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American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Head Trauma**

Variant 1: **Minor or mild acute closed head injury (GCS ≥13), imaging not indicated by NOC or CCHR or NEXUS-II clinical criteria (see Appendix 1). Initial study.**

Radiologic Procedure	Rating	Comments	RRL*
CT head without IV contrast	2		☢☢☢
MRI head without IV contrast	1		O
MRA head and neck without IV contrast	1		O
MRA head and neck without and with IV contrast	1		O
CT head without and with IV contrast	1		☢☢☢
CTA head and neck with IV contrast	1		☢☢☢
MRI head without and with IV contrast	1		O
MRI head without IV contrast with DTI	1		O
CT head with IV contrast	1		☢☢☢
X-ray skull	1		☢
FDG-PET/CT head	1		☢☢☢☢
Arteriography cervicocerebral	1		☢☢☢
Tc-99m HMPAO SPECT head	1		☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 2: **Minor or mild acute closed head injury (GCS ≥13), imaging indicated by NOC or CCHR or NEXUS-II clinical criteria (see Appendix 1). Initial study.**

Radiologic Procedure	Rating	Comments	RRL*
CT head without IV contrast	9		☢☢☢
MRI head without IV contrast	5	This procedure may be appropriate in the outpatient setting, but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	O
MRA head and neck without IV contrast	2		O
MRA head and neck without and with IV contrast	2		O
CTA head and neck with IV contrast	1		☢☢☢
MRI head without and with IV contrast	1		O
MRI head without IV contrast with DTI	1		O
CT head without and with IV contrast	1		☢☢☢
CT head with IV contrast	1		☢☢☢
Tc-99m HMPAO SPECT head	1		☢☢☢☢
FDG-PET/CT head	1		☢☢☢☢
X-ray skull	1		☢
Arteriography cervicocerebral	1		☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 3: **Moderate or severe acute closed head injury (GCS <13). Initial study.**

Radiologic Procedure	Rating	Comments	RRL*
CT head without IV contrast	9		☢☢☢
MRI head without IV contrast	2		O
CTA head and neck with IV contrast	2		☢☢☢
MRA head and neck without IV contrast	1		O
MRA head and neck without and with IV contrast	1		O
CT head without and with IV contrast	1		☢☢☢
MRI head without and with IV contrast	1		O
MRI head without IV contrast with DTI	1		O
X-ray skull	1		☢
CT head with IV contrast	1		☢☢☢
FDG-PET/CT head	1		☢☢☢☢
Arteriography cervicocerebral	1		☢☢☢
Tc-99m HMPAO SPECT head	1		☢☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Head Trauma**

Variant 4: **Short-term follow-up imaging of acute traumatic brain injury. No neurologic deterioration.**

Radiologic Procedure	Rating	Comments	RRL*
CT head without IV contrast	5	This procedure can be used in patients with risk factors (see narrative).	☢☢☢
CTA head and neck with IV contrast	2		☢☢☢
MRI head without IV contrast	2		O
MRA head and neck without IV contrast	2		O
MRA head and neck without and with IV contrast	2		O
CT head without and with IV contrast	1		☢☢☢
CT head with IV contrast	1		☢☢☢
MRI head without and with IV contrast	1		O
MRI head without IV contrast with DTI	1		O
X-ray skull	1		☢
FDG-PET/CT head	1		☢☢☢☢
Tc-99m HMPAO SPECT head	1		☢☢☢☢
Arteriography cervicocerebral	1		☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 5: **Short-term follow-up imaging of acute traumatic brain injury. Neurologic deterioration, delayed recovery, or persistent unexplained deficits.**

Radiologic Procedure	Rating	Comments	RRL*
CT head without IV contrast	9		☢☢☢
MRI head without IV contrast	8	This procedure is complementary if CT does not explain clinical symptoms.	O
CT head without and with IV contrast	5	This procedure can be used in patients with suspected post-traumatic infection.	☢☢☢
CTA head and neck with IV contrast	5	See Variant 7. This procedure may be appropriate in patients with suspected post-traumatic infarction, but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	☢☢☢
MRI head without and with IV contrast	5	This procedure may be appropriate in patients with suspected post-traumatic infection, but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	O
MRA head and neck without IV contrast	5	See Variant 7. This procedure may be appropriate in patients with suspected post-traumatic infarction, but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	O
MRA head and neck without and with IV contrast	5	See Variant 7. This procedure may be appropriate in patients with suspected post-traumatic infarction, but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	O
CT head with IV contrast	4	This procedure can be used in patients with suspected post-traumatic infection.	☢☢☢
MRI head without IV contrast with DTI	2		O
X-ray skull	1		☢
FDG-PET/CT head	1		☢☢☢☢
Tc-99m HMPAO SPECT head	1		☢☢☢☢
Arteriography cervicocerebral	1		☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 6: **Subacute or chronic traumatic brain injury with new cognitive and/or neurologic deficit(s).**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without IV contrast	9		O
CT head without IV contrast	7	This procedure is an alternative; it is usually the first-line procedure in rapidly evolving new neurologic deficits or if MRI is contraindicated.	☢☢☢
MRA head and neck without IV contrast	3		O
MRA head and neck without and with IV contrast	3		O
FDG-PET/CT head	2		☢☢☢☢
CTA head and neck with IV contrast	2		☢☢☢
MRI functional (fMRI) head without IV contrast	2		O
MR spectroscopy head without IV contrast	2		O
MRI head without and with IV contrast	1		O
MRI head without IV contrast with DTI	1		O
CT head without and with IV contrast	1		☢☢☢
CT head with IV contrast	1		☢☢☢
X-ray skull	1		☢
Tc-99m HMPAO SPECT head	1		☢☢☢☢
Arteriography cervicocerebral	1		☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 7: **Suspected intracranial arterial injury.**

Radiologic Procedure	Rating	Comments	RRL*
CTA head and neck with IV contrast	9	This procedure is an alternative; either CTA or MRA can be performed, depending on institutional preference.	☢☢☢
MRA head and neck without and with IV contrast	9	This procedure is an alternative; either CTA or MRA can be performed, depending on institutional preference.	O
MRI head without IV contrast	9	This procedure is complementary, in conjunction with MRA.	O
CT head without IV contrast	9	This procedure is complementary, in conjunction with CTA.	☢☢☢
MRA head and neck without IV contrast	7	This procedure is an alternative; either CTA or MRA can be performed, depending on institutional preference.	O
Arteriography cervicocerebral	6		☢☢☢
MRI head without and with IV contrast	3		O
CT head without and with IV contrast	1		☢☢☢
MRI head without IV contrast with DTI	1		O
CT head with IV contrast	1		☢☢☢
X-ray skull	1		☢
Tc-99m HMPAO SPECT head	1		☢☢☢☢
FDG-PET/CT head	1		☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 8: **Suspected intracranial venous injury.**

Radiologic Procedure	Rating	Comments	RRL*
CT venography head with IV contrast	9	This procedure is an alternative; either CTV or MRV can be performed, depending on institutional preference.	☢☢☢
MR venography head without IV contrast	9	This procedure is an alternative; either CTV or MRV can be performed, depending on institutional preference.	O
MR venography head without and with IV contrast	9	This procedure is an alternative; either CTV or MRV can be performed, depending on institutional preference.	O
CT head without IV contrast	7	This procedure is complementary, in conjunction with CTV.	☢☢☢
MRI head without and with IV contrast	6		O
Arteriography cervicocerebral	6		☢☢☢
MRI head without IV contrast	5	This procedure is complementary, in conjunction with MRV. This procedure may be appropriate but there was disagreement among panel members on the appropriateness rating as defined by the panel's median rating.	O
CT head without and with IV contrast	3		☢☢☢
CT head with IV contrast	2		☢☢☢
MRI head without IV contrast with DTI	1		O
X-ray skull	1		☢
Tc-99m HMPAO SPECT head	1		☢☢☢☢
FDG-PET/CT head	1		☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 9: **Suspected post-traumatic cerebrospinal fluid (CSF) leak.**

Radiologic Procedure	Rating	Comments	RRL*
CT maxillofacial without IV contrast	9	This procedure is an alternative in cases of suspected CSF rhinorrhea.	☢☢☢
CT temporal bone without IV contrast	9	This procedure is an alternative in cases of suspected CSF otorrhea.	☢☢☢
CT head cisternography with IV contrast	8	This procedure is complementary if CT maxillofacial or temporal bone is inconclusive.	☢☢☢
In-111 DTPA cisternography	6		☢☢☢
MRI head without IV contrast	5	This procedure is used for suspected cephalocele.	O
CT head without IV contrast	3		☢☢☢
MRI head without and with IV contrast	3		O
CT head without and with IV contrast	1		☢☢☢
CT head with IV contrast	1		☢☢☢
MRI head without IV contrast with DTI	1		O
X-ray skull	1		☢
FDG-PET/CT head	1		☢☢☢☢
Tc-99m HMPAO SPECT head	1		☢☢☢☢
Arteriography cervicocerebral	1		☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

HEAD TRAUMA

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Summary of Literature Review

Introduction/Background

Head trauma is a common neurologic condition and is associated with significant long-term morbidity and mortality. Neuroimaging plays a critical role in the management of head trauma, from identifying patients with traumatic brain injury (TBI) and determining which of those injuries require immediate treatment to assisting in patient prognosis [1,2]. The Glasgow Coma Scale (GCS) score is commonly used to stratify the severity of TBI into mild (GCS score of 13–15), moderate (GCS score of 9–12), and severe (GCS score of 3–8) [1-3]. Head trauma in the pediatric patient is addressed in the ACR Appropriateness Criteria® "Head Trauma—Child" [4].

Overview of Imaging Modalities

Computed tomography (CT) and magnetic resonance imaging (MRI) are the most widely available neuroimaging modalities in assessing head trauma. Advanced MRI techniques are discussed further in the section on imaging of subacute and chronic TBI. CT angiography (CTA) and MR angiography (MRA) as well as conventional catheter angiography are addressed in the section on imaging of suspected intracranial arterial injury. CT venography (CTV) and MR venography (MRV) are addressed in the section on imaging of suspected intracranial venous injury. CT cisternography is addressed in the section on imaging of suspected post-traumatic cerebrospinal fluid (CSF) leak.

The advantage of CT in evaluating the head-injured patient is its sensitivity for depicting intracranial mass effect, ventricular size and configuration, bone injuries, and acute intracranial hemorrhage regardless of location (ie, parenchymal, subarachnoid, subdural, or epidural spaces) in a rapid and efficient manner that is widely available and compatible with other medical and life-support devices. Multiplanar reformats may add value in detecting certain intracranial hemorrhages, especially along bone surfaces that approximate the transverse plane of axial images [5,6]. CT is also more sensitive than MRI in detecting bony injuries. The use of a dedicated bone algorithm, multiplanar reformats, and 3-D rendering may improve the detection of nondisplaced skull fractures. The limitation of CT is a decreased sensitivity to detect small and predominantly nonhemorrhagic lesions, such as contusion or subtle diffuse axonal injury (DAI), subtle injuries adjacent to bony surfaces, and early cerebral edema, which can be seen in hypoxic-ischemic encephalopathy in patients with moderate or severe acute closed head injury. Potential risks of unnecessary exposure to ionizing radiation warrant judicious patient selection for CT scanning as well as radiation dose management [7].

MRI (including a blood-sensitive sequence such as T2*) is more sensitive than CT in detecting all stages of intracranial hemorrhage, nonhemorrhagic contusions, injuries in the posterior fossa and brainstem, and DAI [1,2,8-12]. The addition of susceptibility-weighted imaging in MRI for head trauma further increases the sensitivity for detection of microhemorrhages and hemorrhagic axonal injury [13,14]. Limitations of MRI lie in its longer acquisition time, relatively circumscribed availability, and potential incompatibility with certain medical devices [1,2,15].

The use of intravenous contrast offers no significant advantage in nonvascular neuroimaging for head trauma and is generally not indicated [16].

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Skull radiography has been supplanted by CT in characterizing skull fractures in the setting of acute TBI, though it may be useful in limited circumstances, such as radiopaque foreign bodies [17].

Discussion of Imaging Modalities by Variant

Variant 1: Minor or mild acute closed head injury (GCS ≥13), imaging not indicated by NOC or CCHR or NEXUS-II clinical criteria (see Appendix 1). Initial study.

Variant 2: Minor or mild acute closed head injury (GCS ≥13), imaging indicated by NOC or CCHR or NEXUS-II clinical criteria (see Appendix 1). Initial study.

One of the challenges facing physicians is determining which patients with minor or mild acute closed head injury can safely avoid noncontrast head CT. The New Orleans Criteria (NOC) [18], Canadian CT Head Rules (CCHR) [19], and National Emergency X-Ray Utilization Study (NEXUS)-II [20] are clinical guidelines with a high sensitivity for identifying patients with minor or mild acute closed head injury who can safely avoid noncontrast head CT [21-23]. All guidelines have a trade-off between sensitivity and specificity for the detection of significant findings in head-injured patients [24,25]. The guidelines proposed by each of these studies are listed in Appendix 1.

Although noncontrast head CT is normal in the majority of patients with minor or mild acute closed head injury, it remains the primary modality for detecting clinically relevant brain injuries in this patient population. Though noncontrast head CT has a high negative predictive value in triaging patients, this does not mean that a patient with a negative head CT does not have TBI, and neurologically abnormal patients should be followed closely despite a negative head CT [1,2].

MRI is not indicated as the initial imaging modality in the setting of minor or mild acute closed head injury [26]. However, it may have a role in follow-up imaging (see Variants 4 and 5).

Variant 3: Moderate or severe acute closed head injury (GCS <13). Initial study.

For patients with moderate or severe acute closed head injury, noncontrast CT is the recommended initial imaging study [26-28].

MRI is not indicated as the initial imaging modality in the setting of moderate to severe acute closed head injury [26]. However, it may have a role in follow-up imaging (see Variants 4 and 5).

Variant 4: Short-term follow-up imaging of acute traumatic brain injury. No neurologic deterioration.

Variant 5: Short-term follow-up imaging of acute traumatic brain injury. Neurologic deterioration, delayed recovery, or persistent unexplained deficits.

Follow-up noncontrast head CT is the recommended imaging modality in trauma patients with acute neurologic deterioration [29-31]. The value of repeat noncontrast head CT in patients with a negative initial head CT and a stable neurologic examination is low [32]. The value of repeat noncontrast head CT in patients with an abnormal initial head CT and a stable neurologic examination is also low [33], unless the patient has subfrontal/temporal intraparenchymal contusions, is anticoagulated, is >65 years of age, or has an intracranial hemorrhage with a volume of >10 mL [33, 34].

MRI is recommended if the patient has ongoing neurologic findings or progressive neurologic symptoms unexplained by CT in minor or mild acute closed head injury and moderate to severe acute closed head injury. MRI has an increased sensitivity to detect intracranial injuries such as contusions, axonal injury, or extra-axial hemorrhage that may be occult on CT. Contrast-enhanced MRI or CT may be helpful if post-traumatic infection is clinically suspected in patients with risk factors such as skull base fractures. For patients in which post-traumatic infarction is suspected from intracranial arterial injury, please see Variant 7. Although the use of MRI in patients with minor or mild acute closed head injury has not been found to change the management or disposition in the acute setting [35], the clinical significance of these findings in the nonemergent setting is an area of active research [36]. In patients with moderate to severe acute closed head injury, early MRI (within 4 weeks) has shown DAI, with a negative prognosis seen in subjects with brainstem injury [37].

Variant 6: Subacute or chronic traumatic brain injury with new cognitive and/or neurologic deficit(s).

Chronic traumatic encephalopathy has come under increased scrutiny in the last several years and clinically represents a wide spectrum of symptoms, including cognitive impairment, epilepsy, and visual and auditory deficits. The biology of chronic traumatic encephalopathy is an area of active investigation. The purposes of imaging patients with chronic TBI are to improve identification of underlying injuries, to assist in patient prognosis, and to guide in the need for referral to a specialist [1,2].

MRI is the principle modality for detecting subacute to chronic TBI, with its increased sensitivity to detect and characterize brain injuries, especially atrophy and microhemorrhages, and is recommended in patients with new, persistent, or increasing neurologic deficits [1,2]. For example, the number, size, and location of MR abnormalities in subacute head injury have been used to predict the recovery outcome of patients in a post-traumatic vegetative state [38].

Although MRI is superior to CT in detection of chronic sequelae of TBI such as microhemorrhages, head CT may suffice if the aim of imaging is to show areas of atrophy and often helps in documenting the absence of other structural abnormalities (such as an enlarging subacute to chronic subdural hematoma) that might require active intervention [1,2,15,35].

Advanced neuroimaging techniques (single-photon emission computed tomography [SPECT], positron emission tomography [PET], perfusion CT and MRI, diffusion tensor imaging [DTI], functional MRI, and magnetic resonance spectroscopy [MRS]) may have a role in assessing cognitive and neuropsychological disturbances as well as their evolution following head trauma [39].

SPECT and PET have been studied in patients with subacute and chronic TBI. SPECT studies have revealed focal areas of hypoperfusion without a correlate on MRI or CT [40-42]. Similarly, PET studies with fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG) tracer have revealed areas of decreased metabolism more extensive than the abnormalities detected on CT or MRI [43]. Finally, perfusion imaging with CT or MRI has also shown areas of decreased cerebral blood flow after trauma without an anatomic correlate on CT or MRI [44,45]. There is ongoing investigation as to whether these findings might explain or predict postinjury neuropsychological and cognitive deficits not explained by anatomic abnormalities detected by MRI or CT [39,42].

DTI is a technique that acquires and reconstructs MR images with diffusion weighting in at least 6 directions, followed by calculation of the tensor to create a model of diffusion in 3-D space. This allows for exploitation of the inherent directionally dependent diffusion in coherently oriented axonal fibers to image white-matter fiber tracts. This information can be postprocessed and displayed as diffusion anisotropy maps, color-coded fiber orientation maps, or 3-D fiber tracking. This technique has shown changes in the white matter of patients with TBI, though only some of these changes have correlated with clinical outcomes [8,46,47].

Functional MRI (fMRI) has been studied in the setting of TBI using task-based methods such as work-memory paradigms but may be circumscribed in its ability to identify changes in TBI patients caused by the potential uncoupling of neural activity and cerebral blood flow by the TBI [48,49].

MRS, an MRI technique used to form a spectrum of the different brain metabolites in a sampled volume of brain tissue, has also been examined in patients with TBI [50]. A reduction in N-acetylaspartate/creatine ratio and absolute N-acetylaspartate on MRS has been seen in several studies [51].

Although these advanced imaging techniques are of particular interest in patients with mild TBI when CT and conventional MRI are negative, there is no conclusive evidence supporting their use for diagnosis or prognostication at the individual patient level at this time [1,2].

Variant 7: Suspected intracranial arterial injury.

Traumatic intracranial arterial injuries such as dissection, occlusion, fistula, and pseudoaneurysm formation are diagnosed in approximately 0.1% of all patients hospitalized for trauma, though the majority of these patients come to attention because of clinical symptoms related to central nervous system ischemia. Screening for traumatic intracranial arterial injury should be considered in patients with neurologic symptoms unexplained by a diagnosed injury and blunt trauma patients with epistaxis from a suspected arterial source. Other risk factors for intracranial arterial injury include GCS ≤8, skull base fracture (particularly those that traverse the carotid canal), DAI, cervical spinal fracture (particularly those from the level of C1 to C3), and LeFort 2 or 3 facial bone fractures [52]. Although conventional catheter angiography is considered the gold standard for detecting intracranial arterial injury, multidetector CTA has been found to have a high sensitivity and specificity for diagnosing vascular injury and is less invasive and more readily available [53,54]. MRA also has a high sensitivity and specificity but may be less readily available. Similarly, conventional catheter angiography is generally used in patients with an inconclusive CTA or in patients undergoing endovascular intervention [55]. Based on the current evidence, CTA or MRA (depending on the institutional preference and availability) is considered first line in imaging patients with suspected intracranial arterial injury.

Variant 8: Suspected intracranial venous injury.

Traumatic dural sinus thrombosis is most commonly seen in patients with skull fractures that extend to a dural venous sinus or the jugular foramen. In a recent study, CTV depicted thrombosis in 40% of patients with skull fractures extending to a dural sinus or jugular bulb [56]. CTV is comparable to MRV for the diagnosis of cerebral venous thrombosis [57], though MRV is more sensitive when combined with MRI [58]. Based on the current evidence, CTV or MRV (depending on the institutional preference and availability) is considered first line in imaging patients with suspected intracranial venous injury.

Variant 9: Suspected post-traumatic cerebrospinal fluid leak.

Acute closed head injury can also be associated with cerebrospinal fluid (CSF) leak. This occurs in 10%–30% of skull base fractures and most often presents with rhinorrhea (80% of cases) in the setting of frontobasal fracture [59,60]. However, it may present with otorrhea in the setting of temporal bone fracture. Most post-traumatic CSF leaks are acute in presentation and can be diagnosed clinically when CSF rhinorrhea or otorrhea is confirmed with a beta-2 transferrin or beta trace protein assay [59]. High-resolution noncontrast CT through the skull base (facial bones for rhinorrhea and temporal bones for otorrhea) can be used to identify the source of the leak in the acute or chronic setting and has been shown to be superior to CT cisternography and radionuclide cisternography [61,62]. Patients with multiple potential sites may require CT cisternography to identify the culprit site [59,63]. Radionuclide cisternography using In-111 DTPA may have a role in cases with evidence of a CSF leak with negative or inconclusive noncontrast skull base CT and CT cisternography [64]. MRI with high-resolution T2-weighted sequences may have a role if a post-traumatic cephalocele is suspected.

Summary of Recommendations

- The New Orleans Criteria, Canadian CT Head Rules, and NEXUS-II studies are published guidelines with a high sensitivity for identifying patients with minor or mild acute closed head injury who can avoid neuroimaging.
- In patients with minor or mild acute closed head injury who require neuroimaging, noncontrast CT is the most appropriate initial imaging study.
- In moderate to severe acute closed head injury, noncontrast CT is the most appropriate initial imaging study.
- In short term follow-up imaging of acute TBI without neurologic deterioration, noncontrast CT is the most appropriate imaging study, but only in patients with risk factors (such as subfrontal/temporal intraparenchymal contusions, anticoagulation, age >65 years, or intracranial hemorrhage with volume >10 mL).
- In short-term follow-up imaging of acute TBI with neurologic deterioration, delayed recovery, or persistent unexplained deficits, noncontrast CT is the most appropriate imaging study, but MRI has a complementary role when the patient has neurologic findings or symptoms not sufficiently explained by CT. In patients with suspected post-traumatic infection, contrast-enhanced MRI or CT may be helpful.
- In subacute to chronic TBI, noncontrast MRI is the most appropriate imaging study for detection of underlying brain injury in patients with new, persistent, or slowly progressive symptoms. In patients with rapidly evolving neurologic deficits, noncontrast CT may be the more appropriate imaging study due to its ready availability. Advanced neuroimaging techniques (SPECT, PET, perfusion CT and MRI, DTI, functional MRI, and MRS) are areas of active research but are not considered routine clinical practice at this time.
- In suspected intracranial arterial injury, CTA or MRA (depending on the institutional preference and availability) is the most appropriate initial imaging study. Catheter angiography is typically reserved for problem solving or in preparation for intervention.
- In suspected intracranial venous injury, CTV or MRV (depending on the institutional preference and availability) is the most appropriate initial imaging study.
- In suspected post-traumatic CSF leak, high-resolution noncontrast skull base CT may be helpful to identify the source of the leak. CT or radionuclide cisternography may have a secondary role if skull base CT is inconclusive. High-resolution MRI may have a role if post-traumatic cephalocele is suspected.

Summary of Evidence

Of the 64 references cited in the *ACR Appropriateness Criteria® Head Trauma* document, 62 are categorized as diagnostic references including 1 well designed study, 12 good quality studies, and 21 quality studies that may have design limitations. Additionally, 1 reference is categorized as a therapeutic reference. There are 29 references that may not be useful as primary evidence. There is 1 reference that is a meta-analysis study.

The 64 references cited in the *ACR Appropriateness Criteria® Head Trauma* document were published from 1974-2015.

While there are references that report on studies with design limitations, 13 well designed or good quality studies provide good evidence.

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

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

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Appendix 1. Three major prediction rules used to identify patients with minor or mild acute closed head injury who can safely avoid undergoing noncontrast head CT.

New Orleans Criteria (NOC) [18]

- Inclusion criteria:
  - GCS 15
  - Age >18 years
  - Blunt head trauma occurring within 24 hours and causing loss of consciousness, amnesia, or disorientation
- Head CT is not required if ALL of the following are absent:
  - Headache
  - Vomiting
  - Age >60 years
  - Alcohol or drug intoxication
  - Deficits in short-term memory
  - Visible trauma above clavicles
  - Seizure

Canadian CT Head Rule (CCHR) [19]

- Exclusion criteria:
  - Age <16 years
  - Minimal head injury (no loss of consciousness, amnesia, or disorientation)
  - No clear history of trauma as the primary event
  - Obvious penetrating skull injury or depressed skull fracture
  - Acute focal neurologic deficit
  - Unstable vital signs associated with major trauma
  - Had seizure before assessment in the emergency department
  - Has a bleeding disorder or is anticoagulated
  - Return visit to emergency department for reassessment of same head injury
  - Pregnancy
- Head CT is not required if ALL of the following are absent:
  - GCS <15 at 2 hours postinjury
  - Suspected open or depressed skull fracture
  - Any sign of basilar skull fracture (hemotympanum, raccoon eye, CSF otorrhea or rhinorrhea, Battle sign)
  - Two or more episodes of vomiting
  - Age ≥65 years
  - Amnesia before impact ≥30 minutes
  - Dangerous mechanism (pedestrian struck by vehicle, ejection from motor vehicle, fall from elevation >3 feet or 5 steps)

National Emergency X-Ray Utilization Study (NEXUS-II) [20]

- Head CT is not required if ALL of the following are absent:
  - Age ≥65 years
  - Evidence of significant skull fracture
  - Scalp hematoma
  - Neurologic deficit
  - Altered level of alertness
  - Abnormal behavior
  - Coagulopathy
  - Recurrent or forceful vomiting