspected abusive head trauma. Initial imaging.
A. Radiography skull

Not all skull fractures are evident by radiographs, and up to 50% of intracranial injuries in children occur in the absence of fracture [2,33]. Therefore, radiographs are not sufficient to evaluate for traumatic injury [9].

Variant 4: Child. Moderate or severe acute blunt head trauma (GCS less than or equal to 13). Excluding suspected abusive head trauma. Initial imaging.
B. CT head

Moderate and severe head injury is typically associated with post-traumatic mental status changes. Despite the lower incidence and fewer numbers of studies addressing more significant injury in children, there is little debate regarding the need for imaging because of the greater incidence of intracranial injury in patients with decreased GCS [36]. CT has the advantage of rapid acquisition and excellent sensitivity for traumatic injuries, such as herniation or hemorrhage, which benefit from prompt intervention.

Variant 4: Child. Moderate or severe acute blunt head trauma (GCS less than or equal to 13). Excluding suspected abusive head trauma. Initial imaging.
C. CTA head

Imaging for vascular injury is primarily guided by clinical suspicion or imaging findings, such as fracture through the skull base or vascular channels. Most literature regarding vascular injury in the pediatric population is confined to small series, and the true incidence and natural history of these injuries in children remains uncertain [19]. However, 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 or vascular channels, which are typically encountered in higher impact traumas [37,38]. CTA provides high spatial resolution and rapid assessment for vascular injuries.

Variant 4: Child. Moderate or severe acute blunt head trauma (GCS less than or equal to 13). Excluding suspected abusive head trauma. Initial imaging.
D. MRI head

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 [25,39]. However, because of the time required to arrange and perform the examination and possible need for sedation, MRI can be difficult to accomplish emergently and should not delay evaluation. IV contrast is typically of little use in evaluation of acute trauma.

Variant 4: Child. Moderate or severe acute blunt head trauma (GCS less than or equal to 13). Excluding suspected abusive head trauma. Initial imaging.
E. MRA head

MRA can evaluate the intracranial vasculature and can be performed in conjunction with MRI when vascular injury is clinically suspected. However, as with standard MRI, this examination may be difficult to perform emergently. MRA can be performed without contrast using time-of-flight sequences, although IV contrast may be helpful for clarification in some instances, particularly when imaging is limited by tortuosity or flow artifact.

Variant 4: Child. Moderate or severe acute blunt head trauma (GCS less than or equal to 13). Excluding suspected abusive head trauma. Initial imaging.
F. Arteriography cerebral

Conventional cerebral angiography remains the definitive diagnostic test for vascular injury and can demonstrate subtle abnormalities that may be occult on either CTA or MRA. However, because of the invasive procedure and need for sedation, conventional angiography should be reserved for problem solving in cases with uncertain noninvasive imaging and high clinical suspicion of vascular injury.

Variant 5: Child. Subacute blunt head trauma with cognitive or neurologic signs.

The exact definition of subacute injury varies, but subacute head injury is typically defined as occurring between 8 days and 1 month after the initial traumatic event [40,41]. Injury may 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 [42].

Variant 5: Child. Subacute blunt head trauma with cognitive or neurologic signs.
A. Radiography skull

There is no relevant literature or expert consensus regarding the use of skull radiographs in children with subacute head trauma and cognitive or neurologic signs.

Variant 5: Child. Subacute blunt head trauma with cognitive or neurologic signs.
B. CT head

Patients with a significant change in neurologic status are at a high risk for progressive intracranial injury, may require neurosurgical intervention, and may benefit from imaging [43]. CT can provide rapid, accurate assessment for progressive hemorrhage, herniation, and hydrocephalus. In one study of 116 children with CT positive for traumatic head injury, 9 patients experienced neurologic deterioration, 6 of whom required neurosurgery [44]. However, all patients undergoing intervention were identified clinically, without imaging, reflecting the importance of clinical examination in this population.

Variant 5: Child. Subacute blunt head trauma with cognitive or neurologic signs.
C. CTA head

Imaging for vascular injury is primarily guided by clinical suspicion. Most literature regarding vascular injury in the pediatric population is confined to small series, and the true incidence and natural history of these injuries in children remains uncertain [19]. However, 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 [37]. CTA provides high spatial resolution and rapid assessment for vascular injury.

Variant 5: Child. Subacute blunt head trauma with cognitive or neurologic signs.
D. MRI head

MRI may be helpful in evaluating persistent, unexplained, or new neurological deficits in the subacute setting. MRI has a high sensitivity for blood products, including small brainstem and infratentorial hemorrhages as well as subacute hemorrhage, which becomes less dense on CT over time. The superior detection of nonhemorrhagic contusions and ischemia may be particularly helpful in the absence of findings on prior CT [38]. However, a standard MRI requires the patient be stable enough to tolerate a lengthier examination.

In recent years, limited rapid MRI techniques have been investigated as a means to evaluate pediatric head trauma without the need for sedation. Preliminary data suggest variations of this method may be helpful in following known intracranial hemorrhage documented by CT, but the sensitivity of rapid MRI in lieu of CT remains uncertain [28-31].

Contrast-enhanced sequences are generally not indicated unless there is a concern for infection, such as from penetrating injury or fractures involving the sinuses.

Variant 5: Child. Subacute blunt head trauma with cognitive or neurologic signs.
E. MRA head

MRA can evaluate the intracranial vasculature and can be performed in conjunction with MRI when vascular injury is clinically suspected. However, as with standard MRI, it may be difficult to perform emergently. MRA can be performed without IV contrast using time-of-flight sequences, although IV contrast may be helpful for clarification in some instances, particularly when imaging is limited by tortuosity or flow artifact.

Variant 5: Child. Subacute blunt head trauma with cognitive or neurologic signs.
F. Arteriography cerebral

Conventional cerebral angiography remains the definitive diagnostic test for vascular injury and can demonstrate subtle abnormalities that may be occult on either CTA or MRA. However, because of the invasive procedure and need for sedation, conventional angiography should be reserved for problem solving in cases with uncertain noninvasive imaging and high clinical suspicion of injury.

Variant 6: Child. Chronic blunt head trauma with new or progressive cognitive or neurologic deficits. Excluding suspected abusive head trauma and post-traumatic seizure.

Postconcussion symptoms are common after head injury. In mild traumatic cases, imaging in the chronic setting is usually negative, and in cases in which more severe trauma or prior intracranial injury has occurred, imaging in the chronic period rarely reveals additional actionable changes [45-47].

Variant 6: Child. Chronic blunt head trauma with new or progressive cognitive or neurologic deficits. Excluding suspected abusive head trauma and post-traumatic seizure.
A. Radiography skull

Although leptomeningeal cysts ("growing fractures”) are a potential complication of prior skull fracture, particularly in very young children, these are often evident by clinical palpation [48]. There is no relevant literature or expert consensus regarding the use of skull radiographs in children with chronic traumatic head injury.

Variant 6: Child. Chronic blunt head trauma with new or progressive cognitive or neurologic deficits. Excluding suspected abusive head trauma and post-traumatic seizure.
B. CT head

There are little data regarding the use of CT in children in the chronic post-traumatic setting. A few studies addressing CT is this setting support a low diagnostic yield for imaging in the post-traumatic setting [46,47]. One study of 52 children with chronic head injury demonstrated CTs performed on only 8 patients [46]. One patient was found to have a fracture. No intracranial injury was detected. CT has limited sensitivity for nonacute intracranial hemorrhage and small contusions. CT likely has little role in evaluating most children with chronic head injury but may be a consideration when results are needed quickly.

Variant 6: Child. Chronic blunt head trauma with new or progressive cognitive or neurologic deficits. Excluding suspected abusive head trauma and post-traumatic seizure.
C. CTA head

Although late post-traumatic vascular complications, such as pseudoaneurysm, can occur, there is no substantial literature or expert consensus supporting the use of CTA in children in chronic traumatic injury. Imaging for vascular injury is primarily guided by clinical suspicion or imaging findings, such as fracture through the skull base or vascular channels. In these instances, CTA provides high spatial resolution and rapid assessment for vascular injury.

Variant 6: Child. Chronic blunt head trauma with new or progressive cognitive or neurologic deficits. Excluding suspected abusive head trauma and post-traumatic seizure.
D. MRI head

MRI in the chronic setting may reveal areas of microhemorrhage or encephalomacia related to prior injury. Hemesensitive techniques, such as susceptibility-weighted imaging, can be particularly helpful. However, imaging in the chronic period, particularly in the setting of mild trauma, is often low yield and of indeterminate significance. MRI can be helpful to exclude development of confounding nontraumatic causes of clinical change, such as a tumor. When post-traumatic findings are present, they rarely result in a change in management. One study of MRI performed in 134 children after concussion demonstrated a 1.5% positivity rate for traumatic injury but with no change in clinical management [47]. Another study of 427 children with chronic post-traumatic symptoms demonstrated microhemorrhage in only 2 children (0.5%) [45]. Other studies have also concluded a low yield of positive traumatic findings and no findings requiring intervention [46,49]. Some studies [41,49] have used segmentation analysis to demonstrate areas of cortical thinning in pediatric patients that may correlate with post-traumatic symptoms, although more robust investigation is warranted. Contrast is typically not useful for evaluating post-traumatic injury but may be considered if there is clinical suspicion for an alternative etiology of the patient's symptoms.

Variant 6: Child. Chronic blunt head trauma with new or progressive cognitive or neurologic deficits. Excluding suspected abusive head trauma and post-traumatic seizure.
E. MRA head

Although late post-traumatic vascular complications, such as pseudoaneurysm, can occur, there is no substantial literature or expert consensus supporting the use of MRA in children in chronic traumatic injury. Imaging for vascular injury is primarily guided by clinical suspicion or imaging findings, such as fracture through the skull base or vascular channels. MRA can be performed without IV contrast using time-of-flight sequences, although contrast may be helpful for clarification in some instances, particularly when imaging is limited by tortuosity or flow artifact.

Variant 6: Child. Chronic blunt head trauma with new or progressive cognitive or neurologic deficits. Excluding suspected abusive head trauma and post-traumatic seizure.
F. Arteriography cerebral

There is no relevant literature or expert consensus regarding the use of conventional cerebral angiography in evaluating children with chronic head trauma.

Variant 6: Child. Chronic blunt head trauma with new or progressive cognitive or neurologic deficits. Excluding suspected abusive head trauma and post-traumatic seizure.
G. FDG-PET/CT Brain

There is no relevant literature or expert consensus regarding the use of fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT of the brain in evaluating children with chronic head trauma.

Variant 6: Child. Chronic blunt head trauma with new or progressive cognitive or neurologic deficits. Excluding suspected abusive head trauma and post-traumatic seizure.
H. MR Spectroscopy Head

There have been few studies investigating spectroscopic changes in the brain of children with prior head trauma. Some preliminary data suggest there may be reduced *N*-acetyl aspartate metabolites in the corpus callosum in these children [50]. However, these studies are limited by patient selection and very small sample size, and the clinical relevance of these findings in children is unclear.

Variant 6: Child. Chronic blunt head trauma with new or progressive cognitive or neurologic deficits. Excluding suspected abusive head trauma and post-traumatic seizure.
I. MRI Head without IV Contrast with DTI

There have been a few studies suggesting that post-traumatic microstructural changes in the white matter can be identified with diffusion-tensor imaging (DTI). However, these studies are usually in older adolescents and young adults, and the data remain limited by small sample sizes in select populations. There are little data regarding the routine use of this technique in children.

Variant 6: Child. Chronic blunt head trauma with new or progressive cognitive or neurologic deficits. Excluding suspected abusive head trauma and post-traumatic seizure.
J. MRI functional (fMRI) head without IV contrast

Some preliminary work suggests that changes in connectivity in pediatric patients may correlate with postconcussion symptoms [51,52]. However, studies are limited by small, select sample sizes, and there remains no strong literature to support the routine use of functional MRI (fMRI) in evaluation of post-traumatic head injury.

Summary of Highlights

- **Variant 1:** Imaging is not recommended for children with minor acute blunt head trauma (excluding suspected abusive head trauma) with very low risk for clinically important brain injury per PECARN criteria.
- **Variant 2:** Careful clinical observation or CT head without IV contrast may be appropriate for the initial imaging of children with minor acute blunt head trauma (excluding suspected abusive head trauma) with intermediate risk for clinically important brain injury per PECARN criteria.
- **Variant 3:** CT head without IV contrast is usually appropriate for the initial imaging of children with minor acute blunt head trauma (excluding suspected abusive head trauma) with high risk for clinically important brain injury per PECARN criteria.
- **Variant 4:** CT head without IV contrast is usually appropriate for the initial imaging of children with moderate or severe acute blunt head trauma (GCS ≤13), excluding suspected abusive head trauma.

- **Variant 5:** CT head without IV contrast or MRI head without IV contrast is usually appropriate for children with subacute blunt head trauma with cognitive or neurologic signs. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 6:** MRI head without IV contrast is usually appropriate for children with chronic blunt head trauma with new or progressive cognitive or neurologic deficits (excluding suspected abusive head trauma and post-traumatic seizure). The panel did not agree on recommending CT head without IV contrast, MRA head without IV contrast, MRI head without and with IV contrast, or MRI head without IV contrast with DTI in this clinical scenario. There is insufficient medical literature to conclude whether or not these patients would benefit from routine use of these procedures.

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.

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.”

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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.

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