HEAD INJURY

CONCUSSION/MILD TBI

Description

The Centers for Disease Control and Prevention (CDC) use the term mTBI, which accounts for 88% to 92% of cases of TBI, interchangeably with the term concussion. mTBI or concussion is defined as a complex pathophysiologic process affecting the brain, induced by traumatic biomechanical forces secondary to direct or indirect forces to the head. mTBI is caused by a blow or jolt to the head that disrupts the function of the brain. mTBI results in a constellation of physical, cognitive, emotional and sleep-related symptoms. Duration of symptoms is variable and may last as long as several days, weeks, months or even longer in some cases.4

This disturbance of brain function is typically associated with neurometabolic dysfunction with normal structural anatomy. The neurometabolic cascade following concussion consists of calcium influx, increase in glucose consumption, andincreased metabolic demand.5

Concussion can result in a variety of physical, cognitive, emotional, and sleeprelatedsymptoms lasting from days to months. Table 1 lists these symptoms,including those most concerning, such as depression and anxiety. Unrecognized and poorly managed concussion can result in postconcussion syndrome, with durationof symptoms lasting beyond 2 weeks and up to several months.6 Research hasdemonstrated promise in early intervention and a program of graduated return toplay, sport, and school work for youth with concussion

Concussion symptom checklist

Physical	Cognitive	Emotional	Sleep
Headache	Feeling mentally foggy	Irritability	Drowsiness
Nausea	Feeling slowed down	Sadness	Sleeping less than usual
Vomiting	Difficulty concentrating	More emotional	Sleeping more than usual
Balance problems	Difficulty remembering	Nervousness	Trouble falling asleep
Dizziness			
Visual problems			
Fatigue			
Sensitivity to light			
Sensitivity to noise			
Numbness			
Tingling			

Adapted from Centers for Disease Control and Prevention. Heads up: brain injury in your practice. Available at: http://www.cdc.gov/concussion/HeadsUp/physicians_tool_kit.html.

Evaluation

The history and physical examination is the cornerstone of the diagnosis of concussion. Psychometrically validated concussion-screening tools based on the history and physical examination such as the Acute

Concussion Evaluation (ACE) are effective, and have been coupled with management or “concussion care plans” available

Sports Concussion

If a student athlete is suspected to have a concussion, the athlete is removed from play and requires clearance, in most cases from a licensed medical professional, toreturn to play. The recommendation is for those on the sidelines such as coaches and athletic trainers to pull a child from the field when concussion is suspected and to have the player “sit it out, if in doubt.” The reasons for this proactive removal from play are to:

- Allow for healing
- Prevent “second-impact syndrome,” a serious diffuse axonal injury resulting in uncal herniation14
- Prevent neurocognitive sequelae of reinjury15

In addition to restrictions on physical activity, both the American Academy of Pediatrics and Zurich Consensus Statement on Concussion in Sport recommend limitation of scholastic and other cognitive activities for athletes following concussion

Table 2
Return-to-play guidelines for pediatric sport concussion

	Restrictions	Return to Play
Physical rest	No sports No weight training No cardiovascular training No Physical Education No bike riding	Clearance by Licensed Independent Practitioner (LIP) or concussion expert If symptom-free at rest and exertion Pass neurocognitive and balance assessment
Cognitive rest	No homework Shortened school day No reading No video games, computers, cell phones, or texting No television No travel Increased rest and sleep	Able to complete symptom-limited exercise program No same-day return to play!

Immediate removal of athlete from play recommended if any sign or symptom of concussion is witnessed.

Adapted from The Zurich Consensus Statement, an international conference of concussion experts, McCrory P, Meeuwisse, Aubry M, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. Br J Sports Med 2013;47:250–8; with permission.

Chronic Traumatic Encephalopathy

The postmortem neuropathologic studies of McKee and colleagues22 on chronic traumatic encephalopathy (CTE) resulting from repetitive head trauma have gained widespread media attention. Blinded to the patient's clinical history, McKee and colleagues22 have documented CTE and associated neuropathologic changes with tau-immunoreactive neurofibrillary tangles in the cortex, resulting in a progressive motor neuron disease. These changes have been noted in a series of professional and youth athletes and a host of others who have suffered repetitive head trauma.

Neuropathologic findings and symptoms associated with chronic traumatic encephalopathy

Neuropathologic Changes	Symptoms
Decreased brain mass	Depression/apathy
Enlarged lateral and third ventricles	Suicidal behavior
Brain atrophy	Problems with executive function
Neurofibrillary tangles	Problems with short term memory
β-Amyloid deposits	Emotionally labile
Pallor	Problems with impulse control

Adapted from Stern RA, Riley DO, Daneshvar DH, et al. Long-term consequences of repetitive brain trauma: chronic traumatic encephalopathy. Phys Med Rehabil 2011;3:S460–7; with permission.

Prediction Rules for Cranial CT after Head Trauma

In 2009, the Pediatric Emergency Care Applied Research Network (PECARN)29 published 2 validated prediction rules to identify children at very low risk of clinically important TBI (ciTBI), not in need of a CT scan.30 More than 40,000 children 0 to 18 years of age were prospectively enrolled in the PECARN study. Table 4 lists the two prediction rules, one for preverbal children (<2 years) and the other for verbal children (≥2 years).

The PECARN prediction rules have excellent performance characteristics, and were derived by incorporating clinical findings that were readily available and had good interobserver reliability.31 If none of the 6 predictors in either prediction rule is present, the child is at very low risk of ciTBI, and CT can be avoided.

For children younger than 2 years the prediction rule had:

- Negative predictive value of 100% (95% confidence interval [CI] 99.7–100.0)
- Sensitivity of 100% (95% CI 86.3–100.0)

For children 2 years and older the prediction rule had:

 Negative predictive value of 99.95% (95%CI 99.81–99.99)

 Sensitivity of 96.8% (95% CI 89.0–99.6)

ciTBI, the outcome of interest, was defined as:

 Death from TBI

 Neurosurgical intervention for TBI Intubation longer than 24 hours

 Hospitalization 2 nights or longer for TBI; with TBI on CT

The PECARN study risk stratifies children with minor head trauma into high risk, intermediate risk, and low risk, for clinically important TBI This risk stratification provides the Emergency Physician with easy-to-use recommendations for CTJ

.

Table 4
PECARN prediction rule for clinically important TBI (ciTBI) in children younger than 2 and in those 2 years and older

PECARN Prediction Rule for <2 y	PECARN Prediction Rule for ≥2 y
GCS <15	GCS <15
Sign of altered mental status	Signs of altered mental status
Palpable skull fracture	Signs of basilar skull fracture
Occipital, parietal, or temporal scalp hematoma	Severe headache
History of LOC ≥5 s	History of LOC
Severe mechanism of injury[a]	Severe mechanism of injury[a]
Not acting normally per parent	History of vomiting

If patients have no sign or symptom in the prediction rule, CT scan is not recommended as they are at very low risk of ciTBI.

Abbreviations: GCS, Glasgow Coma Scale score; LOC, loss of consciousness.

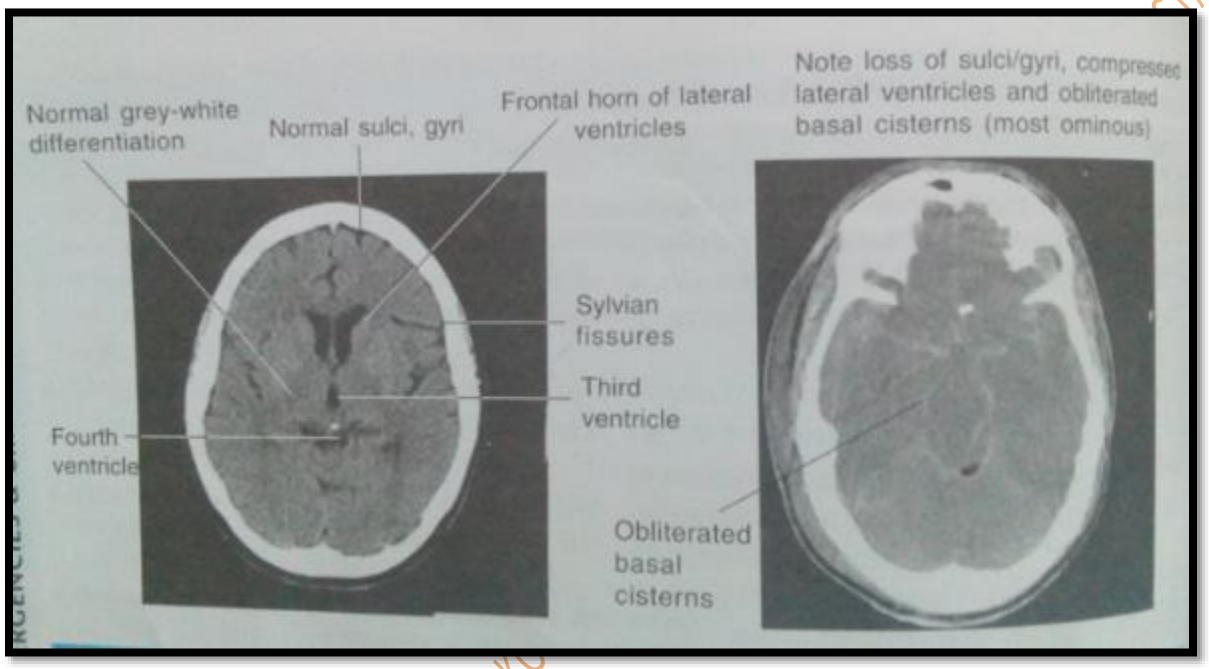
[a] Severe mechanism of injury: motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by a motorized vehicle; falls more than 0.9 m (3 feet) for <2 years or more than 1.5 m (5 feet) for ≥2 years; head struck by a high-impact object.

Data from Kuppermann N, Holmes JF, Dayan PS, et al, for the Pediatric Emergency Care Applied Research Network (PECARN). Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. Lancet 2009;374:1160–70.

decision making. For the low-risk group CT is not recommended, and for the high-risk group (those with altered mental status, Glasgow Coma Scale [GCS] <15 or signs of skull fracture) CT is recommended. For the intermediate-risk group, for whom observation is recommended versus CT scan, observation often rovides a reasonablealternative to cranial CT in the evaluation of the child with minor TBI. This finding holdsparticularly true for children with isolated predictors, such as isolated loss of consciousness,

32 isolated headache, or vomiting,33,34 who have a low risk of ciTBI. In asecondary analysis of the ECARN cohort, with clinical observation periods documentedto be 3 to 6 hours, investigators found that clinical observation was associated with reduced CT use.

Application of the PECARN prediction rules in general EDs, where the majority of children with head trauma are evaluated and CT scan rates are close to 50%, could result in a significant reduction in Unnecessary scans



NORMAL CT

CT WITH ICT

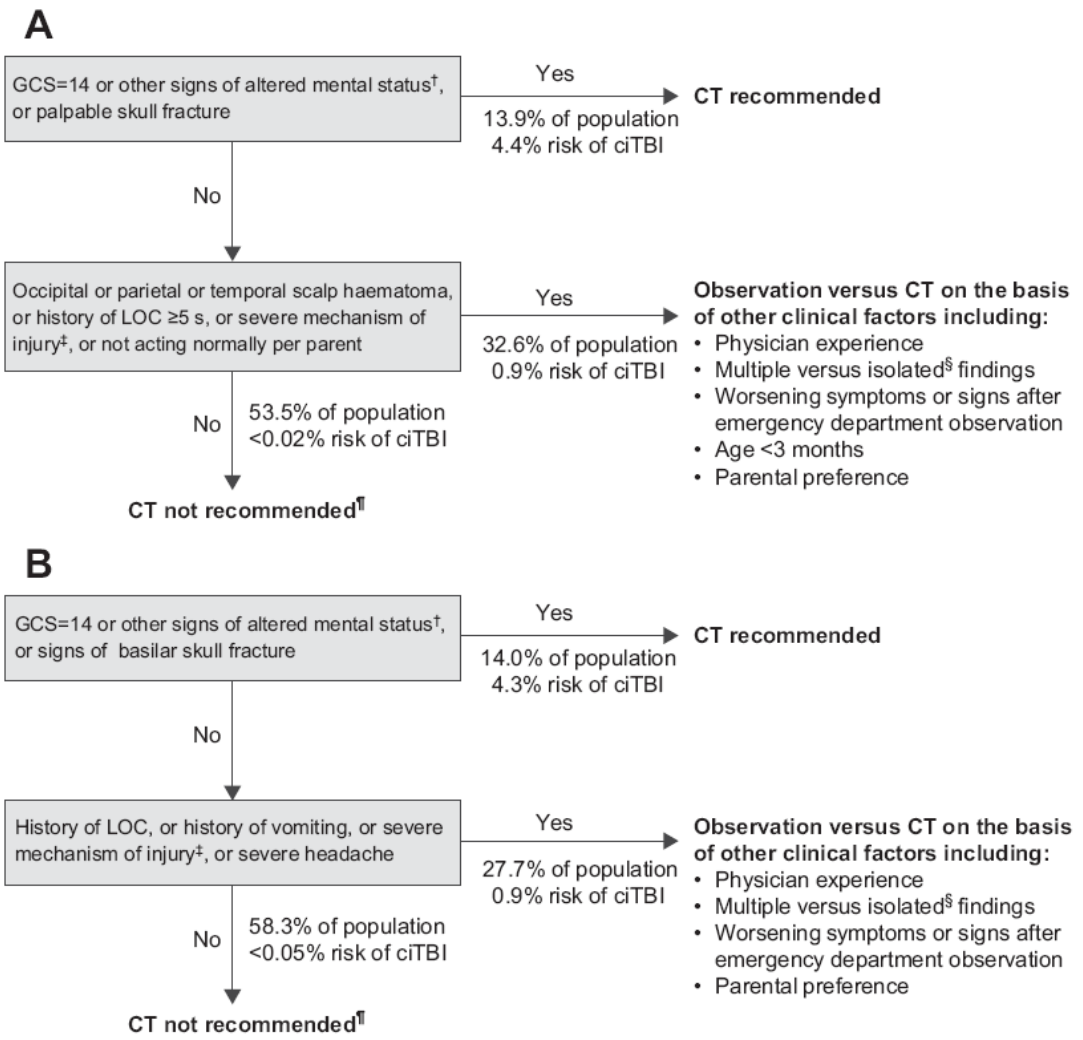


Fig. 1. Suggested computed tomography (CT) algorithm for children younger than 2 years (*A*) and for those aged 2 years and older (*B*) with Glasgow Coma Scale (GCS) scores of 14 to 15 after head trauma (Data are from the combined derivation and validation populations). ciTBI, clinically important traumatic brain injury; LOC, loss of consciousness. † Other signs of altered mental status: agitation, somnolence, repetitive questioning, or slow response to verbal communication; ‡ Severe mechanism of injury: motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by a motorised vehicle; falls of more than 0.9 m (3 feet) (or more than 1.5 m [5 feet] for panel B); or head struck by a high-impact object; § Patients with certain isolated findings (ie, with no other findings suggestive of traumatic brain injury), such as isolated LOC, isolated headache, isolated vomiting, and certain types of isolated scalp haematomas in infants older than 3 months, have a risk of ciTBI substantially lower than 1%; ¶ Risk of ciTBI exceedingly low, generally lower than risk of CT-induced malignancies. Therefore, CT scans are not indicated for most patients in this group. (*From* Kuppermann N, Holmes JF, Dayan PS, et al, for the Pediatric Emergency Care Applied Research Network (PECARN). Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. Lancet 2009;374:1160–70; with permission.)

Hospitalization

Children with minor blunt head trauma seen in the ED frequently undergo CT, and are hospitalized for observation and serial neurologic examinations. These children may at times also receive subsequent CT scans. Children with blunt head trauma and normal cranial CT results generally do not require hospitalization for neurologic observation. Holmes and colleagues35 found that of approximately 14,000 children with minor blunt head trauma (GCS 14 or 15) and normal ED CT scans, nearly one-fifth were hospitalized and 2% had subsequent neuroimaging, although none required neurosurgical intervention.

MODERATE AND SEVERE TBI

TBI is the leading cause of morbidity and mortality in children. The incidence of TBI has increased worldwide, most likely as a result of increased automobile use. The World Health Organization (WHO) projects that mortality from TBI related to road traffic accidents will double over a 2-decade period from 2000 to 2020.36

It is essential to assess the pedestrian struck by an automobile for head trauma, as demonstrated in Waddell's triad 38

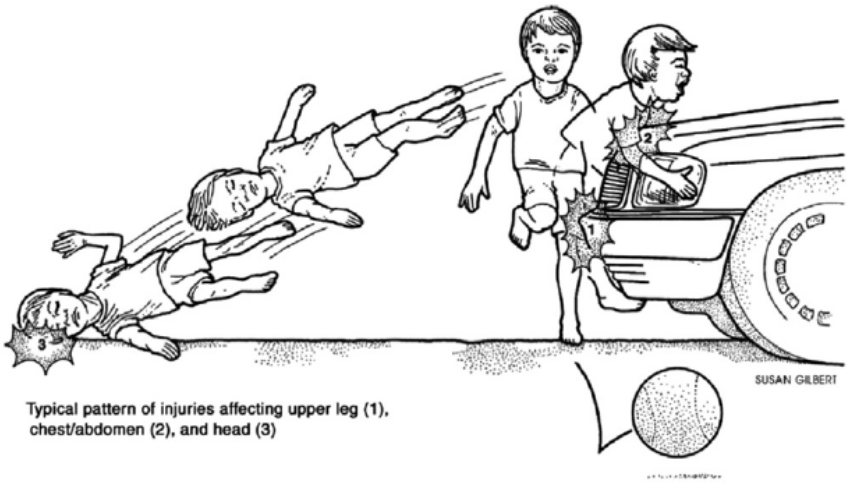


Fig. 2. Waddell's triad[37] demonstrates a pedestrian child struck by an automobile. The child is hit on the left side with bumper impact to the femur and fender impact to the abdomen, then is thrown to the ground with impact to the head. (*From* Atabaki SM. Prehospital evaluation and management of traumatic brain injury in children. Clin Pediatr Emerg Med 2006;7:94–104; with permission.)

Head trauma resulting in neuronal injury in moderate or severe TBI follows a

biphasic pattern:

Primary injury

Acute

Secondary injury

May occur hours to days after head trauma

Indirect injury resulting from

- Hypoxemia

- Hypotension

- Cerebral edema

- Hypoglycemia

Early initiation of therapy and the use of standardized guidelines in the management of moderate and severe TBI are essential to improve outcomes in children. However, randomized controlled trials in children with moderate and severe TBI are rare and children and are often excluded from large randomized controlled trials in adults.

Prehospital care for severe TBI has not changed in the past decade, and focuses on:

The management of ABCs (Airway, Breathing, Circulation)

Patient with GCS less than 9 should be intubated via rapid-sequence intubation

Ketamine is contraindicated, as it can increase intracranial pressure (ICP)

Triage to a trauma center

Based on GCS

Signs of ICP, Cushing's triad, unequal pupils

Higher survival in severe TBI for patients directly transported by emergency medical services to a pediatric trauma center39

Reduced mortality in subdural hematoma if operated within 4 hours after injury4

Prevention and treatment of hypoxemia41

Brain injury can lead to respiratory depression and failure

Treatment of hypotension

Fluid resuscitation

 Maintain systolic blood pressure higher than 70 1 (2 age in years)

- Prehospital initiation of treatment of hypotension improves outcomes42

- Hypotension is a sensitive indicator of mortality43

Treatment of hypoglycemia44

- Glucose should be checked

- TBI induces increased energy demands and hyperglycolysis

Indications for hypertonic saline or mannitol and hyperventilation include signs of increased ICP or cerebral herniation such as:

 Cushing's triad

 Triad of hypertension, bradycardia, and irregular respirations

 Abnormal pupil examination

 Asymmetric, fixed, or dilated pupils

 Neurologic deterioration

 Drop in GCS greater than 2 points for patients with GCS less than 953

 Posturing

 Extensor posturing

Prophylaxis of Posttraumatic Seizure

Head trauma is the cause of 5% of epilepsy in children and is the cause of 20,000 new cases of epilepsy each year.54 Nearly 20% of patients with severe TBI will develop posttraumatic epilepsy (PTE).54,55 Prior trials of phenytoin, carbamazepine, and valproate to prevent PTE in animal models and humans have not been successful.56,57 However, prophylaxis with phenytoin to prevent early posttraumatic seizure may be considered.

Levetiracetam has emerged as a promising therapy to prevent PTE. Levetiracetam has been effective in animal models in preventing PTE and is used in humans to treat nontraumatic epilepsy.58 Recently

published studies on the safety and pharmacokinetics of levetiracetam in children with severe TBI and intracranial hemorrhages pave the way for future randomized controlled trials.

Intraventricular Hemorrhage

Children with isolated intraventricular hemorrhage (IVH) have better outcomes than those with combination of IVH and other intracranial injury on CT (nonisolated IVH). Lichenstein and colleagues61 report that of approximately 15,000 children with CT for head trauma, 7% had intracranial injury and 0.9% had isolated IVH. This isolated IVH group had good outcomes; none required neurosurgery or died. By contrast, of 37% of patients with nonisolated IVH, 37% died and 42% required neurosurgery

Skull Fractures

Head trauma in younger children often results in skull fracture, which may also be associated with an Underlying intracranial injury. If skull fracture is suspected to result from a hematoma in the presence of underlying bony step-off or significant tenderness of the skull, and intracranial injury is also suspected, a cranial CT scan is warranted. Signs of skull fracture place children at higher risk of ciTBI, and a CT scan is often recommended in this population to uncover underlying intracranial disorder. In general, the majority of skull fractures are linear and are associated with good outcomes.

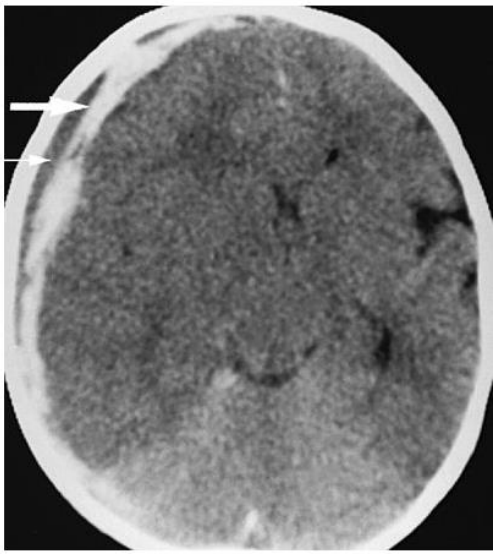
Basilar Skull Fracture

If a basilar skull fracture is suspected a CT scan should be obtained, owing to the poor sensitivity of plain radiography in detecting these injuries. Patients with identified basilar skull fractures are no longer routinely hospitalized, and can be closely observed by guardians as outpatients. The routine administration of prophylactic antibiotic is also no longer recommended. However, these children should be closely observed for signs of intracranial infection, and told to return for immediate medical attention if they develop a fever or neurologic deficit, especially within the first few weeks following head trauma

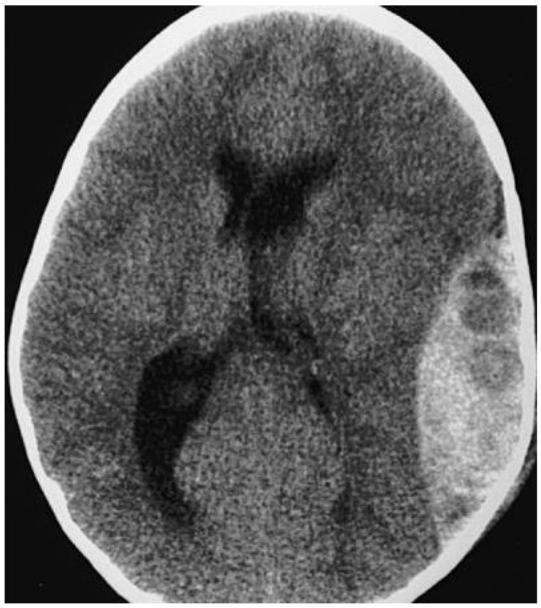
REFERENCE

Updates in the General Approach to Pediatric Head Trauma and Concussion
Shireen M. Atabaki, MD, MPH

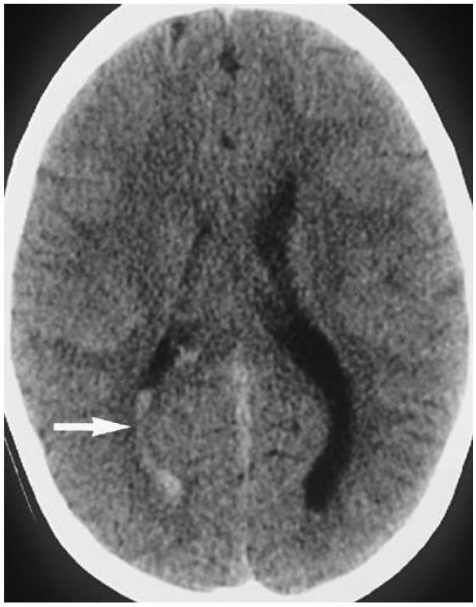
Pediatr Clin N Am 60 (2013) 1107–1122



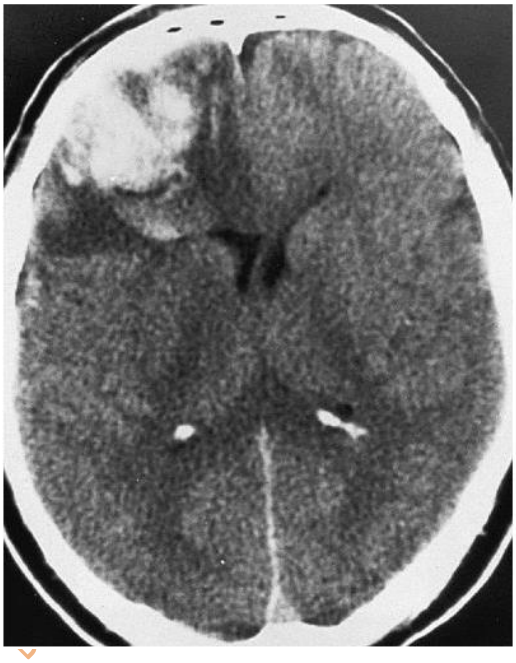
Subdural hematoma (SDH) and brain swelling. This 9-month-old boy reportedly became suddenly unresponsive. There was no history of trauma. On examination, he was comatose with fixed dilated pupils and extensor posturing. Massive bilateral retinal hemorrhages were seen. This head computed tomographic scan shows a right-sided SDH, with acute hyperdense (thick arrow) and hyperacute isodense (thin arrow) components. Midline shift to the left is noted. There is also evidence of brain swelling, with effacement of the sulci and poor gray–white differentiation. The diffuse hypodensity of the cerebral cortex can be contrasted with the normal density of the cerebellum, which appears whiter in this view. A diagnosis of child abuse was made



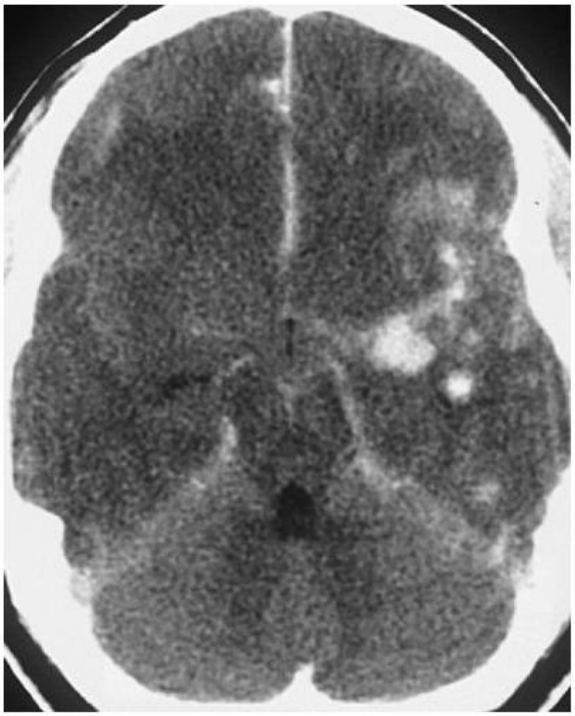
Epidural hematoma (EDH). This 11-month-old boy presented with progressive lethargy and vomiting after falling 2 ft off of a bed. Several hours after the injury, he became unresponsive with dilated, nonreactive pupils. This head computed tomographic scan shows a large EDH, with intermingled hypodense areas representing active bleeding. Note also the midline shift and the compression of the ipsilateral ventricle. After an emergency craniotomy, the patient made a full recovery.



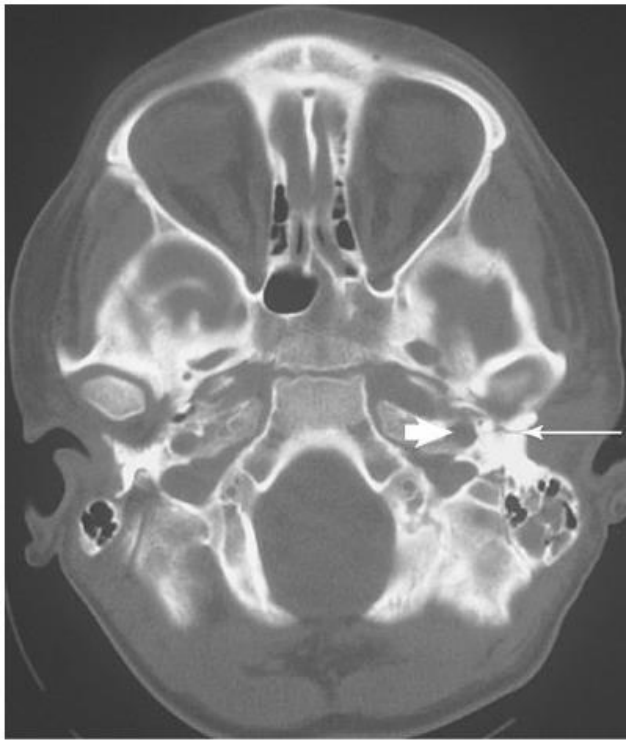
Intraventricular hemorrhage. This head computed tomographic (CT) scan was performed on an 8-year-old girl who was involved in a sledding accident. She presented in coma. The arrow indicates hemorrhage in the right lateral ventricle. Note the layering of blood inferiorly in this supine patient. Other “cuts” of the CT showed areas of punctate hemorrhage consistent with diffuse axonal injury. The patient made an excellent recovery, with minimal neurologic deficits



Intraparenchymal hemorrhage. This adolescent boy was an unrestrained passenger in a high-speed motor vehicle collision. He was comatose on presentation. A head computed tomographic scan shows a large area of intraparenchymal hemorrhage in the right frontal region. Note also the surrounding area of low-density cerebral contusion

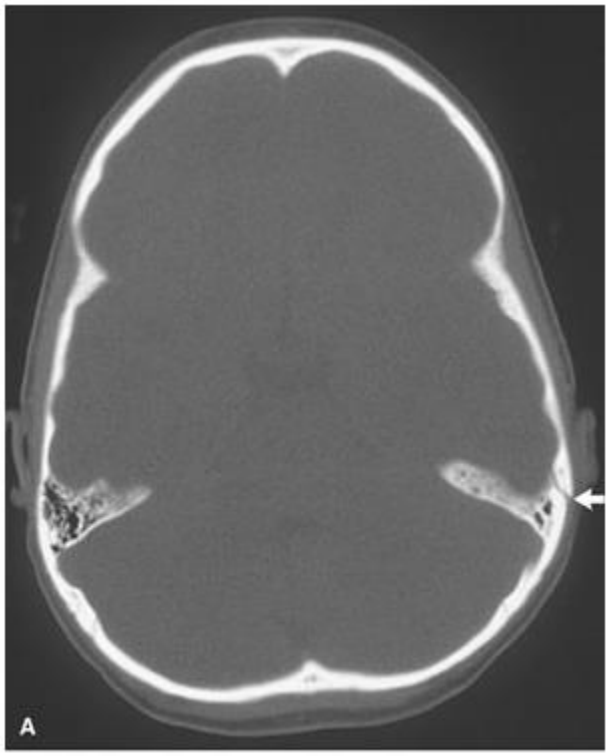


Cerebral contusion. This 16-year-old adolescent girl was comatose after being a passenger in a high-speed motor vehicle collision. A head computed tomographic scan shows hemorrhagic contusion of the left temporal lobe, subdural hematoma along the tentorial margins, and effacement of the sulci throughout. The patient died despite intensive medical management for increased intracranial pressure.

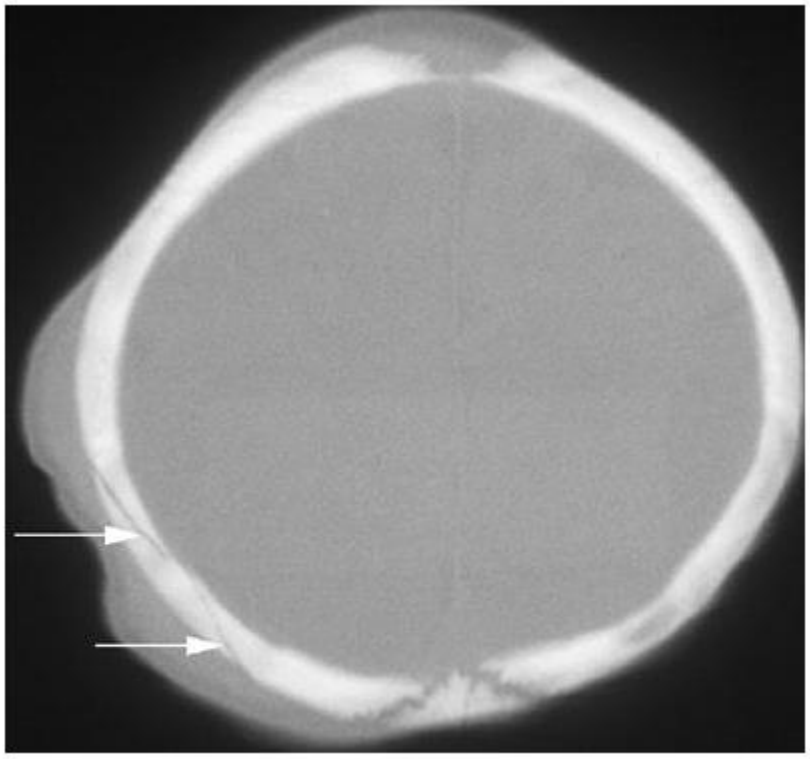


Basilar skull fracture. This 10-year-old boy fell 10 ft to the ground. He had left hemotympanum. A head computed tomographic (CT) scan shows a fracture

through the petrous portion of the temporal bone (thin arrow), extending toward the internal carotid canal (thick arrow). The left mastoid air cells are somewhat opacified. Other “cuts” of the CT scan confirm that the fracture involves the wall of the carotid canal. A cerebral angiogram was performed, which showed normal vascular integrity



A: The arrow indicates a fracture of the left temporal bone. The adjacent mastoid air cells are somewhat opacified



Linear skull fracture. This is a head computed tomography scan performed on a 6-month-old girl who fell down 20 steps. The arrows indicate a comminuted linear right parietal skull fracture. Note also the extensive soft-tissue swelling of the right parietal scalp. No intracranial abnormalities were identified