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## Head Injury

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# Head Injury

Rainer Gedeit, MD\*

**Objectives** After completing this article, readers should be able to:

1. Delineate the evaluation of head injury.
2. List the essential factors for the best possible outcomes following head injury.
3. Enumerate potential lasting effects of minor head injury.
4. Explain the situations in which radiologic imaging is required for head injury.
5. Describe the evaluation of sports-related concussions.

## Introduction

Traumatic head injury continues to be a major problem in pediatrics, despite efforts to reduce its incidence. Both minor and major head injuries result in significant morbidity and mortality. Physicians who care for children must understand the need for timely evaluation and treatment of head injuries and the possible long-term problems. Appropriate management of patients suffering from head trauma is important to minimize complications. Despite increased understanding of the pathophysiology of traumatic brain injury, no new pharmacotherapies have been developed, and supportive care continues to be the mainstay of therapy. Because of this, prevention remains of utmost importance. A synopsis of the American Academy of Pediatrics Practice Parameter on Head Injury appears in the December 2000 issue of *Pediatrics in Review*.

## Epidemiology

Head trauma is one of the most frequent reasons for an acute visit to physicians and the leading cause of death and disability in children, accounting for more than 50% of the deaths in the pediatric population. Approximately 100,000 to 200,000 pediatric head injuries occur per year, with a rate of 193 to 367 per 100,000. The incidence peaks early in childhood and again in mid to late adolescence, mirroring the risks of nonaccidental and vehicular trauma, respectively. Males are affected more than females, with a ratio of 2 to 4:1 in adolescents and the highest rate occurring among the lowest socioeconomic classes. About 10% to 15% of hospitalized children who have a head injury have a serious head injury; 33% to 50% of these children will die. Survivors of severe head injury often have permanent disability, but children who have mild or moderate head injury also are at risk for long-term cognitive and motor dysfunction.

## Definitions

Head trauma is classified as mild, moderate, or severe based on neurologic status using the Glasgow Coma Score (Table 1), which is modified for use in children. A GCS of at least 13 defines mild head injury, 9 to 12 indicates moderate head injury, and 8 or less is considered severe head injury.

A concussion is defined as minor head trauma that causes confusion or loss of consciousness (<1 min). Concussion can be associated with seizure, vomiting, confusion, headache, or lethargy. There may be associated computed tomography (CT) evidence of intraparenchymal injury with concussion.

A brain contusion occurs when the brain is injured directly. Areas of focal cortical injury result from either direct trauma from external contact forces or from the brain contacting

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Table 1. Modified Glasgow Coma Score

Score	>1 year	<1 year	
<b>Eye Opening Response</b>			
4	Spontaneous	Spontaneous	
3	To verbal command	To shout	
2	To pain	To pain	
1	None	None	
<b>Motor Response</b>			
6	Obeys commands	Spontaneous	
5	Localizes pain	Localizes pain	
4	Withdraws to pain	Withdraws to pain	
3	Has abnormal flexion to pain (decorticate)	Has abnormal flexion to pain (decorticate)	
2	Has abnormal extension to pain (decerebrate)	Has abnormal extension to pain (decerebrate)	
1	None	None	
Score	>5 years	2 to 5 years	0 to 2 years
<b>Verbal Response</b>			
5	Is oriented and converses	Uses appropriate words and phrases	Babbles, coos appropriately
4	Has confused conversation	Uses inappropriate words	Cries but is consolable
3	Uses inappropriate words	Cries or screams persistently to pain	Cries or screams persistently to pain
2	Makes incomprehensible sounds	Grunts or moans upon pain	Grunts or moans upon pain
1	None	None	None

intracranial surfaces with acceleration/deceleration trauma. These intraparenchymal abnormalities can be visualized by CT.

Bleeding due to tearing of the middle meningeal artery, middle meningeal vein, or dural sinus most often causes epidural hemorrhages. An epidural hemorrhage frequently is heralded by a brief loss of consciousness followed by a “lucid interval” and subsequent neurologic deterioration due to the mass effect of the expanding hematoma. The epidural hemorrhage can occur without a concomitant skull fracture and can be either acute or subacute, depending on the rate of bleeding. An epidural hematoma can enlarge very rapidly because of its arterial origin and, therefore, must be treated aggressively with immediate surgical drainage in most cases.

A subdural hemorrhage occurs when trauma results in tearing of bridging veins or dura. Subdural hemorrhages may be acute, subacute, or chronic, and the neurologic impact of this type of hemorrhage is proportional to the size of the bleed. Subdural hemorrhage can occur without a skull fracture. A subdural hemorrhage may need to be drained, depending on the size, the presence of mass effect, and associated neurologic deficits.

Subarachnoid hemorrhages, which are common with severe brain injury, result from bleeding into the cere-

brospinal fluid (CSF) from small vessels torn by forces generated by trauma. Subarachnoid bleeding can result in vasospasm and cerebral ischemia, leading to ischemic brain injury.

### Pathophysiology

Axonal injury is the primary pathologic feature of traumatic brain injury. Traumatic forces produce strains and distortions within the brain that disrupt axons and small blood vessels, causing brain edema. The immediate life-threatening complications are a result of this axonal disruption. The disruption is manifested as alteration or loss of consciousness. The cerebral impairment may be so severe that respiratory drive is affected, and the patient hypoventilates or becomes apneic, hypoxic, and hypercarbic. These developments eventually affect cardiovascular function if not addressed appropriately.

The number of axons injured and degree of edema increase with the traumatic force. Less severe axonal injury is reversible; more severe injury can be permanent. These forces also disrupt veins, arteries, and dural sinuses, resulting in subdural hematoma, epidural hematoma, and contusion. Subdural bleeding, epidural bleeding, and edema compress the brain parenchyma, shift intracranial structures, and increase intracranial pressure.

A significant increase in intracranial pressure impairs cerebral blood flow, thereby inducing ischemic brain injury and furthering brain injury and edema.

Primary brain injury from direct trauma is complicated by secondary neuronal injuries that result from abnormalities in blood flow, disturbances of capillary permeability, and inflammation. Traumatic injury begins a cascade of cellular responses that impair metabolism, alter blood flow, and worsen cerebral swelling. Studies have shown that local and global ischemia, abnormalities in glucose metabolism and autoregulatory mechanisms that regulate cerebral blood flow, and abnormal permeability of the blood-brain barrier increase brain edema. Other important factors, such as inflammation, free radical formation, and calcium influx, cause cell damage that worsens edema. These responses initiate a cycle of continued damage that may become irreversible. There is no specific therapy to treat or prevent secondary injury.

### Mild Head Trauma Evaluation

Mild head trauma is defined by a GCS of at least 13. It can be associated with temporary loss of consciousness (<1 min), seizure immediately after injury, vomiting, headache, or lethargy. As noted previously, it is one of the most common reasons for a visit to a physician, and it can have long-lasting effects. Therefore, it is important to perform a thorough and appropriate evaluation of the child. Many factors, including the age of the child, mechanism and severity of injury, presence of signs and symptoms, and availability of radiologic and neurosurgical consultants, influence the evaluation. The child who suffers mild head injury may have loss of consciousness and persistent symptoms following the injury. A thorough history should be obtained from all children who present for evaluation following head injury that recounts the event and witnessed symptoms (Table 2). A physical examination that includes a search for evidence of skull fracture, funduscopic examination to assess the presence of papilledema, and complete neurologic evaluation that encompasses scoring using the GCS must be performed. The information obtained should include: mechanism of injury, presence and duration of loss of consciousness, seizure activity, emesis, lethargy, confusion, and the presence of other possible injuries. For the infant and young child, the funduscopic examination should determine the presence of retinal hemorrhages if nonaccidental trauma is suspected. This initial assessment will determine the process of evaluation and treatment. Children who have moderate or severe head

### Table 2. Early Signs and Symptoms of Mild Head Injury (Concussion)

- Amnesia for the event
- Retrograde amnesia
- Vacant stare
- Confusion
- Disorientation
- Slurred speech
- Incoordination
- Inappropriate or exaggerated emotions
- Memory deficit
- Headache
- Nausea
- Dizziness
- Visual abnormalities
- "Foggy" feeling
- Irritability

trauma require CT imaging; those who have mild injury may require radiologic imaging.

### Management

The child who has normal findings on physical and neurologic examinations requires no further evaluation. Because there is no substantial risk of significant intracranial injury, CT is not indicated. However, the child must be observed for evidence of neurologic deterioration. The family should be made aware of this necessity and be able to identify worrisome symptoms, such as seizure, persistent headache, worsening lethargy, unremitting emesis, or other neurologic abnormalities (Table 2). If there is acute change, the child should be returned to medical attention for a repeat full evaluation that most likely includes CT. Long-term sequelae may follow mild head trauma (Table 3). Therefore, any changes in school performance or behavior should be brought to the attention of the child's physician.

The child who has persistent and significant symptoms following mild head injury requires CT because there is an increased risk of intracranial injury. Abnormalities on CT (bleeding, edema, contusion, skull fracture) coupled with persistent symptoms indicate significant head injury. These children should be admitted to a medical facility that has appropriate radiologic and neurosurgical consultation and operating room facilities because of the possible need for surgical intervention. Children whose symptoms are worsening require repeat CT to delineate intracranial pathology.

The child who has symptoms but normal findings on

### Table 3. Late Signs and Symptoms of Mild Head Injury (Concussion)

- Persistent headache
- Light-headedness
- Memory problems
- Poor concentration
- Easy fatigability
- Irritability
- Visual disturbances
- Noise intolerance
- Sleep disturbances
- Deterioration of school performance
- Changes in behavior

CT may be discharged from the hospital with appropriate instructions for observation and return to medical care if there is any change in status. The threshold for admission of these children depends on both patient age and parental ability to understand the need for close observation. Local practices and the availability of CT and neurosurgical consultation also affect the decision to admit or observe at home. These children also should be observed for any changes in school performance or behavior, with any problems being referred to the child's physician.

The child who has underlying chronic illness and sustains a head injury may need closer follow-up. The child who has significant developmental or communication abnormalities may not be able to relate symptoms to caregivers, necessitating hospitalization for close observation. Children who have underlying seizure disorders may be at higher risk for seizures following trauma. Therefore, appropriate information should be given to parents. Children who have bleeding disorders such as hemophilia need factor replacement and hospitalization following even mild head trauma because of the increased risk for intracranial bleeding. Physicians must have a low threshold for radiologic imaging in these patients.

#### Sports-related Head Injury

Return to play is an important issue for the child who suffers sports-related mild head injury because repeated head injury is associated with long-term sequelae. Many guidelines have been drafted that outline recommendations for evaluation and return to play. These guidelines stress the importance of appropriate evaluation and classification of the injury. The child must be evaluated for signs and symptom of concussion (Table 2), the duration

of signs and symptoms, and any loss of consciousness. Return to play depends on the severity of injury, persistence of symptoms (Table 3), and previous head injury (Table 4). Each case should be individualized, with the guidelines in mind.

#### Moderate and Severe Head Injury Evaluation

The priority in managing the patient who has moderate (GCS 9 to 12) or severe (GCS  $\leq 8$ ) head injury is to minimize secondary brain injury, with evaluation and treatment occurring simultaneously. Maintenance of adequate hemodynamics and oxygenation are of utmost importance. If hypoxic or ischemic injury occurs in addition to the traumatic injury, the prognosis worsens. The ABCs of emergency medical care apply as in every life-threatening situation: airway, breathing, and circulation. Endotracheal intubation and mechanical ventilation should be performed in patients who have a modified GCS of 8 or less, hypoventilation, apnea, cardiorespiratory arrest, or other significant injury. Hypoxia and hypercarbia should be avoided through the use of supplemental oxygen and controlled ventilation because even mild-to-moderate hypoxia or hypercarbia can affect cerebral blood flow and result in further brain injury. Patients who exhibit signs of impaired cardiac output, such as tachycardia or borderline or low blood pressures, should receive a bolus of isotonic fluid intravenously to ensure adequate circulating volume to maintain blood flow to the compromised brain. Those who continue to demonstrate hemodynamic compromise despite fluid resuscitation should receive inotropic/vasoactive medications to support cerebral circulation. The neurologic status of the patient must be followed during the period of resuscitation using the GCS to evaluate the response to therapy. The use of hyperventilation (PCO<sub>2</sub> of 30 to 35 torr) and mannitol (0.25 to 0.50 mg/kg) is appropriate for patients in whom herniation is impending until the neurologic evaluation is completed and the patient is stabilized. Seizures are common after traumatic and hypoxic brain injury and should be treated with benzodiazepines, phenytoin, and phenobarbital as needed.

After initial evaluation and stabilization, all children who have moderate or severe head injury require CT of the head. Significant subdural or epidural hemorrhage requires urgent or emergent evacuation to prevent secondary injury. Severe cerebral edema identified by CT may require placement of an intracranial pressure monitor, which necessitates consultation with a pediatric neurosurgeon. In the patient whose mental status is altered, there is a significant possibility of a spinal cord injury that

Table 4. Grading of Sports-related Concussion and Clinical Management

Symptoms	Management
<b>Grade 1</b> 1) No loss of consciousness 2) Transient confusion 3) Symptoms resolve in <15 min	1) Examine at 5-min intervals 2) May return to contest if no symptoms after 15 min 3) Second grade 1 in same contest eliminates player 4) May return if asymptomatic for 1 wk at rest and with exercise
<b>Grade 2</b> 1) No loss of consciousness 2) Transient confusion 3) Symptoms last >15 min	1) Remove from play that day 2) Examine frequently on site 3) Consider evaluation by a physician 4) Obtain CT or MRI if symptoms persist >1 wk 5) Return to play if asymptomatic for 1 wk at rest and with exercise 6) Following a second grade 2 concussion: Return when symptom-free for 2 wk at rest and with exercise 7) Any abnormality on CT or MRI terminates season
<b>Grade 3</b> 1) Any loss of consciousness	1) Remove from play for day 2) Perform thorough neurologic evaluation 3) Consider transport to medical attention (depending on severity of signs and symptoms) 4) Brief loss of consciousness: Return to play when symptom-free for 1 wk at rest and with exercise 5) Prolonged loss of consciousness: Return to play when symptom-free for 2 wk at rest and with exercise 6) Following a second grade 3 concussion: Return to play after symptom-free for 1 mo at rest and with exercise 7) Obtain CT or MRI if symptoms last >1 wk 8) Any abnormality on CT or MRI terminates season

CT = computed tomography; MRI = magnetic resonance imaging.

requires appropriate immobilization. Spinal cord immobilization must be continued until proper evaluation is completed. If other injuries are present or suspected, a pediatric surgery consultation is required. If nonaccidental trauma is suspected, an ophthalmology consultation is required to verify the presence of retinal hemorrhages and document their presence with photographs. Also, child advocacy team and social work consultations should be obtained whenever abuse is suspected.

The extent of laboratory and radiographic investigations needed varies with the patient's clinical status. Children who have severe brain injury need more extensive laboratory and radiographic investigation than those who have less severe injury. Follow-up evaluations also should be tailored to the clinical context. Children should be admitted to a pediatric intensive care unit if they have a GCS less than 12, a significant mechanism for head injury, other visceral injuries, or a deteriorating GCS in the period following initial evaluation.

### Management

Maintenance of cerebral perfusion and lowering of intracranial pressure are the goals of head injury management.

Cerebral perfusion pressure (CPP) is calculated as the difference between the mean arterial pressure and intracranial pressure (ICP). Maintenance of CPP greater than 60 mm Hg is required for adolescents; a CPP of 50 mm Hg or more may be adequate in infants and children. The ICP should be maintained at less than 15 mm Hg with therapies that include evacuation of intracranial bleeding, CSF drainage, sedation, osmolar therapy, and maintenance of adequate blood pressure. This type of management has led to decreased morbidity and mortality and improved functional outcomes for victims of traumatic head injury. Such interventions attempt to lessen the secondary injuries that result from ongoing hypoxia or inadequate perfusion.

Monitoring of ICP is required to manage increased ICP properly and to assist in the management of traumatic brain injury that involves cerebral swelling. Monitoring can guide therapy by allowing the clinician to see the results of specific therapies and to maintain an adequate CPP by manipulating ICP and systemic blood pressures. The ideal method of monitoring pressure is through the use of an intraventricular catheter because it can be used to measure pressure and drain CSF to reduce

pressure. Other methods of monitoring include intraparenchymal fiberoptic monitoring, which is inserted easily but does not allow for drainage of CSF.

Sedation is used in head-injured patients to reduce ICP and cerebral oxygen demand. Noxious stimuli that can cause increases in ICP need to be limited and can be blunted with appropriate use of sedation. The judicious use of benzodiazepines, narcotics, and barbiturates allows for adequate sedation without affecting hemodynamics. Barbiturate-induced coma should be considered for patients whose elevated ICP is refractory to other therapies.

Osmolar therapy is an important adjunct to management of the patient who has elevated ICP. Mannitol is used to elevate osmolality and help reduce brain water. It also has rheologic properties that will reduce ICP within minutes of its administration. However, its diuretic action may result in reduced intravascular volume and cerebral perfusion. Therefore, hemodynamics must be monitored carefully when using mannitol. Other therapies for reduction of ICP and secondary cerebral injury, such as corticosteroids and hypothermia, have not been shown to have significant benefits.

## Outcome

Overall mortality in head injury is lower in children than in adults at about 5%, although this increases to 59% if the trauma is severe. However, multiple factors, including mechanism of injury, age, severity of injury, and extent of secondary injury, influence outcome in children. Mortality can be as high as 90% if there is associated multiple trauma, hypoxia, hypercarbia, or hypotension. Survival is stratified by age, with children younger than 4 years and mid to late adolescents having higher mortality rates compared with school-age children. Mechanisms of injury are a factor in age-related mortality, with young children generally suffering diffuse and multiple injuries from nonaccidental trauma and adolescents suffering high-impact injuries from motor vehicle collisions. In school-age children, the injuries generally are focal and less severe, resulting in lower mortality rates.

Children usually have better functional outcomes than adults, but this recovery depends on age and stage of neural development. Generally, injury in infancy and early childhood results in greater morbidity than is seen in later childhood. This is believed to be due to the lack of myelination and developmental stage of the central nervous system.

The length of coma and posttraumatic amnesia corre-

late directly with functional outcome. Fewer than 24 hours of coma rarely is associated with permanent neurologic abnormalities, but recovery of normal intelligence has been reported with a coma of more than 1 week in duration. Coma lasting more than 3 weeks results in impaired intelligence that worsens as the time in the coma is extended. The outcome for children whose comas last between 1 and 3 weeks is variable. Improvements in function can continue for up to 1 year following head injury, especially in the older child and adolescent. Deficits can occur in all areas of neurologic function: cognitive, speech and language, motor, and behavior. The severity of deficit is related directly to the severity of injury.

Outcome after mild head injury is more difficult to assess because no formal studies have been performed. However, evidence in adolescents and young adults shows that multiple injuries result in cognitive deficits, as demonstrated by findings in college athletes. Mild head injury also can result in prolonged complaints of headache, visual disturbances, and problems with concentration. The full extent of these problems needs to be studied to determine effective treatment.

Most importantly, prevention needs to be emphasized. The importance of car seat, air bag, and bike helmet safety cannot be overstated, and physicians need to educate their patients and families about these safety measures. Prevention of nonaccidental trauma is a continuing problem that also requires effective prevention. Finally, all physicians should advocate the use of effective helmets and mouth guards in child athletes as well as thorough training for coaches, trainers, and athletes in the prevention of head injury. Prevention, as always, is our most effective tool.

## Suggested Reading

- Adelson PD, Kochanek PM. Head injury in children. *J Child Neurol.* 1998;13:2–15
- Collins MW, Lovell MR, Mckeag DB. Current issues in managing sports-related concussion. *JAMA.* 1999;282:2283–2285
- Committee on Quality Improvement, American Academy of Pediatrics: Commission on Clinical Policies and Research, American Academy of Family Physicians. Practice guideline: the management of minor closed head injury in children. *Pediatrics.* 1999; 104:1407–1415
- Coombs JG, Davis RL. A synopsis of the American Academy of Pediatrics' practice parameter on the management of minor closed head injury in children. *Pediatr Rev.* 2000;21:413–415
- James HE. Pediatric head injury: what is unique and different. *Acta Neurochir.* 1999;73(suppl):85–88

## PIR Quiz

Quiz also available online at [www.pedsinreview.org](http://www.pedsinreview.org).

6. Which of the following statements regarding head trauma in children is *true*?
  - A. All epidural hematomas are associated with overlying skull fractures.
  - B. Mild head trauma, by definition, is not associated with a loss of consciousness.
  - C. Only children who have severe head injury are at risk for long-term neurologic dysfunction.
  - D. Secondary cellular responses contribute significantly to brain injury after a direct traumatic insult.
  - E. The incidence of head trauma is highest among children ages 4 through 10 years.
  
7. You are evaluating a 3-year-old boy who fell off his tricycle and hit his head on concrete 2 hours ago. He had a 5-second seizure immediately after he fell, but there has been no further loss of consciousness. Findings on physical examination are normal, including mental status and neurologic evaluation. His parents are very concerned about his status. Of the following, the *most* appropriate course of management is:
  - A. Admission to the hospital for overnight observation.
  - B. Discharge to home with instructions to the parents for close follow-up.
  - C. Obtaining a neurosurgical consultation.
  - D. Obtaining a skull radiograph.
  - E. Obtaining immediate computed tomography of the head.
  
8. You are seeing an 8-year-old boy who has hemophilia. He reports falling at school and hitting his head 1 hour ago. He has vomited twice, but findings on neurologic evaluation are within normal limits. Of the following, the most important *next* management option is:
  - A. Admission to the hospital for observation.
  - B. Initiation of maintenance intravenous fluids.
  - C. Obtaining a neurosurgical consultation.
  - D. Obtaining immediate computed tomography of the head.
  - E. Ordering immediate factor replacement.
  
9. Which of the following is *not* an important part of the management of a moderate-to-severe head injury?
  - A. Fluid restriction.
  - B. Frequent neurologic examinations.
  - C. Head computed tomography.
  - D. Intubation with hyperventilation.
  - E. Medication for seizure prophylaxis.



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Erratum: In the article on Head Trauma that appeared in the April 2001 issue of *Pediatrics in Review*, the correct dosage for mannitol should be 0.25 to 0.5 g/kg rather than 0.25 to 0.5 mg/kg.