

2011 Imaging Criteria

Computed Tomography (CT), Brain (Pediatric)^(1, 2)

ICD-9-CM: 87.03

CPT: 70450, 70460, 70470, 76380

I/O Setting: Outpatient

INDICATION(S)

- 100 Acute onset persistent neurologic Sx/findings ♦
- 200 New transient neurologic Sx/findings ♦
- 300 Suspected subarachnoid hemorrhage (SAH) ♦
- 400 Suspected neonatal intraventricular hemorrhage
- 500 Headache
- 600 Seizure
- 700 Head trauma ♦
- 800 Suspected nonaccidental head trauma
- 900 Suspected CNS infection and MRI not feasible
- 1000 Follow-up of intracranial abscess
- 1100 Follow-up of primary brain tumor
- 1200 CNS evaluation for brain metastases
- 1300 Follow-up of AVM and MRI not feasible
- 1400 Post intracranial procedure/craniotomy/craniectomy
- 1500 Suspected CNS involvement with systemic disease
- 1600 New/worsening CNS Sx/findings with CNS shunt ♦
- 1700 Suspected hydrocephalus
- 1800 Nonacute onset mental status changes
- 1900 Macrocephaly
- 2000 Microcephaly and MRI not feasible
- 2100 Craniosynostosis

- 100 Acute onset persistent neurologic Sx/findings [One] ♦⁽³⁾
 - 110 Sensory deficit⁽⁴⁾
 - 120 Motor deficit⁽⁵⁾
 - 130 Language deficit⁽⁶⁾
 - 140 Cognitive dysfunction of unknown etiology^(7, 8)
 - 150 Visual impairment⁽⁹⁾
 - 160 Altered level of consciousness⁽¹⁰⁾
- 200 New transient neurologic Sx/findings [One] ♦
 - 210 Sensory deficit⁽⁴⁾

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- 220 Motor deficit^(5, 11)
- 230 Language deficit⁽⁶⁾
- 240 Visual impairment⁽⁹⁾
- 250 Memory loss by Hx/PE⁽¹²⁾

- 300 Suspected subarachnoid hemorrhage (SAH) [**One**] ♦^(13, 14)
 - 310 Abrupt onset severe headache
 - 320 Abrupt onset exertional headache
 - 330 Warning or "thunderclap" headache by Hx⁽¹⁵⁾
 - 340 Headache **with** associated Sx/findings [**One**]
 - 341 Vomiting
 - 342 Meningismus⁽¹⁶⁾
 - 343 Focal neurologic finding by PE⁽¹⁷⁾
 - 344 Retinal hemorrhage
 - 345 Syncope⁽¹⁸⁾
 - 346 Mental status changes by Hx/PE⁽¹⁹⁾
 - 347 Blood/xanthochromia by LP⁽²⁰⁾
 - 348 Seizure⁽²¹⁾
 - 349 AVM/aneurysm by Hx^(22, 23)

- 400 Suspected neonatal intraventricular hemorrhage [**Both**]⁽²⁴⁾
 - 410 Sx/findings [**One**]
 - 411 Bulging fontanel by PE
 - 412 Apnea
 - 413 Bradycardia
 - 414 Hypotonia
 - 415 Decreased/absent Moro reflex⁽²⁵⁾
 - 416 Mental status changes by Hx/PE⁽¹⁹⁾
 - 417 Hct decrease ≥ 6% from baseline
 - 420 Cranial US nondiagnostic for etiology of Sx/findings⁽²⁶⁾

- 500 Headache [**One**]^(27*RIN, 28)
 - 510 Papilledema by PE and MRI not feasible^(29, 30, 31)
 - 520 New headache [**One**]⁽³²⁾
 - 521 Focal neurologic finding by PE⁽¹⁷⁾
 - 522 Headache with syncope by Hx⁽¹⁸⁾
 - 523 Mental status changes by Hx/PE⁽¹⁹⁾
 - 524 Headache onset with exertion/Valsalva maneuver by Hx
 - 525 Headache causes awakening from sleep by Hx⁽³³⁾
 - 526 Headache with nocturnal vomiting by Hx⁽³⁴⁾
 - 530 Chronic headache [**Both**]⁽³⁵⁾

- 531 MRI not feasible⁽³⁶⁾
- 532 Sx/findings **[One]**
- 1 Focal neurologic finding by PE⁽¹⁷⁾
 - 2 Headache with syncope by Hx⁽¹⁸⁾
 - 3 Mental status changes by Hx/PE⁽¹⁹⁾
 - 4 Worsening of previously stable chronic headache by Hx⁽³⁷⁾
- 600 Seizure **[One]**⁽³⁸⁾
- 610 Seizure with focal neurologic finding by PE^(39, 40)
- 620 New onset seizure **[Both]** ♦⁽⁴¹⁾
- 621 Patient afebrile⁽⁴²⁾
 - 622 MRI not feasible⁽³⁶⁾
- 630 Seizure disorder by Hx **[Both]**
- 631 MRI not feasible^(36, 43)
 - 632 Refractory to Rx **[All]**^(44, 45)
 - 1 Increased seizure activity with therapeutic blood levels of anticonvulsant
 - 2 ≥ 12 wks since initiation of anticonvulsant Rx⁽⁴⁶⁾
 - 3 No concurrent seizure-provoking medication⁽⁴⁷⁾
- 700 Head trauma **[One]** ♦⁽⁴⁸⁾
- 710 Age ≤ 6 mos⁽⁴⁹⁾
- 720 Sx/findings **[One]**
- 721 Retrograde/anterograde amnesia^(50, 51)
 - 722 LOC by Hx/PE
 - 723 Mental status changes by Hx/PE⁽¹⁹⁾
 - 724 Irritability/behavioral changes by Hx/PE
 - 725 Vomiting⁽⁵²⁾
 - 726 Bulging fontanel by PE
 - 727 Focal neurologic finding by PE⁽¹⁷⁾
 - 728 Headache by Hx
 - 729 Seizure by Hx/PE
 - 730 Coagulopathy by Hx
 - 731 Skull fracture by PE/x-ray⁽⁵³⁾
- 800 Suspected nonaccidental head trauma **[One]**^(54, 55)
- 810 Irritability/behavioral changes by Hx/PE
 - 820 Seizure by Hx/PE
 - 830 Retinal hemorrhage⁽⁵⁶⁾
 - 840 Cutaneous bruising/swelling
 - 850 Multiple/bilateral skull fracture by PE/x-ray⁽⁵⁷⁾
 - 860 Vague/absent Hx of head trauma with findings by PE⁽⁵⁸⁾

- 900 Suspected CNS infection and MRI not feasible **[One]**^(59, 60, 61)
- 910 New/worsening CNS Sx/findings **[One]** ♦⁽⁶²⁾
- 911 Focal neurologic finding by PE⁽¹⁷⁾
- 912 Headache by Hx
- 913 Meningismus^(16, 63)
- 914 Mental status changes by Hx/PE⁽¹⁹⁾
- 915 Seizure by Hx/PE
- 920 Follow-up assessment⁽⁶⁴⁾
- 1000 Follow-up of intracranial abscess **[One]**^(65, 66, 67)
- 1010 New/worsening CNS Sx/findings **[One]** ♦⁽¹⁷⁾
- 1011 Focal neurologic finding by PE⁽¹⁷⁾
- 1012 Vomiting
- 1013 Headache by Hx
- 1014 Mental status changes by Hx/PE⁽¹⁹⁾
- 1015 Seizure by Hx/PE
- 1020 New onset temperature > 100.4 F(38.0 C)⁽⁶⁸⁾
- 1030 Continued temperature > 100.4 F(38.0 C) after 1 week IV Abx Rx⁽⁶⁸⁾
- 1040 Follow-up assessment during Rx⁽⁶⁹⁾
- 1050 Follow-up assessment after Rx completed
- 1100 Follow-up of primary brain tumor **[One]**^(70*RIN)
- 1110 New/worsening CNS Sx/findings ♦^(71, 72)
- 1120 Periodic assessment
- 1200 CNS evaluation for brain metastases **[One]**
- 1210 Baseline scan as part of staging **[One]**
- 1211 Sarcoma
- 1212 Melanoma
- 1220 Baseline scan positive **[One]**
- 1221 Periodic assessment during chemotherapy/radiation Rx⁽⁷³⁾
- 1222 Restaging after chemotherapy/radiation Rx completed⁽⁷⁴⁾
- 1230 New/worsening CNS Sx/findings **[One]** ♦
- 1231 Known cancer elsewhere
- 1232 Known brain metastasis by prior CT/MRI
- 1300 Follow-up of AVM and MRI not feasible^(22, 36, 75)
- 1400 Post intracranial procedure/craniotomy/craniectomy **[One]**⁽⁶⁵⁾
- 1410 New/worsening CNS Sx/findings ♦

- 1420 Follow-up assessment⁽⁷⁶⁾
- 1500 Suspected CNS involvement with systemic disease **[One]**⁽⁶⁵⁾
- 1510 Systemic lupus erythematosus (SLE)/vasculitis⁽⁷⁷⁾
- 1520 HIV^(77, 78)
- 1530 Neurofibromatosis (von Recklinghausen's disease)^(79, 80)
- 1540 Tuberous sclerosis (Bourneville's disease)^(81, 82)
- 1550 TB⁽⁸³⁾
- 1600 New/worsening CNS Sx/findings with CNS shunt ♦
- 1700 Suspected hydrocephalus **[One]**⁽⁸⁴⁾
- 1710 Excessive rate of head growth
- 1720 Bulging fontanel by PE
- 1730 Papilledema by PE and MRI not feasible^(29, 30, 31)
- 1800 Nonacute onset mental status changes **[All]**⁽⁸⁵⁾
- 1810 MRI not feasible
- 1820 Sxs/findings **[One]**
- 1821 Memory loss by Hx/PE⁽¹²⁾
- 1822 Confusion/disorientation by Hx/PE⁽⁸⁶⁾
- 1823 Behavioral changes by Hx/PE
- 1830 Lab results nondiagnostic for etiology of mental status change **[All]**
- 1831 Na ≥ 128 mEq/L(128 mmol/L)
- 1832 Glucose ≥ 60 and ≤ 250 mg/dL(3.33 and < 13.9mmol/L]
- 1833 BUN ≤ 80 mg/dL(28.6 mmol/L)
- 1834 Ca ≤ 11 mg/dL(2.75 mmol/L)
- 1835 TSH normal
- 1836 LFTs/ammonia normal
- 1840 Urine drug/toxicology screen **[One]**
- 1841 Negative
- 1842 Not indicated
- 1900 Macrocephaly **[One]**^(87, 88)
- 1910 Excessive rate of head growth
- 1920 Focal neurologic finding by PE⁽¹⁷⁾
- 2000 Microcephaly and MRI not feasible^(36, 89, 90)
- 2100 Craniosynostosis^(91, 92)

Notes

(1)

CT and MRI each have relative advantages and disadvantages. CT, which tends to be better tolerated by patients, has the advantages of a shorter study time, better sensitivity for detecting acute hemorrhage, and excellent visualization of bony structures with less degradation of image quality by motion artifact. CT is often the preferred modality in rapidly evolving neurologic conditions (e.g., SAH, ICH) because it is widely available and may be performed easily in the setting of life support equipment. CT, however, poses the disadvantage of patient radiation exposure which carries an increased long-term risk of cancer. MRI tends to be more sensitive in detecting lesions in the brain, as well as assessment of cerebral ischemia. In acute stroke imaging, both CT and MRI are used to rapidly obtain the necessary anatomical, vascular, and functional information (Adam and Dixon, Grainger & Allison's Diagnostic Radiology: A Textbook of Medical Imaging 5th ed. 2008, 1936 p.).

(2)

Current magnetic resonance techniques lack ionizing radiation and provide images with high spatial resolution, excellent soft-tissue contrast, and multi-planar imaging capability (Widjaja and Raybaud, Neurosurg Focus 2008; 25(3): E3). Newer techniques include diffusion-weighted MRI and magnetic resonance spectroscopy. Diffusion-weighted imaging is being used for the evaluation of demyelinating disorders, presurgical evaluation and planning of brain tumors, and seizure disorders. Magnetic resonance spectroscopy is being used for evaluating many brain disorders, including brain tumors, leukodystrophies, and brain injuries (Abdelhalim and Alberico, Neurol Clin 2009; 27(1): 285-301, x; Provenzale, Emerg Radiol 2007; 14(1): 1-12).

(3)

In children, the acute onset of persistent CNS findings may be due to lesions in the brain or spinal cord, inflammatory or vascular disorders, ischemic encephalopathy (e.g., near drowning), trauma, paroxysmal disease (e.g., seizures), or metabolic abnormalities. Ingestion of drugs and toxins can also cause acute neurologic symptoms (Lehman, Clinical Pediatric Emergency Medicine 2008; 9(2): 688-675; Eicher and Avery, Neurol Clin 2005; 23(2): 353-376). A recent study that looked at data sets for pediatric discharges with stroke, reported 3.70 per 100,000 hospitalizations for ischemic stroke and 2.37 per 100,000 for hemorrhagic stroke (Lo et al., J Child Neurol 2009; 24(2): 194-203). Stroke in children can be caused by AVM rupture, congenital or acquired heart disease, structural anomalies, infection, and hematologic abnormalities (Amlie-Lefond et al., Lancet Neurol 2008; 7(5): 425-435; Roach et al., Stroke 2008; 39(9): 2644-2691). Whether to perform CT or MRI is dependent on the child's clinical stability and is a matter of clinical judgement.

(4)

Sensory deficits commonly seen in stroke or TIA include hemianesthesia, single limb anesthesia, facial hemianesthesia or hypesthesia, and contralateral neglect (a neglect of the side opposite to the brain insult).

(5)

Motor deficits include motor weakness or paralysis (hemiparesis, quadriparesis, single limb involvement, or unilateral facial weakness), impaired coordination or ataxia, or dysphagia.

(6)

Language deficits most commonly present as aphasia or dysarthria. In the pediatric population, it may present as mutism.

(7)

Cognitive dysfunction may present as memory loss, confusion, disorientation, or behavioral changes.

(8)

Patients presenting with an acute onset of cognitive dysfunction should undergo imaging to search for potentially reversible structural causes of the mental status change, most notably subdural hematoma or acute hemorrhage (Christensen, Am J Emerg Med 2004; 22(3): 228-229). Acute cognitive changes are more likely the result of a toxic or metabolic disorder rather than structural pathology; however, these patients often cannot provide a clear history, making imaging, along with a metabolic evaluation, an important element of the diagnostic algorithm.

(9)

Common visual symptoms include new vision loss, diplopia, visual field impairment and gaze impairment, and with TIA.

(10)

Altered levels of consciousness (e.g., coma, marked lethargy) may be due to a variety of mechanisms (e.g., increased ICP, infarct involving arousal systems).

(11)

Motor weakness occurring with a stroke or TIA tends to be focal (e.g., injury to a particular area of the brain results in a specific deficit).

(12)

In children, memory loss may present as declining school performance or regression in developmental milestones.

(13)

SAH is suspected when a patient presents with a sudden onset of severe headache, classically described as the "worst headache of my life." CT is the preferred modality to look for acute hemorrhage (Bederson et al., Guidelines for the management of aneurysmal subarachnoid hemorrhage: a statement for healthcare professionals from a special writing group of the Stroke Council, American Heart Association. 2009 [cited 40 3]; Brisman et al., N Engl J Med 2006; 355(9): 928-939; Suarez et al., N Engl J Med 2006; 354(4): 387-396). Conventional MRI is relatively insensitive for acute hemorrhage and is not recommended in this setting. Advanced MRI techniques such as proton-density-weighted images or fluid attenuated inversion recovery images have improved the diagnosis of acute SAH; limitations such as routine availability and longer study time limit practical use in the emergency setting (Bederson et al., Guidelines for the management of aneurysmal subarachnoid hemorrhage: a statement for healthcare professionals from a special writing group of the Stroke Council, American Heart Association. 2009 [cited 40 3]). If the CT is negative and a high suspicion for SAH remains, an LP to assess for blood in the CSF should be considered because smaller hemorrhages may not be detected by imaging studies performed acutely (Perry et al., Ann Emerg Med 2008; 51(6): 707-713).

(14)

CT is more sensitive than an MRI in the detection of acute subarachnoid blood (Slovic, Caffey's pediatric diagnostic imaging 11th ed. 2007, 3536).

(15)

Between 20% and 50% of patients with documented SAH report a distinct, severe headache in the days or weeks before they present for medical treatment. This warning or "thunderclap" headache classically develops in seconds, achieves maximal intensity within minutes, and may last hours to days (Bederson et al., Guidelines for the management of aneurysmal subarachnoid hemorrhage: a statement for healthcare professionals from a special writing group of the Stroke Council, American Heart Association. 2009 [cited 40 3]; Ferro et al., J Neurol 2008; 255(4): 465-479; Manno, Neurol Clin 2004; 22(2): 347-366).

(16)-DEF:

Meningismus is a symptom complex associated with meningeal irritation, such as neck stiffness or a positive Kernig's or Brudzinski's sign (stretching of the nerve roots causes neck pain).

(17)

Focal neurologic finding refers to a specific deficit that corresponds to a particular area of the brain (e.g., right arm weakness from a left motor cortex insult).

(18)-DEF:

Syncope is the transient loss of consciousness and postural tone caused by diminished cerebral blood flow characterized by rapid onset, short duration, and spontaneous complete recovery.

(19)

Mental status changes include confusion, lethargy, disorientation, somnolence, stupor, and coma.

(20)

Xanthochromia refers to a yellowish discoloration of the spinal fluid suggestive of past hemorrhage, develops 2 to 12 hours after bleeding, and takes at least 2 weeks to clear. Spectrophotometry of the CSF is the recommended method of analysis and should be done on the final sample of CSF collected (Bederson et al., Guidelines for the management of aneurysmal subarachnoid hemorrhage: a statement for healthcare professionals from a special writing group of the Stroke Council, American Heart Association. 2009 [cited 40 3]; Suarez et al., N Engl J Med 2006; 354(4): 387-396).

(21)

Subarachnoid hemorrhage is rare in pediatric patients, but seizures may be the presenting sign in 10% of patients (Marx et al., Rosen's emergency medicine : concepts and clinical practice, 6th ed. 2006).

(22)-DEF:

An arteriovenous malformation (AVM) is a vascular lesion consisting of dilated feeding arteries and a core of tangled vascular loops that terminate in draining veins.

(23)

Imaging is performed to determine whether the AVM or aneurysm is the cause of the neurologic symptoms and findings and if the lesion merits further treatment.

(24)

Approximately 25% to 40% of all newborns weighing < 2000 grams develop intraventricular hemorrhage, with an increased incidence with decreased birthweight. More than 50% of cases occur during the first 24 hours of life, with less than 5% occurring after day 4 to 5 (Linder et al., Pediatrics 2003; 111(5 Pt 1): e590-595; Shalak and Perlman, Clin Perinatol 2002; 29(4): 745-763).

(25)-DEF:

The Moro reflex is tested by placing the infant in a semi-upright position and allowing the head to fall back momentarily while being supported by the examiner's hand. The infant will symmetrically abduct and extend the arms, flex the thumbs, and flex the upper extremities. Absence of this reflex suggests significant CNS dysfunction. An asymmetric response signifies a fractured clavicle, brachial plexus injury, or hemiparesis.

(26)

Cranial US is excellent for displaying bleeding and can be used for monitoring ventricular size. CT may be necessary for full evaluation of the cerebral parenchyma, the posterior fossa, and the subarachnoid, subdural, and epidural spaces (Correa et al., AJNR Am J Neuroradiol 2004; 25(7): 1274-1282).

(27)-RIN:

These criteria address headache when there is no specific underlying etiology. If there is concern that the headache may be a sign of a SAH or CNS infection, see indications 300 and 900, respectively within this criteria subset.

(28)

Imaging should be reserved for children who are at high risk of intracranial tumor or pathology (e.g., abnormal neurologic exam). Although traditionally CT has been the study of choice due to its availability and lower cost, MRI has recently emerged as the optimal initial study due to its capability to provide multiplanar views, its enhanced sensitivity in the detection of soft tissue changes, and its lack of ionizing radiation. However, since MRI requires more time and higher levels of sedation, CT is often obtained in rapidly evolving neurologic conditions in the pediatric population (Evans, Neurol Clin 2009; 27(2): 393-415). Whether to perform CT or MRI is a matter of clinical judgement.

(29)-DEF:

Papilledema is swelling of the optic disc, manifested by indistinct margins, hyperemia, venous engorgement, and lack of normal venous pulsations. Papilledema is a sign of increased ICP.

(30)

MRI is preferred for the evaluation of papilledema, but in cases where MRI is not available or the patient cannot tolerate the study, CT with contrast is a reasonable option.

(31)

Papilledema is not seen in neonates or infants with open fontanel; the increased ICP will cause bulging of the fontanel, sparing the optic disks. Older children with increased ICP and closed sutures may develop papilledema.

(32)

These criteria address a new or not as yet investigated headache. The symptom may actually have been present for some time before seeking medical attention. These criteria define risk factors which are worrisome for intracranial pathology (e.g., tumor).

(33)

Headaches causing patients to awaken from sleep may be caused by increased ICP.

(34)

Nocturnal vomiting may signify an intracranial tumor or may represent increased ICP.

(35)

Migraine is the most common type of chronic headache, triggered by factors such as stress, certain foods, hormonal changes, or lack of sleep. Treatment involves sleep, analgesics, and biobehavioral therapies (e.g., diet, relaxation techniques, cognitive therapies). Diagnosis of most patients with chronic headaches (e.g., migraine, tension headache) usually does not require imaging, particularly in the absence of neurologic signs and symptoms (Friedman and Grosberg, Emerg Med Clin North Am 2009; 27(1): 71-87; Lewis, Neurol Clin 2009; 27(2): 481-501; Pearlman, Prim Care 2004; 31(2): 407-415, viii).

(36)

MRI is not feasible if it is not readily available or if the patient cannot tolerate the MRI study.

(37)

Headache patterns of frequency and severity are often cyclical and related to environmental, hormonal, or social factors. Significant worsening of a previously stable headache can indicate new pathology and warrants imaging.

(38)

Seizures are categorized as either focal (partial) or generalized. Focal seizures can occur without impairment of consciousness (simple partial seizure) or with impairment of consciousness (complex partial seizure). Focal seizures can be associated with structural brain abnormalities; generalized seizures typically are not (Shneker and Fountain, *Dis Mon* 2003; 49(7): 426-478).

(39)

Seizure with accompanying neurologic findings may suggest an anatomic cause for the seizure (Adams and Knowles, *Am Fam Physician* 2007; 75(9): 1342-1347; Shneker and Fountain, *Dis Mon* 2003; 49(7): 426-478).

(40)

Neuroimaging is recommended in children with a postictal focal neurologic deficit that does not resolve, or when the child does not return to baseline neurologic function within several hours (Adams and Knowles, *Am Fam Physician* 2007; 75(9): 1342-1347).

(41)

Neuroimaging is recommended for the evaluation of patients presenting with a new onset seizure (Krumholz et al., *Neurology* 2007; 69(21): 1996-2007; ACEP Clinical Policies Committee, *Ann Emerg Med* 2004; 43(5): 605-625). MRI is the study of choice due to its enhanced sensitivity, although CT is a reasonable alternative when MRI is not feasible (Friedman and Sharieff, *Pediatr Clin North Am* 2006; 53(2): 257-277; Vattipally and Bronen, *Neuroimaging Clin N Am* 2004; 14(3): 349-372).

(42)

Seizures that occur in children with fever between the ages of 6 months and 5 years are called febrile seizures. Most are generalized and brief (lasting < 15 minutes) (American Academy of Pediatric (AAP), *Pediatrics* 2008; 121(6): 1281-1286). They may develop early in the course of an episode of otitis media or pharyngitis. Imaging is not necessary unless the child has accompanying focal neurologic findings.

(43)

Imaging is a crucial tool in the evaluation of children with refractory seizures. In some situations, advanced MR imaging techniques may be necessary to accurately localize the seizure foci. Newer imaging techniques include diffusion-weighted imaging, PET, and SPECT imaging. Further studies are needed however to evaluate their full efficacy (Widjaja and Raybaud, *Neurosurg Focus* 2008; 25(3): E3).

(44)

Refractory seizures do not require imaging unless a new lesion is suspected (e.g., change in seizure pattern) or management will change based on the results of the scan.

(45)

Refractory seizures in children may be treated surgically at a young age if a resectable seizure focus can be identified (Shneker and Fountain, *Dis Mon* 2003; 49(7): 426-478).

(46)

Time is required to adjust medications and assess their results before assuming that the seizures are refractory to treatment.

(47)

Prescription medications such as TCAs, antipsychotics, theophylline, and lidocaine can lower the seizure threshold. Attempts should be made to reduce or discontinue all such medications, but the risks and benefits of such an intervention need to be considered for each patient.

Recreational CNS stimulants (e.g., cocaine) can also cause seizures.

(48)

After head trauma, CT is the initial imaging modality of choice. It is widely available, fast, easy to obtain, and is capable of accommodating life-support and monitoring equipment (Slovic, *Caffey's pediatric diagnostic imaging* 11th ed. 2007, 3536). MRI may be more sensitive in assessing neural injury after the first 24 hours and for detecting small subdural hematomas. The utility of MRI for imaging head trauma may increase as technology such as magnetic resonance spectroscopy, diffusion-tensor imaging, and magnetization transfer MRI evolves (Jagoda et al., *Ann Emerg Med* 2008; 52(6): 714-748; Sigmund et al., *Pediatr Neurol* 2007; 36(4): 217-226; Smits et al., *Radiology* 2007; 245(3):831-838).

(49)

Clinical signs and symptoms of brain injury post trauma may be relatively insensitive indicators of intracranial injury in younger children, particularly those ≤ 6 months of age. A normal mental status or the absence of neurologic deficit does not exclude a serious brain injury (Thiessen and Woolridge, *Pediatr Clin North Am* 2006; 53(1):1-26, v). Infants < 3 months of age or who have a large scalp hematoma are especially at risk for skull fracture and intracranial injury. Imaging evaluation should, therefore, include children who are symptomatic after any head trauma but should also be directed to asymptomatic children who are 6 months of age or younger depending upon the child's clinical status.

(50)-DEF:

Retrograde amnesia is having no memory of the events that occurred before the trauma or condition.

(51)-DEF:

Anterograde amnesia is having no memory for events that occurred after the trauma or condition.

(52)

Vomiting after head trauma may be an early indication of increased ICP.

(53)

Clinical signs of skull fracture may include step-off or large hematoma, raccoon eyes, Battle's sign (post-auricular ecchymosis), hemotympanum, CSF otorrhea, rhinorrhea, or crepitance (Slovic, *Caffey's pediatric diagnostic imaging* 11th ed. 2007, 3536).

(54)

Nonaccidental injuries, more commonly known as the "shaken baby syndrome" or the "shaking-impact syndrome" are largely restricted to children < 3 years of age. Risk factors include young parents, unstable family situations, low socioeconomic status, and disability or prematurity of the child (Christian, *Clin Fam Practice* 2003; 5(1): 21-46). Clinical features include retinal, subdural, and subarachnoid hemorrhage in an infant with little signs of external trauma (Gerber and Coffman, *Childs Nerv Syst* 2007; 23(5): 499-507).

(55)

CT is the preferred initial study for the child with suspected acute nonaccidental head trauma. Findings may include subdural hemorrhage, skeletal injuries and soft-tissue lesions. MRI may be used to further delineate the extent of injury, including subtle brain contusions, diffuse axonal injury, or loss of gray-white matter differentiation. MRI may also show involvement of the cervical spine or hemorrhage into the spinal canal as a result of the trauma (Reynolds, *Radiol Technol* 2008; 80(2): 151-170; Slovic, *Caffey's pediatric diagnostic imaging* 11th ed. 2007, 3536; Eltermann et al., *J Child Neurol* 2007; 22(2):170-175).

(56)

Retinal hemorrhages are a cardinal manifestation of nonaccidental head trauma characterized by repetitive acceleration-deceleration forces with or without blunt head impact (shaken baby syndrome). Approximately 85% of affected children have retinal hemorrhage, with just under two thirds having extensive, "too numerous to count" multilayered hemorrhages extending out to the edges of the retina (Levin, *Pediatr Clin North Am* 2009; 56(2): 333-344). Although the presence of retinal hemorrhages does not confirm the diagnosis of shaken baby syndrome, studies report that retinal hemorrhages are common in abused children and rare in cases of accidental head injury in children under age 3 (Togioka et al., *Retinal hemorrhages and shaken baby syndrome: An evidence-based review*. 2008 [cited 2009 April 3]).

(57)

Fractures caused by abuse are more often multiple, bilateral, or associated with an intracranial subdural hematoma in comparison with those that result from accidental trauma (Kemp et al., *BMJ* 2008; 337: a1518).

(58)

Nonaccidental head injury is significantly more common when physical findings of traumatic head injury are present, and there is no history of trauma given. Imaging is essential to determine the extent of injury and to document the abuse (Schutzman and Greenes, *Ann Emerg Med* 2001; 37(1): 65-74).

(59)

These criteria address CNS infection where the concern is generally for meningitis or encephalitis. Encephalitis generally presents with an altered sensorium in children. MRI is the preferred imaging modality as it is able to detect brain inflammation and edema in the cortex, the gray-white matter junction, the basal ganglia, or the cerebellum (Nichols and Rogers textbook of pediatric intensive care 4th edition ed. 2008, 1886 pages).

(60)

The superior contrast resolution of MRI makes it a more sensitive imaging tool for evaluating intracerebral abnormalities associated with a variety of complicated CNS infectious processes. Gadolinium contrast improves lesion delineation, localizes regions likely to provide positive biopsy, and identifies active disease. Additional information may be obtained from using diffusion-weighted imaging. In uncomplicated cases, CT may be obtained initially to identify patients at higher risk for herniation with intracranial abnormalities such as hydrocephalus, mass lesions, cerebral edema, and midline brain shift. LP often follows CT in the event the patient is considered low risk for herniation (Fitch et al., *Infect Dis Clin North Am* 2008; 22(1): 33-52, v-vi; Kastrup et al., *NeuroRx* 2005; 2(2): 324-332).

(61)

MRI is not feasible if it is not readily available or if the patient cannot tolerate the MRI study.

(62)

In the setting of meningitis or encephalitis, an immunocompetent host will usually demonstrate signs of infection such as fever, elevated WBC, neck stiffness, or neurologic signs. Imaging in this context is helpful to rule out other possible etiologies that might confound or complicate the diagnosis.

(63)

Meningismus may be seen with any meningeal irritant but should raise the suspicion of infectious meningitis.

(64)

Follow-up assessment is not necessary more frequently than every 7 to 10 days if the patient is stable or improving.

(65)

Whether to perform CT or MRI in this setting is a matter of clinical judgment.

(66)

Abscesses involving the CNS are uncommon. They sometimes result from direct trauma or neurosurgery, but may be caused by meningitis, rhinosinusitis, mastoiditis, and other extra-cranial sources (Ziai and Lewin, *Neurol Clin* 2008; 26(2): 427-468, viii).

(67)

Children with congenital heart disease (e.g., tetralogy of Fallot) are at risk of intracranial abscess from septic emboli (Ziai and Lewin, *Neurol Clin* 2008; 26(2): 427-468, viii; Overturf, *Pediatr Crit Care Med* 2005; 6(3 Suppl): S14-18).

(68)

A new or continued fever in a patient with a known abscess could indicate treatment failure or new primary infection.

(69)

The frequency of assessment is a matter of clinical judgment based upon the size, location, and number of intracranial abscesses. Follow-up is necessary to monitor resolution of the abscess in response to antibiotic therapy. If there is no progress, surgical drainage may be necessary.

(70)-RIN:

These criteria address a previously diagnosed brain tumor. For symptomatology which makes one suspect a new brain lesion, see the appropriate indication within this criteria subset.

(71)

Whether to perform a CT or MRI in this setting is a matter of clinical judgment. While MRI provides greater detail, CT is often sufficient for follow-up studies. It is generally best to perform the same study serially as this allows direct comparison of studies.

(72)

MRI (structural, diffusion weighted, or functional), PET scan, or magnetoencephalography are advanced imaging technologies that may be used to map pediatric brain tumors for interventional or operative planning (Nejat et al., *J Child Neurol* 2008; 23(10): 1136-1148).

(73)

The interval for periodic assessment in stable patients is a matter of clinical judgment. Studies are generally performed no more frequently than every two cycles of chemotherapy.

(74)

The post treatment assessment is generally performed 4 to 6 weeks after therapy is completed.

(75)

Treatment of brain AVM's in children depends on the size, venous drainage pattern (superficial or deep), and the location of the AVM (Jordan and Hillis, *Pediatr Neurol* 2007; 36(2):73-80).

(76)

It may be reasonable to obtain imaging studies in the immediate postoperative period following an intracranial procedure. These patients are often acutely ill and the determination of neurologic status can be difficult, as it is often complicated by sedating medication or cerebral edema. Clinical judgment may dictate early scanning if the patient fails to progress as expected, even if worrisome focal neurologic signs are absent.

(77)

Symptoms and findings of CNS involvement by SLE or vasculitis are quite varied but typically include headache, mental status changes, seizure, or stroke. Focal or nonspecific neurologic findings may also accompany HIV, without concomitant opportunistic CNS infection. These diseases have characteristic imaging findings that aid in diagnosis and thereby guide therapy.

(78)

HIV in children is most often acquired by vertical transmission in utero, often with direct involvement of the brain by HIV. Characteristic MRI findings include cerebral atrophy, white matter abnormalities, and basal ganglia calcification (Hunter and Morriss, *Semin Pediatr Infect Dis* 2003; 14(2): 140-164).

(79)-DEF:

Type I neurofibromatosis (von Recklinghausen's disease) is a disorder characterized by cafe au lait spots, neurofibromas, freckling in the axillary or inguinal areas, optic gliomas, and osseous lesions. It most commonly presents with cognitive or psychomotor problems, learning disabilities, or mental retardation.

(80)

Brain imaging in neurofibromatosis is performed with special cuts through the optic nerves to exclude optic gliomas which can occur in up to 15% of patients. Baseline MRI or CT provides information on growth characterization of the tumor and assists in plans for treatment (e.g. chemotherapy) (Williams et al., *Pediatrics* 2009; 123(1): 124-133).

(81)-DEF:

Tuberous sclerosis (Bourneville's disease) is an inherited disease of unknown etiology. The classic triad of seizures, mental retardation, and sebaceous adenomas is seen in only 1/3 of patients. Tuberous sclerosis typically presents with a wide variety of symptoms, from simple skin findings (e.g., facial angiofibromas) to seizure disorders with mental retardation later in life.

(82)

CT findings in tuberous sclerosis include pathognomonic subependymal calcifications, widened gyri, and brain tumors. MRI often detects hypomyelinated lesions that are associated with tubers or developmental abnormalities of the cerebral cortex, which are present in over 80% of patients. Tubers can calcify or undergo cystic degeneration. Molecular genetic testing of the TSC1 or TSC2 loci is currently viewed as corroborative (Crino et al., *N Engl J Med* 2006; 355(13): 1345-1356; Kandt, *Neurol Clin* 2003; 21(4): 983-1004).

(83)

Although the lungs are the primary site of infection in TB, approximately 10% of immunocompromised patients will develop CNS involvement. The most severe CNS complication is the development of tuberculous meningitis (Thwaites and Tran, *Lancet Neurol* 2005; 4(3): 160-170).

(84)-DEF:

Hydrocephalus is an excessive accumulation of cerebrospinal fluid intracranially often resulting in ventricular dilation and increased ICP.

(85)

Diagnostic evaluation of the child with mental status changes typically involves identification and rapid elimination of hypoglycemia, abnormalities of electrolytes or renal function, and intoxicants.

(86)

Confusion is characterized by fluctuating levels of consciousness and attention. Most commonly, confusion has a toxic or metabolic etiology, but imaging may be required to exclude a structural cause.

(87)-DEF:

Macrocephaly is defined as a head circumference >2 SD above the mean for age and sex.

(88)

Imaging for patients with macrocephaly is indicated when there is focal neurologic findings or excessive head growth which could suggest increased ICP most likely caused by hydrocephalus, fluid collections, or neoplasm. Imaging is not needed if the head circumference is large but growing according to the growth curves and not at an accelerated rate. Macrocephaly with normal head

growth implies familial macrocephaly. Imaging permits accurate diagnosis and prognosis, serves as a basis for comparison as the child grows, and is performed to define any structural cause of the macrocephaly that may be amenable to operative repair (e.g., brain tumor, arachnoid cyst) (Adam and Dixon, *Allison's diagnostic radiology : a textbook of medical imaging*, 5th ed. 2008, 950p, 174p; Medina et al., *AJNR Am J Neuroradiol* 2001; 22(3): 564-570).

(89)-DEF:

Microcephaly is defined as a head circumference > 3 SD below the mean for age and sex.

(90)

Microcephaly should be suspected in full-term newborns and infants up to 6 months of age whose chest circumference exceeds head circumference (unless the child is very obese). Imaging permits accurate diagnosis and may demonstrate calcifications, malformations, or atrophic patterns that suggest congenital infections (e.g., TORCH, Coxsackie B virus) or genetic syndromes (e.g., trisomy 13, 18, 21) that can cause microcephaly (Adam and Dixon, *Allison's diagnostic radiology : a textbook of medical imaging*, 5th ed. 2008, 950p, 174p). MRI can also help to determine a specific diagnosis in patients with microcephaly and global developmental delay (Shevell et al., *Neurology* 2003; 60(3): 367-380).

(91)-DEF:

Craniosynostosis is premature closure of the cranial sutures and can result in scaphocephaly (elongation of the head in the anterior-posterior direction) or brachycephaly (an increase in cranial diameter from left to right).

(92)

CT is obtained to define suture lines, analyze the intracerebral anatomy, and determine if there are enlarged ventricles secondary to increased ICP (Adam and Dixon, *Allison's diagnostic radiology : a textbook of medical imaging*, 5th ed. 2008, 950p, 174p).