Date of origin: 1996
Last review date: 2006

American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Head Trauma**

Variant 1: **Minor or mild acute closed head injury (GCS ≥13), without risk factors or neurologic deficit.**

Radiologic Procedure	Rating	Comments	RRL*
CT head without contrast	7	Known to be low yield.	Low
X-ray and/or CT cervical spine	5		Low
MRI head without contrast	4		None
MRA head and neck	3	Rarely indicated with mild trauma.	None
CT head without and with contrast	3		Low
CTA head and neck	3	Rarely indicated with mild trauma.	Low
MRI head without and with contrast	2		None
CT head xenon-enhanced	1		Low
X-ray skull	1		Min
FDG-PET head	1		High
US transcranial Doppler	1		None
INV angiography cerebral	1		IP
NUC SPECT head	1		High
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Clinical Condition: **Head Trauma**

Variant 2: **Minor or mild acute closed head injury, focal neurologic deficit and/or risk factors.**

Radiologic Procedure	Rating	Comments	RRL*
CT head without contrast	9		Low
MRI head without contrast	6	For problem solving.	None
X-ray and/or CT cervical spine	6		Low
MRA head and neck	5	If vascular injury is suspected. For problem solving.	None
CTA head and neck	5	If vascular injury is suspected. For problem solving.	Low
MRI head without and with contrast	3		None
CT head without and with contrast	2		Low
NUC SPECT head	1		High
FDG-PET head	1		High
US transcranial Doppler	1		None
X-ray skull	1		Min
INV angiography cerebral	1		IP
CT head xenon-enhanced	1		Low
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 3: **Moderate or severe acute closed head injury.**

Radiologic Procedure	Rating	Comments	RRL*
CT head without contrast	9		Low
X-ray and/or CT cervical spine	8		Low
MRI head without contrast	6		None
MRA head and neck	5		None
CTA head and neck	5		Low
CT head without and with contrast	2		Low
MRI head without and with contrast	2		None
X-ray skull	2		Min
US transcranial Doppler	1		None
FDG-PET head	1		High
INV angiography cerebral	1		IP
CT head xenon-enhanced	1		Low
NUC SPECT head	1		High
Rating Scale: 1=Least appropriate, 9=Most appropriate			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 4: **Mild or moderate acute closed head injury, child <2 years old.**

Radiologic Procedure	Rating	Comments	RRL*
CT head without contrast	9		Low
X-ray and/or CT cervical spine	7		Low
MRI head without contrast	7	Diffusion weighted imaging especially helpful for non-accidental trauma.	None
X-ray skull	5		Min
MRI head without and with contrast	4	Potentially useful in suspected non-accidental trauma.	None
MRA head and neck	4	If vascular abnormality suspected.	None
CTA head and neck	4	If vascular abnormality suspected.	Low
CT head without and with contrast	2		Low
FDG-PET head	1		High
NUC SPECT head	1		High
US transcranial Doppler	1		None
INV angiography cerebral	1		IP
CT head xenon-enhanced	1		Low
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 5: **Subacute or chronic closed head injury with cognitive and/or neurologic deficit(s).**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without contrast	8		None
CT head without contrast	6		Low
NUC SPECT head	4	For selected cases.	High
FDG-PET head	4	For selected cases.	High
MRA head and neck	4	For selected cases.	None
CTA head and neck	4	For selected cases.	Low
MRI head without and with contrast	3		None
CT head without and with contrast	2		Low
X-ray and/or CT cervical spine	2	Assuming there are no spinal neurologic deficits.	Low
X-ray skull	2		Min
fMRI head	2		None
US transcranial Doppler	1		None
INV angiography cerebral	1		IP
CT head xenon-enhanced	1		Low
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 6: **Closed head injury; rule out carotid or vertebral artery dissection.**

Radiologic Procedure	Rating	Comments	RRL*
MRA head and neck	8	Add T1 images.	None
MRI head without contrast	8	Include diffusion-weighted images.	None
CT head without contrast	8		Low
CTA head and neck	8		Low
CT head without and with contrast	6	Consider perfusion.	Low
INV angiography cerebral	6	For problem solving.	IP
MRI head without and with contrast	6		None
X-ray and/or CT cervical spine	5		Low
X-ray skull	2		Min
NUC SPECT head	1		High
US transcranial Doppler	1		None
FDG-PET head	1		High
CT head xenon-enhanced	1		Low
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 7: **Penetrating injury, stable, neurologically intact.**

Radiologic Procedure	Rating	Comments	RRL*
CT head without contrast	9		Low
X-ray and/or CT cervical spine	8	If neck or C-spine is site of injury.	Low
X-ray skull	8	If calvarium is site of injury.	Min
CTA head and neck	7		Low
MRA head and neck	6	If MR is safe.	None
INV angiography cerebral	5	If vascular injury suspected.	IP
MRI head without contrast	5	If MRI is safe.	None
CT head without and with contrast	4	Consider perfusion.	Low
MRI head without and with contrast	4	If MRI is safe.	None
US transcranial Doppler	1		None
NUC SPECT head	1		High
CT head xenon-enhanced	1		Low
FDG-PET head	1		High
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

Clinical Condition: **Head Trauma**

Variant 8: **Skull fracture.**

Radiologic Procedure	Rating	Comments	RRL*
CT head without contrast	9		Low
CTA head and neck	7	If vascular injury suspected.	Low
MRI head without contrast	6	If MRI is safe.	None
X-ray and/or CT cervical spine	6		Low
X-ray skull	5	For selected cases.	Min
MRI head without and with contrast	4	Useful if infection suspected. If MRI is safe.	None
CT head without and with contrast	4		Low
MRA head and neck	4	If MRI is safe.	None
US transcranial Doppler	1		None
NUC SPECT head	1		High
INV angiography cerebral	1		IP
FDG-PET head	1		High
CT head xenon-enhanced	1		Low
Rating Scale: **1=Least appropriate, 9=Most appropriate**			***Relative Radiation Level**

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Summary of Literature Review

Craniocerebral injuries are a common cause of hospital admission following trauma, and are associated with significant long-term morbidity and mortality, particularly in the adolescent and young adult populations. Neuroimaging plays an essential role in identification and characterization of traumatic brain injuries. Computed tomography (CT) remains essential for detecting lesions that require immediate neurosurgical intervention (ie, acute subdural hematoma) as well as those that require in-hospital observation and medical management [1]. For patients with minor head injury (Glasgow Coma Scale [GSG] score of 13-15), the New Orleans Criteria [2] and the Canadian CT Head Rule [3] are clinical guidelines with high sensitivity for detecting injuries that require neurosurgical intervention and offer a potential reduction in unnecessary CT scans [4-6].

Other imaging modalities such as magnetic resonance imaging (MRI) depict nonsurgical pathology not visible on CT. Single photon emission computed tomography (SPECT), positron emission tomography (PET), and transcranial Doppler (TCD) have a complementary role in the assessment of brain injury. Because cervical spine trauma may accompany a head injury, cervical spine imaging is indicated for patients with head injury who have signs, symptoms, or a mechanism of injury that might result in spinal injury, and in those who are neurologically impaired.

Skull Radiography

Masters et al [7] developed and prospectively tested a management strategy for selecting patients who may benefit from skull radiography following head trauma, and offered recommendations for selecting patients who should receive CT scanning following head injury. The effect of that study was to shift the focus of neuroimaging of head trauma away from skull radiography and toward recognition of intracranial pathology as demonstrated by CT scanning. Skull radiography is useful for imaging of calvarial fractures, penetrating injuries, and radiopaque foreign bodies.

Computed Tomography

CT advantages for evaluation of the head-injured patient include its sensitivity for demonstrating mass effect, ventricular size and configuration, bone injuries, and acute hemorrhage regardless of location (ie, parenchymal, subarachnoid, subdural, or epidural spaces). Other advantages include its widespread availability, rapidity of scanning, and compatibility with other medical and life support devices. Its limitations include insensitivity in detecting small and predominantly nonhemorrhagic lesions associated with trauma such as contusion, particularly when adjacent to bony surfaces (ie, frontal lobes adjacent to the orbital roof, anterior temporal lobe adjacent to the greater sphenoid wing, etc). Likewise, diffuse axonal injuries (DAIs) that result in small focal lesions throughout the cerebral hemispheres, corpus callosum, and upper brainstem and cerebellum often go undetected on CT. CT is relatively insensitive for detecting increased intracranial pressure or cerebral edema and for early demonstration of hypoxic-ischemic encephalopathy (HIE) that may accompany moderate or severe head injury. Potential risks of unnecessary exposure to ionizing radiation warrant judicious patient selection for CT scanning as well as radiation dose management [8].

There is now a general consensus that patients identified as moderate-risk or high-risk for intracranial injury should undergo early post injury noncontrast CT for evidence of intracerebral hematoma, midline shift, or increased intracranial pressure. A number of clinical criteria similar to those of Masters et al [7] are used to predict patient risk categories for intracranial injury. There is an inverse relationship between declining clinical or neurologic status as described by the GCS [9] and the incidence and severity of CT abnormalities related to head injury [10-12].

Although experienced physicians can often predict the likelihood of an abnormal CT scan in moderate or severe head injury, clinical selection criteria of patients with minor or mild injury (ie, GCS score >12) who harbor significant intracranial pathology and/or require acute surgical intervention have been problematic. Rapid CT scanning is readily available in most hospitals that treat

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head injured patients; thus the routine use of CT has been advocated as a screening tool to triage minor or mild head-injured patients who require hospital admission or surgical intervention from those who can be safely discharged without hospital admission [13-15]. Although CT triage of head-injured patients who require hospital admission offers a reduced burden on inpatient hospital services at lower cost than routine hospital admission for observation, the result is greater CT use in the emergency setting [11, 13-15]. In the minor head injury setting with a GCS score of 15, the New Orleans Criteria [2] found a 100% sensitivity for CT identification of an acute trauma lesion using risk factors of headache, vomiting, drug or alcohol intoxication, older than age 60, short-term memory deficit, physical findings of supraclavicular trauma, and/or seizure. Stiell et al [3] reported 100% sensitivity for detecting neurosurgical and/or clinically important brain injury in subjects with a GCS score of 13-15 based on high-risk factors of failure to reach a GCS score of 15 within 2 hours, suspected open skull fracture, 2 or more vomiting episodes, sign of basal skull fracture, or age ≥65.

Clinical criteria for scanning of children with head injury have been less reliable than those for adults, particularly for children younger than age two [16, 17]. For this reason, more liberal use of CT scanning has been suggested for pediatric patients. On the other hand, this must be balanced with the higher risk of radiation exposure in childhood via judicious patient selection for scanning as well as management of radiation dose [8, 18-19]. Noncontrast head CT plays an essential role in the evaluation of children with suspected physical injury from child abuse; appropriateness criteria for imaging of child abuse have already been described (see the pediatric sections of ACR Appropriateness Criteria®).

Early and sometimes repeated CT scanning may be required for clinical or neurologic deterioration, especially in the first 72 hours after head injury, to detect delayed hematoma, hypoxic-ischemic lesions, or cerebral edema [20]. CT has a role in subacute or chronic head injury for depicting atrophy, focal encephalomalacia, hydrocephalus, and chronic subdural hematoma.

Cerebral Angiography

Since the development of CT in the mid-1970s, the need for cerebral angiography for head injury has dramatically declined. Cerebral angiography has a role in demonstrating and managing of traumatic vascular injuries such as pseudoaneurysm, dissection, or diagnosis and neurointerventional treatment of uncontrolled hemorrhage. Vascular injuries typically occur with penetrating trauma (ie, gunshot wound or stabbing), basal skull fracture, or trauma to the neck [21-23].

Dynamic spiral CT angiography (CTA) and magnetic resonance angiography (MRA) have a role as less invasive screening tools for detection of traumatic vascular lesions. MRA and fat-suppressed T1-weighted MR [22] or CTA may reveal carotid or vertebral dissection, although angiography remains the gold standard for dissection depiction. Cerebral infarction is an infrequent accompaniment to head injury, and patterns of infarction suggest that direct vascular compression related to intracranial mass lesions is the most common underlying mechanism [24].

Magnetic Resonance Imaging

Although the role of MRI in imaging of head trauma is growing, its use is hindered by its limited availability in the acute trauma setting, long imaging times, sensitivity to patient motion, incompatibility with various medical and life support devices, and relative insensitivity to subarachnoid hemorrhage. Other factors include the need for MRI-specific monitoring equipment and ventilators, and the risk of scanning patients with certain indwelling devices (eg, cardiac pacemaker, cerebral aneurysm clip) or occult foreign bodies. In part, these limitations can be overcome by situating MRI scanners close to emergency care areas with appropriate design and equipment for managing acutely injured patients [25-26]. MRI advances such as open bore geometry, faster imaging sequences, and improved patient monitoring equipment allow a greater role for MRI in closed head injuries.

MRI is very sensitive for detecting and characterizing of subacute and chronic brain injuries. The number, size, and location of MR abnormalities in subacute head injury have been used to predict the recovery outcome of post-traumatic vegetative state [27]. While CT is sensitive for detecting of injuries requiring a change in treatment [28], MRI also is used for acute head-injured patients with nonsurgical, medically stable pathology. Hemosiderin-sensitive T2-weighted gradient echo sequences are helpful for imaging small or subacute or chronic hemorrhages. Diffusion sequences improve detection of acute infarction associated with head injury. Fluid attenuated inversion recovery (FLAIR) images are more sensitive than conventional MRI sequences for depicting of subarachnoid hemorrhage and for lesions bordered by cerebrospinal fluid (CSF) [29]. MRA is helpful for screening of vascular lesions such as thromboses, pseudoaneurysms, or dissection. Lang et al [30] found that the addition of gadolinium enhancement offered no significant advantage for lesion detection or characterization compared with noncontrast MRI images in head-injury patients.

The soft tissue detail offered by MRI is superior to that of CT for depicting nonhemorrhagic primary lesions such as contusions, for secondary effects of trauma such as edema and hypoxic-ischemic encephalopathy, and for imaging of

DAI [31-33]. DAI results from a shear-strain pattern of acceleration-deceleration with characteristic lesions in increasing order of injury severity in the: 1) cerebral white matter and gray-white matter junction, 2) corpus callosum, particularly the splenium, and 3) dorsal upper brain stem and cerebellum [31, 38].

Although management of surgical injuries is not likely to be altered by the substitution of MRI for CT [28], superior depiction of nonsurgical lesions with MRI may affect medical management and predict the degree of neurologic recovery [31,34]. Diffusion-weighted MRI and apparent diffusion coefficient (ADC) mapping depict cytotoxic injury almost immediately. In acute brain trauma, focal contusion and DAI may show restricted diffusion and evolve over time to atrophy / encephalomalacia [35, 36]. At present, perfusion imaging with CT or MRI is investigational tools which may prove helpful as markers for disorders of vascular autoregulation or ischemia [37]. Diffusion tensor imaging and MR spectroscopy (MRS) are ancillary tools that may offer additional insight into the biochemical and structural patterns of injury following head trauma, as well as prognosis [38, 39].

Other Imaging Modalities

A few reports of selected head-injury subjects suggest a role for functional imaging techniques (SPECT, PET, xenon-enhanced CT, functional MRI) to assess cognitive and neuropsychologic disturbances as well as recovery following head trauma [40-44]. SPECT studies may reveal focal areas of hypoperfusion that are discordant with findings of MRI or CT [42-44]. On the basis of these results, some investigators suggest that these functional imaging techniques may explain or predict post injury neuropsychologic and cognitive deficits that are not explained by MRI or CT abnormalities [42-44]. Furthermore, focal lesions demonstrated by SPECT offer objective evidence of organic injury in patients whose neuroimaging studies are otherwise normal [44]. Oder et al [45] found that a pattern of global reduction of cerebral blood flow detected by SPECT predicted a poor likelihood of recovery in persistent vegetative state patients due to head injury. SPECT, PET, and xenon-enhanced CT do not provide the anatomic detail or image resolution of CT or MRI for demonstrating acute or neurosurgical lesions of closed head injury, so their use is generally limited to subacute or chronic patients.

Transcranial Doppler sonography (TCD) offers a noninvasive bedside evaluation of cerebral blood flow velocity and resistance in the major proximal vessels of the circle of Willis. Several investigators have suggested that TCD can be used to monitor early changes in blood flow velocities that may relate to vasospasm, hypervolemia, low velocity state, or edema [46-48], especially in management of the acutely brain injured patient.

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