American Association of Neurological Surgeons

Traumatic Brain Injury

Patient Information

This resource, developed by neurosurgeons, provides patients and their families trustworthy information on neurosurgical conditions and treatments.

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A traumatic brain injury (TBI) is defined as a blow to the head or a penetrating head injury that disrupts the normal function of the brain. TBI can result when the head suddenly and violently hits an object or when an object pierces the skull and enters brain tissue. Symptoms of a TBI can be mild, moderate or severe, depending on the extent of damage to the brain. Mild cases may result in a brief change in mental state or consciousness, while severe cases may result in extended periods of unconsciousness, coma or even death.

Prevalence

About 1.7 million cases of TBI occur in the U.S. every year. Approximately 5.3 million people live with a disability caused by TBI in the U.S. alone.

Incidence and Demographics

- Annual direct and indirect TBI costs are estimated at $48-56 billion.
- There are about 235,000 hospitalizations for TBI every year, which is more than 20 times the number of hospitalizations for spinal cord injury.
- Among children ages 14 and younger, TBI accounts for an estimated 2,685 deaths, 37,000 hospitalizations and 435,000 emergency room visits.
- Every year, 80,000-90,000 people experience the onset of long-term or lifelong disabilities associated with TBI.
- Males represent 78.8 percent of all reported TBI accidents and females represent 21.2 percent.
- National statistics estimate between 50-70 percent of TBI accidents are the result of a motor vehicle crash.
- Sports and recreational activities contribute to about 21 percent of all TBIs among American children and adolescents.
- The mortality rate for TBI is 30 per 100,000, or an estimated 50,000 deaths in the U.S. annually. Of those who die, 50 percent do so within the first two hours of their injury.
- Deaths from head injuries account for 34 percent of all traumatic deaths. Beginning at age 30, the mortality risk after head injury begins to increase. Persons age 60 and older have the highest death rate after TBI, primarily because of falls, which have a rising incidence in this age group.

Sources:

Centers for Disease Control and Prevention (CDC), Traumatic Brain Injury (TBI): Incidence and Distribution, 2004.

Traumatic Brain Injury Model System, University of Alabama at Birmingham, Introduction to Brain Injury – Facts and Stats, February, 2000

TBI Symptoms

Symptoms vary greatly depending on the severity of the head injury, but may include any of the following:

- Vomiting
- Lethargy
- Headache
- Confusion
- Paralysis
- Coma
- Loss of consciousness
- Dilated pupils
- Vision changes (blurred vision or seeing double, not able to tolerate bright light, loss of eye movement, blindness)
- Cerebrospinal fluid (CSF) (which may be clear or blood-tinged) coming out of the ears or nose
- Dizziness and balance problems
- Breathing problems
- Slow pulse
- Slow breathing rate, with an increase in blood pressure
- Ringing in the ears or changes in hearing
- Cognitive difficulties
- Inappropriate emotional responses
- Speech difficulties (slurred speech, inability to understand and/or articulate words)
- Difficulty swallowing
- Body numbness or tingling
- Droopy eyelid or facial weakness
- Loss of bowel control or bladder control

If a TBI is suspected, call 911 immediately or take the person to an emergency room.

Surgical Lesions

When discussing TBI, the term "mass lesion" is often used. This refers to an area of localized injury that may cause pressure within the brain. The most common mass lesions related to TBI are hematomas and contusions.

A hematoma is a blood clot within the brain or on its surface. Hematomas may occur anywhere within the brain. An epidural hematoma is a collection of blood between the dura mater (the protective covering of the brain) and the inside of the skull. A subdural hematoma is a collection of blood between the dura mater and the arachnoid layer, which sits directly on the surface of the brain.

A cerebral contusion is bruising of brain tissue. When examined under a microscope, cerebral contusions are comparable to bruises in other parts of the body. They consist of areas of injured or swollen brain mixed with blood that has leaked out of arteries, veins or capillaries. Contusions are seen most commonly at the base of the front parts of the brain, but they may occur anywhere.

An intracerebral hemorrhage (ICH) describes bleeding within the brain tissue, which may be related to other brain injuries, especially contusions. The size and location of the hemorrhage helps determine whether it can be removed surgically.

Subarachnoid hemorrhage (SAH) is caused by bleeding into the subarachnoid space. It appears as diffuse blood spread thinly over the surface of the brain and is seen commonly after TBI. Most cases of SAH associated with head trauma are mild. Hydrocephalus may result from severe traumatic SAH.

Diffuse Injuries

TBI can produce microscopic changes that cannot be seen on CT scans that are scattered throughout the brain. This category of injuries is called diffuse brain injury, which may occur with or without an associated mass lesion.

Diffuse axonal injury refers to impaired function and gradual loss of some axons, which are the long extensions of a nerve cell that enable such cells to communicate with each other even if they are located in parts of the brain that are far apart. If enough axons are injured in this way, then the ability of nerve cells to communicate with each other and to integrate their function may be lost or greatly impaired, possibly leaving a patient with severe disabilities.

Another type of diffuse injury is ischemia, or insufficient blood supply to certain parts of the brain. It has been shown that a decrease in blood supply to very low levels may occur commonly in a significant number of TBI patients. This is crucial because a brain that has just undergone a traumatic injury is especially sensitive to even slight reductions in blood flow. Changes in blood pressure during the first few days after head injury can also have an adverse effect.

Skull Fractures

No treatment is required for most linear skull fractures, which are simple breaks or "cracks" in the skull. Of greater concern is the possibility that forces strong enough to cause a skull fracture may also have caused some damage to the underlying brain. Fractures of the base of the skull are problematic if they cause injury to nerves, arteries or other structures. If a fracture extends into the sinuses, there may be leakage of cerebrospinal fluid (CSF) from the nose or ears. Most leaks will stop spontaneously. Sometimes, however, it may be necessary to insert a lumbar drain, which is a long, thin, flexible tube that is inserted into the CSF space in the spine of the lower back. This provides an alternate route for CSF drainage so that the dural tear that is responsible for the CSF leak in the base of the skull has time to seal.

Depressed skull fractures are those in which part of the bone presses on or into the brain. These may require surgical treatment. The damage caused by depressed skull fractures depends upon the region of the brain in which they are located and also upon the possible coexistence of any associated diffuse brain injury.

Diagnosis

Like all trauma patients, persons with TBI need to undergo a systematic yet rapid evaluation in the emergency room. Cardiac and pulmonary function is assessed first. Next, a quick examination of the entire body is performed, followed by a complete neurological examination. The neurological examination includes an assessment utilizing the Glasgow Coma Scale (GCS). In addition to the GCS, the ability of the pupils to become smaller in bright light is also tested. In patients with large mass lesions or with high intracranial pressure (ICP), one or both pupils may be very wide or "blown". The presence of a wide or dilated pupil on only one side suggests that a large mass lesion may be present on the same side as the dilated pupil. Brainstem reflexes including gag and corneal (blink) may also be tested.

Radiological Tests

A computed tomography scan (CT or CAT scan) is the gold standard for the radiological assessment of a TBI patient. A CT scan is easy to perform and is an excellent test for detecting the presence of blood and fractures, which are the most crucial lesions to identify in medical trauma cases. Plain x-rays of the skull are recommended by some as a way to evaluate patients with only mild neurological dysfunction. However, most centers in the U.S. have readily available CT scanning, which is a more accurate test. For this reason, the routine use of skull x-rays for TBI patients has declined.

Magnetic resonance imaging (MRI) is not commonly used for acute head injury because it takes longer to perform MRI than a CT. MRI is not as practical for acute trauma because it is difficult to transport an acutely-injured patient from the emergency room to the MRI scanner. However, after a patient has been stabilized, MRI may demonstrate the existence of lesions that were not detected on the CT scan. This information is generally more useful for determining prognosis than for influencing treatment.

Surgical Treatment

Many patients with moderate or severe head injuries are taken directly from the emergency room to the operating room. In many cases, surgery is performed to remove a large hematoma or contusion that is significantly compressing the brain or raising the pressure within the skull. After surgery, these patients are usually observed and monitored in the intensive care unit (ICU).

Other head-injured patients may not go to the operating room immediately, but instead are taken from the emergency room to the ICU. Contusions or hematomas may enlarge over the first hours or days after head injury, so some patients are not taken to surgery until several days after an injury. Delayed hematomas may be discovered when a patient's neurological exam worsens or when their ICP increases. On other occasions, a routine follow-up CT scan that was ordered to determine if a small lesion has changed in size indicates that the hematoma or contusion has enlarged significantly. In many cases, removing the lesion before it enlarges and causes neurological damage may be the safest approach for the patient.

At surgery, the hair over the affected part of the head is usually shaved. After the scalp incision is made, the bone that is removed is usually taken out in a single piece or flap, which is then replaced after surgery. Sometimes, however, the bone may be shattered or heavily contaminated. In these cases, the contaminated or shattered fragments may be removed and not replaced. The dura mater is carefully cut to reveal the underlying brain. After any hematoma or contusion is removed, the neurosurgeon ensures that the area is not bleeding. He or she then closes the dura, replaces the bone and closes the scalp. If the brain is very swollen, some neurosurgeons may decide not to replace the bone until the swelling decreases, which may take up to several weeks. The neurosurgeon may elect to place an ICP monitor or other types of monitors if these were not already in place. The patient is then returned to the ICU for observation and additional care.

Medical Treatment

At the present time, there is no medication or "miracle treatment" that can be given to prevent nerve damage or promote nerve healing after TBI. The primary goal in the ICU is to prevent any secondary injury to the brain. The "primary insult" refers to the initial trauma to the brain, whereas the "secondary insult" is any subsequent development that may contribute to neurological injury. For example, an injured brain is especially sensitive and vulnerable to decreases in blood pressure that might otherwise be well tolerated. One way of avoiding secondary insults is to try to maintain normal or slightly elevated blood pressure levels. Likewise, increases in ICP, decreases in blood oxygenation, increases in body temperature, increases in blood glucose and many other disturbances can potentially worsen neurological damage. The prevention of secondary insults is a major part of the ICU management of head-injured patients.

Various monitoring devices may assist health care personnel in caring for the patient. Placement of an ICP monitor into the brain itself can help detect excessive swelling of the brain. One commonly used type of ICP monitor is a ventriculostomy, which is a narrow, flexible, hollow catheter that is passed into the ventricles, or fluid spaces in the center of the brain, to monitor ICP and to drain CSF if ICP increases. Another commonly used type of intracranial pressure monitoring device involves placement of a small fiberoptic catheter directly into the brain tissue. Additional catheters may be added that measure brain temperature and brain tissue oxygenation. Placement of an oxygen sensor into the jugular vein can detect how much oxygen in the blood is arising from the brain and can indicate how much oxygen the brain is using. This may be related to the degree of brain damage. Many other monitoring techniques are currently under investigation to see if they can help to improve outcome after head injury or provide other critical information about caring for TBI patients.

Outcome

One of the most widely used systems to classify outcome from head injury is the Glasgow Outcome Scale (GOS). Patients with mild head injury (usually defined as GCS score on admission of 13-15) tend to do well. They may experience headaches, dizziness, irritability or similar symptoms, but these gradually improve in most cases.

Patients with moderate head injuries fare less well. Approximately 60 percent will make a positive recovery, and an estimated 25 percent will be left with a moderate degree of disability. Death or a persistent vegetative state will be the outcome in about 7 to 10 percent of cases. The remainder of patients will have a severe degree of disability.

The group comprised of severely head-injured patients has the worst outcomes. Only 25 to 33 percent of these patients have positive outcomes. Moderate disability and severe disability each occur in about a sixth of patients, with moderate disability being slightly more common. About 33 percent of these patients do not survive. The remaining few percent remain persistently vegetative.

The above statistics apply to patients with so-called closed head injuries. For penetrating head injuries, which today are caused most commonly by handguns, outcomes follow a different pattern. More than 50 percent of all patients with gunshot wounds to the head who are alive upon arrival at a hospital do not survive because their initial injuries are so severe. However, most of the remaining patients tend to do fairly well, largely because their injuries are relatively mild (GCS score of 13-15). Relatively few patients suffer injuries of intermediate severity (GCS score of 9-12) from gunshot wounds, but it is this group that has the most variability in outcomes.

Despite its usefulness, the GOS is not a good tool with which to measure subtle emotional or cognitive problems. Several months after a severe head injury, patients who have a good score on the GOS may in fact have significant neuropsychological disabilities. Tremendous effort is being directed into finding better ways to evaluate these problems, into improving the quality of prehospital, acute and rehabilitative care, and into research to learn more about the effects of head injury and potential treatment options.

Table 1: Glasgow Coma Scale

SCALE VALUE	BEST MOTOR RESPONSE	BEST VERBAL RESPONSE	BEST EYE OPENING RESPONSE
6	Obeys Commands	Oriented	--
5	Localizes stimulus	Oriented	--

SCALE VALUE	BEST MOTOR RESPONSE	BEST VERBAL RESPONSE	BEST EYE OPENING RESPONSE
4	Withdraws from stimulus	Conversant, but confused	Eyes open spontaneously
3	Flexes arm	States recognizable words or phrases	Eyes open to voice
2	Extends arm	Makes unintelligible sounds	Eyes open to painful stimulus
1	No response	No response	Remain closed

Table 2: Glasgow Outcome Scale

OUTCOME	SCORE	DESCRIPTION
Good Recovery (GR)	5	Minor disabilities, but able to resume normal life
Moderate Disability (MD)	4	More significant disabilities, but still able to live independently. Can use public transportation, work in an assisted situation, etc.
Severe Disability (SD)	3	Conscious, but dependent upon others for daily care. Often institutionalized.
Persistent Vegetative State (PVS)	2	Not conscious, though eyes may be open and may "track" movement.
Death (D)	1	Self-explanatory.

Sources:

Teasdale G, Jennett B. Assessment of coma and impaired consciousness. Lancet 1974; 81-84.

Teasdale G, Jennett B. Assessment and prognosis of coma after head injury. Acta Neurochir 1976; 34:45-55.

Rehabilitation

Once head-injured patients leave the acute-care hospital, some may benefit from a rehabilitation program. Prime candidates for rehabilitation are patients that had less severe initial injuries or those that have started to show significant improvement. In some cases, further recovery may be expedited by transfer to a rehabilitation hospital or to the rehabilitation service of a large hospital. For more severely injured patients or for those whose recovery is slow, constant vigilance is required to prevent the gradual onset of problems with joint mobility, skin integrity, respiratory status, infection and many other physiological functions. Patients with moderate or mild injuries, as well as severely injured patients who have improved sufficiently, may be candidates for outpatient therapy.

Regardless of the setting, most head-injury rehabilitation centers emphasize compensatory strategies, which essentially help patients learn to reach the maximum level of function allowed by their impairments. The concept of cognitive retraining, which presumes that at least some of the brain's cognitive capacity can be restored by constant repetition of certain simple tasks, is more controversial but is also emphasized at many centers. Another major goal of head injury rehabilitation is working with patients' families to educate them about what they can realistically expect and how they can best help their injured family member.

General Head Injury Prevention Tips

- Wear a seatbelt every time you drive or ride in a motor vehicle.
- Never drive while under the influence of drugs or alcohol or ride as a passenger with anybody else who is under the influence.
- Keep firearms unloaded in a locked cabinet or safe, and store ammunition in a separate, secure location.
- Remove hazards in the home that may contribute to falls. Secure rugs and loose electrical cords, put away toys, use safety gates and install window guards. Install grab bars and handrails if you are frail or elderly.

Sports and Recreation Head Injury Prevention Tips

- Buy and use helmets or protective head gear approved by the American Society for Testing and Materials (ASTM) for specific sports 100 percent of the time.
- Supervise younger children at all times, and do not let them use sporting equipment or play sports unsuitable for their age. Do not let them use playgrounds with hard surface grounds.
- Follow all rules and warning signs at water parks, swimming pools and public beaches.
- Do not dive in water less than 12 feet deep or in above-ground pools. Check the depth – and check for debris in the water before diving.
- Wear appropriate clothing for the sport.
- Do not wear any clothing that can interfere with your vision.

- Do not participate in sports when you are ill or very tired.
- Obey all traffic signals, and be aware of drivers when cycling or skateboarding.
- Avoid uneven or unpaved surfaces when cycling, skateboarding or in-line skating.
- Perform regular safety checks of sports fields, playgrounds and equipment.
- Discard and replace sporting equipment or protective gear that is damaged.
- Never slide head-first when stealing a base.

Glossary of Terms

- **Agnosia** – failure to recognize familiar objects even though the sensory mechanism is intact
- **Agraphia** – the inability to express thoughts in writing
- **Alexia** – the inability to read
- **Amnesia** – lack of memory about events occurring during a particular period of time
- **Anosmia** – loss of the sense of smell
- **Anoxia** – a condition in which there is an absence of oxygen supply to an organ's tissues although there is adequate blood flow to the tissue
- **Aphasia** – loss of the ability to express oneself and/or to understand language
- **Arachnoid** – middle layer of membranes covering the brain and spinal cord
- **Ataxia** – shaky and unsteady movements that result from the brain's failure to regulate the body's posture and the strength and direction of movements
- **Axon** – the nerve fiber that carries an impulse from the nerve cell to a target and also carries materials from the nerve terminals back to the nerve cell
- **Brain Stem** – the stemlike part of the brain that connects to the spinal cord
- **Closed Head Injury** – impact to the head from an outside force, without any skull fracture or displacement
- **Concussion** – a disruption, usually temporary, of neurological function resulting from a head injury or violent shaking
- **CSF** – a clear fluid surrounding the brain and spinal cord
- **Contusion** – a bruise; an area in which blood that has leaked out of blood vessels is mixed with brain tissue
- **Coup-Contrecoup Injury** – contusions that are both at the site of the impact and on the complete opposite side of the brain
- **Depressed skull fracture** – a break in the bones of the head in which some bone is pushed inward, possibly pushing on or pressing into the brain
- **Diplopia** – a condition in which a single object appears as two objects; also called double vision
- **Dura mater** – the outermost, toughest and most fibrous of the three membranes (meninges) covering the brain and the spinal cord
- **Dysarthria** – speech that is characteristically slurred, slow and difficult to understand
- **Edema** – collection of fluid in the tissue causing swelling
- **Epidural** – located on or outside the dura mater, the outermost, toughest and most fibrous of the three membranes (meninges) covering the brain
- **Hemiplegia** – paralysis of one side of the body as a result of injury to neurons carrying signals to muscles from the motor areas of the brain or spinal cord
- **Hemiparesis** – weakness, paralysis or loss of movement on one side of the body
- **Hemianopsia** – loss of part of one's visual field in one or both eyes
- **Hydrocephalus** – a condition in which excess CSF builds up within the ventricles (fluid-containing cavities) of the brain and may cause increased pressure within the head
- **Hypoxia** – a condition in which there is a decrease of oxygen to the tissue despite adequate blood flow to the tissue
- **Intraparenchymal** – inside the parenchyma of the brain
- **Ischemia** – a reduction of blood flow that is thought to be a major cause of secondary injury to the brain or spinal cord after trauma
- **Locked-in Syndrome** – a rare neurological condition in which a person cannot physically move any part of the body except the eyes
- **Open head injury** – trauma to the brain resulting in loss of consciousness due to the penetration of the brain by a foreign object, such as a bullet
- **Subarachnoid hemorrhage** – Blood in, or bleeding into, the space under the arachnoid membrane, most commonly from trauma or from rupture of an aneurysm
- **Subcortical** – the region beneath the cerbral cortex
- **Subdural** – the area beneath the dura covering the brain and spinal cord
- **Vasospasm** – spasm of blood vessels which decreases their diameter
- **Ventricles (brain)** – four natural cavities in the brain which are filled with CSF

Traumatic Brain Injury Resources

- Brain Injury Association of America
- Brain Injury Resource Foundation
- BrainLine
- International Brain Injury Association
- The Bob Woodruff Foundation/reMIND
- The Brain Injury Recovery Network