TRAUMA SERIES:  
HEAD TRAUMA

INTRODUCTION

Head trauma is one of the most common injuries sustained during a trauma situation. In fact, approximately fifty percent of individuals who experience trauma show signs of a head injury (1). Head trauma can range from minor bumps that cause slight discomfort to a serious injury that result in permanent disability or impairment, or even death. Head trauma is a serious matter that affects people of all ages. Sports, auto accidents, and physical abuse are some of the leading causes of head trauma, but while the cause may be obvious, the effects are not always readily seen (2). In fact, sometimes head trauma may manifest over a period of days, weeks, or even years. For this reason, it's important to closely monitor any incidence of head trauma and adjust treatment according to changing symptoms.

Overview

Head trauma involves any trauma to the scalp, skull or brain and may include an alteration in consciousness, even if it is brief. Patients who experience head trauma will have a range of symptoms depending on the type of injury, the force, the location and the severity of the injury. In some patients, the injury will be mild and will resolve over a short period of time. However, in other patients, the trauma will produce severe injuries that will have long-term effects.

The most common causes of head trauma include:

- Motor vehicle accidents
- Firearm-related injuries
- Falls
- Assaults
• Sports-related injuries
• Recreational accidents (5)

ANATOMY AND PHYSIOLOGY OF THE BRAIN

The head is a complex region comprised of various components, all of which can be injured during head trauma situations. The components of the head and brain include:

Nervous System
The brain is part of the nervous system and operates in conjunction with other parts of the body to provide operative functions (6). The nervous system is comprised of two regions:
  • Central Nervous System (CNS)
  • Peripheral Nervous System (PNS)

The central nervous system houses the brain and spinal cord, while the peripheral nervous system is comprised of spinal nerves and cranial nerves (7). The spinal nerves branch from the spinal cord outward and the cranial nerves branch from the brain outward. The peripheral nervous system also houses the autonomic nervous system (6). The autonomic nervous system controls various functions including:
  • Breathing
  • Digestion
  • Heart rate
  • Secretion of hormones (8)

Scalp
The scalp is the soft tissue that covers the entire area of the skull. It is comprised of five layers:
  • Skin
  • Connective tissue
  • Epicranial aponeurosis
  • Loose areolar tissue
• Pericranium (7)

The first three layers of the scalp are joined together to form one unit, but the unit is able to move freely along the loose areolar tissue that covers the pericranium. The pericranium adheres to the calvaria (6).

Skull
The skull provides protection for the brain. It consists of two distinct regions:

Cranial Bones:
• Foramen Magnum
• Frontal
• Temporal
• Occipital
• Parietal

Facial Bones:
• Lacrimel bone
• Inferior nasal conchae
• Vomer
• Nasal bone
• Malar
• Maxilla bone
• Mandible bone (8)

A dense white fibrous membrane called the periosteum, which is very vascular, covers the skull bone. The periosteum provides nutrition to the bone cells through branches that it sends into the bone. These nutrients are necessary for brain growth and repair. At the base of the skull is the foramen magnum, which is an opening in the occipital bone through which the spinal cord passes (9).

Meninges
The region between the brain and the skull is called the meninges. This area is comprised of three layers of tissue. The tissue covers the brain and the spinal cord and provides protection to both areas. The three layers of the meninges are:

- Dura mater
- Arachnoid
- Pia mater (7)

The dura mater is the outermost layer of the meninges, and the pia mater is the innermost layer. The dura mater contains two layers of membrane. The outer layer is called the periosteum and the inner layer is the dura. The dura lines the inside of the entire skull. It helps protect and secure the brain by creating small folds and compartments. The folds of the dura are called the falx and the tentorium. The right and left sides of the brain are separated by the falx. The upper and lower parts of the brain are separated by the tentorium (8).

The arachnoid layer of the meninges is thin and delicate and contains a number of blood vessels. It covers the entire surface of the brain. The space between the dura and arachnoid membranes is referred to as the subdural space (10).

The pia mater is the layer of the meninges that is located closest to the surface of the brain. The pia mater is comprised of a number of blood vessels that branch far into the brain. The pia covers the entire surface of the brain and follows the folds of the brain. The major arteries supply blood to the brain. The area between the arachnoid and the pia is referred to as the subarachnoid space, which contains cerebrospinal fluid (11).

**Cranial Vault (brain)**
The cranial vault is the region of the head that houses the cerebrum, cerebellum, and brainstem (6). The cranial vault is comprised of the following components:

- Brain tissue (80%)
- Cerebral Spinal Fluid (CSF) (10%)
- Blood (within blood vessels) (10%) (12)

The following table provides descriptions of each area of the cranial vault:
<table>
<thead>
<tr>
<th>Region</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerebrum</td>
<td>The cerebrum is the largest part of the brain and is composed of right and left hemispheres. It performs higher functions like interpreting touch, vision and hearing, as well as speech, reasoning, emotions, learning, and fine control of movement. The surface of the cerebrum has a folded appearance called the cortex. The cortex contains about 70% of the 100 billion nerve cells. The nerve cell bodies color the cortex grey-brown giving it its name – gray matter (Fig. 4). Beneath the cortex are long connecting fibers between neurons, called axons, which make up the white matter. The folding of the cortex increases the brain’s surface area allowing more neurons to fit inside the skull and enabling higher functions. Each fold is called a gyrus, and each groove between folds is called a sulcus. There are names for the folds and grooves that help define specific brain regions.</td>
</tr>
<tr>
<td>Cerebellum</td>
<td>The cerebellum is located under the cerebrum. Its function is to coordinate muscle movements, maintain posture, and balance.</td>
</tr>
<tr>
<td>Brainstem</td>
<td>The brainstem includes the midbrain, pons, and medulla. It acts as a relay center connecting the cerebrum and cerebellum to the spinal cord. It performs many automatic functions such as breathing, heart rate, body temperature, wake and sleep cycles, digestion, sneezing, coughing, vomiting, and swallowing. Ten of the twelve cranial nerves originate in the brainstem.</td>
</tr>
</tbody>
</table>

(7)

**Hemispheres:**
The brain is divided into two hemispheres, the right hemisphere and the left hemisphere, which are joined by the corpus callosum fibers. These fibers are responsible for delivering messages to each hemisphere. The right hemisphere controls the left side of the body and the left hemisphere controls the right side of the body (13).

The left hemisphere controls the following functions:
- Speech
- Comprehension
- Arithmetic
- Writing

The right hemisphere controls the following functions:
- Creativity
- Spatial ability
- Artistic skills
- Musical skills (8)

Injury to the cranial vault commonly produces an increase in intracranial pressure. Ultimately, according to the Monroe-Kellie Doctrine, when the volume of any of the three cranial components increases, the volume of one or both of the others must decrease or the intracranial pressure will rise (14). Intracranial volume typically increases when the patient experiences a cerebral edema, and intracranial mass, or an increase in blood or cerebral spinal fluid (15).

Lobes
The right and left hemispheres are further divided into lobes by fissures. Each hemisphere contains four lobes:
- Frontal
- Temporal
- Parietal
- Occipital (16)
Each of the lobes is divided into areas that control specific functions. However, while the lobes are divided, they do not function independently. The complexity of the cranial cavity requires consistent relationships between the various lobes as well as between the left and right hemispheres (6).

The following table provides information on the different functions of each lobe:

<table>
<thead>
<tr>
<th>Lobe</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal Lobes</td>
<td>The frontal lobes are the largest of the four lobes responsible for many different functions. These include motor skills such as voluntary movement, speech, intellectual and behavioral functions. The areas that produce movement in parts of the body are found in the primary motor cortex or precentral gyrus. The prefrontal cortex plays an important part in memory, intelligence, concentration, temper and personality. The premotor cortex is a region found beside the primary motor cortex. It guides eye and head movements and a person’s sense of orientation. Broca’s area, important in language production, is found in the frontal lobe, usually on the left side.</td>
</tr>
<tr>
<td>Occipital Lobes</td>
<td>These lobes are located at the back of the brain and enable humans to receive and process visual information. They influence how humans process colors and shapes. The occipital lobe on the right interprets visual signals from the left visual space, while the left occipital lobe performs the same function for the right visual space.</td>
</tr>
<tr>
<td>Parietal Lobes</td>
<td>These lobes interpret simultaneously, signals received from other areas of the brain such as vision, hearing, motor, sensory and memory. A person’s memory and the new</td>
</tr>
</tbody>
</table>
sensory information received, give meaning to objects.

| Temporal Lobes | These lobes are located on each side of the brain at about ear level, and can be divided into two parts. One part is on the bottom (ventral) of each hemisphere, and the other part is on the side (lateral) of each hemisphere. An area on the right side is involved in visual memory and helps humans recognize objects and peoples’ faces. An area on the left side is involved in verbal memory and helps humans remember and understand language. The rear of the temporal lobe enables humans to interpret other people’s emotions and reactions. |

(8)

**Vascular System**

Regular and consistent blood flow is crucial to the maintenance of brain activity. Approximately 20% of the cardiac output of blood is used for arterial blood flow (6). The brain is responsible for the regulation of blood flow over various blood pressure ranges using vasodilation or vasoconstriction of the arteries (15). Blood is supplied to the brain by two primary arteries, as outlined below:

*Carotid Arteries:*

These arteries are responsible for providing circulation to the anterior region of the brain. The anterior region of the brain includes the frontal, temporal, partial, and occipital lobes. The carotid arteries supply the brain with approximately 80% of the blood flow.

*Vertebral Arteries:*

The vertebral arteries are responsible for the posterior circulation of the brain. These arteries join together and form the basilar artery. The vertebral arteries provide approximately 20% of the blood flow to the brain (17).
While the anterior and posterior circulation function independent of each other, they often communicate with each other using communicating arteries that come together to form the Circle of Willis (10). The Circle of Willis responds to decreased arterial flow by establishing a protective mechanism. It shunts blood from the anterior to posterior regions of the brain, or vice versa. This protective measure helps delay the deteriorating neurological signs and symptoms that are often present in individuals with head trauma (7).

The following table provides an overview of the different arterial regions and functions:

### Anterior Circulation

<table>
<thead>
<tr>
<th>Artery</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Cerebral Artery (ACA)</td>
<td>Supplies most medial portions of frontal lobe and superior medial parietal lobes</td>
</tr>
<tr>
<td>Anterior Communicating Artery (AcomA)</td>
<td>Connects the anterior cerebral arteries at their closest juncture</td>
</tr>
<tr>
<td>Internal Carotid Artery (ICA)</td>
<td>Ascends through the base of the skull to give rise to the anterior and middle cerebral arteries, and connects with the posterior half of the circle of Willis via the posterior communicating artery</td>
</tr>
<tr>
<td>Middle Cerebral Artery (MCA)</td>
<td>Trifurcates off the ICA and supplies the lateral aspects of the temporal, frontal and parietal lobes</td>
</tr>
</tbody>
</table>

### Posterior Circulation

<table>
<thead>
<tr>
<th>Artery</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior Communicating Artery (PcomA)</td>
<td>Connects to the anterior circle of Willis with the posterior cerebral artery of vertebral-basilar circulation posteriorly</td>
</tr>
<tr>
<td>Posterior Cerebral Artery (PCA)</td>
<td>Supplies the occipital lobe and the inferior portion of the temporal lobe. A branch supplies the choroid plexus</td>
</tr>
<tr>
<td>Basilar Artery (BA)</td>
<td>Formed by the junction of the two vertebral arteries, it terminates as a bifurcation into the posterior and cerebral arteries supplying the brainstem</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Vertebral Artery (VA)</td>
<td>The vertebrales emerge from the posterior base of the skull (Foramen Magnum) and merge to form the basilar artery supplying the brainstem</td>
</tr>
</tbody>
</table>

(6)

**Cranial Nerves**

The brain includes twelve cranial nerves that control specific bodily functions (18). The following is a list of the cranial nerves and the functions that they control:

- Olfactory: Smell
- Optic: Visual fields and ability to see
- Oculomotor: Eye movements; eyelid opening
- Trochlear: Eye movements
- Trigeminal: Facial sensation
- Abducens: Eye movements
- Facial: Eyelid closing; facial expression; taste sensation
- Auditory/vestibular: Hearing; sense of balance
- Glossopharyngeal: Taste sensation; swallowing
- Vagus: Swallowing; taste sensation
- Accessory: Control of neck and shoulder muscles
- Hypoglossal: Tongue movement (19)

**Hypothalamus**

The hypothalamus is directly responsible for sending messages to the pituitary gland (7). The structure itself is very small, but it contains a number of nerve connections that make communication between the hypothalamus and the pituitary gland possible (2).
The hypothalamus receives information from the autonomic nervous system and is responsible for the following functions:

- Eating
- Sexual behavior
- Sleeping
- Body temperature regulation
- Emotions
- Hormone secretion
- Movement

Brain Stem
The brainstem is the part of the brain that connects the brain to the spinal cord. It is located in front of the cerebellum (15). The brainstem is comprised of three components:

- **Midbrain** – responsible for ocular motion
- **Pons** – responsible for coordinating eye and facial movements, facial sensations, hearing, and balance
- **Medulla Oblongata** – controls breathing, blood pressure, heart rhythms, and swallowing

The pons and the brainstem transmit messages from the cortex to the spinal cord and are responsible for maintaining the basic life functions (20). If this area of the brainstem is damaged or destroyed, it can cause brain death in the patient (21). Humans require these basic functions to survive and if transmission is interrupted, survival is not possible (12).

The midbrain, pons, medulla and part of the thalamus contain the reticular activating system. This system is responsible for controlling wakefulness as well as attentiveness and the regulation of sleep patterns (6).

The brainstem contains ten of the twelve cranial nerves that control the following:

- Hearing
- Eye movement
- Facial sensations
- Taste
- Swallowing
- Movements of the face, neck, shoulder and tongue muscles (8)

**Brain Cells**
The two types of cells contained within the brain are the neurons and glial cells. They are sometimes referred to as the neuroglia and glia. There are approximately 50% more glial cells than neurons (22). The primary job of the neuron is to send and receive nerve impulses and signals (23). The glial cells are responsible for the following:
- Provide nutrition
- Provide support
- Maintain homeostasis
- Form myelin
- Facilitate signal transmission in the nervous system (6)

**Cerebrospinal Fluid (CSF)**
Cerebrospinal fluid is a clear, watery substance that surrounds the brain and the spinal cord. It provides a cushion that helps protect the brain and spinal cord from injury (19). The fluid constantly circulates throughout the various channels around and within the spinal cord and brain. It is absorbed and replenished on a continuous basis (8). The fluid is produced within the ventricles, which are hollow channels within the brain (24). The choroid plexus is the ventricle structure that is responsible for the majority of cerebrospinal fluid. Typically, the amount of CSF that is produced is balanced with the amount that is absorbed (7).

**Ventricles**
There are four cavities that comprise the ventricular system. The four cavities are referred to as ventricles (25). They are connected by a series of holes that are referred to as foramen, as well as tubes (7). The cerebral hemisphere contains two ventricles
referred to as the lateral ventricles. Their job is to communicate with the third ventricle using a separate opening that is called the Foramen of Munro (26). The third ventricle serves as the center of the brain, with walls comprised of the thalamus and the hypothalamus (6). The Aqueduct of Sylvius is a long tube that connects the third ventricle to the fourth ventricle (2).

**Other parts of the brain**

*Limbic System:*
The limbic system includes the hypothalamus, the thalamus, the amygdala, and the hippocampus. All of these components are involved in hormone and emotional regulation (12).

*Pineal Gland:*
The pineal gland is attached to the posterior region of the third ventricle. There is no concrete understanding of the exact role of the pineal gland. However, there is some indication that it plays a role in sexual maturation (8).

*Pituitary Gland:*
The pituitary gland is located at the base of the brain within the region known as the pituitary fossa or sella turcica. This area is located behind the nose (6). The pituitary gland controls the secretion of hormones and is responsible for the control and coordination of the following activities:

- Growth and development
- The function of various body organs (i.e. kidneys, breasts and uterus)
- The function of other glands (i.e. thyroid, gonads, and adrenal glands) (23)

Due to the fact that the pituitary gland is responsible for controlling hormone secretion, it is often referred to as the “Master Gland.” (12)

*Thalamus:*
The thalamus is comprised of the basal ganglia as well as four components:

- Hypothalamus
• Epythalamus
• Ventral thalamus
• Dorsal thalamus (15)

The thalamus is responsible for transmitting all information to and from the cortex. The primary information that is transmitted by the thalamus includes:
• Pain sensation
• Attention
• Alertness (8)

**TYPES OF HEAD TRAUMA**

The injuries sustained during head trauma are complex as they are impacted by a number of factors, including the type of trauma, the amount of force, the region, and the region injured. Since the head and brain involve a number of different structures that operate both independent of and with each other, injuries can range from mild to severe. Injuries can affect more than one area of the brain, which can cause complex injuries.

Head injuries are caused when an object strikes the head and transfers force to the brain tissue. The type of trauma is either blunt or penetrating. Blunt trauma produces a closed head injury, while penetrating trauma produces an open injury (27). When an individual experiences blunt trauma one of the following types of force will occur:
• Deceleration
• Acceleration
• Acceleration-deceleration
• Rotational
• Deformation (28)

The following is an explanation of the different injuries that can occur as a result of the forces listed above:
Deceleration forces occur when the head hits an immovable object such as the forehead hitting the windshield. This causes the skull to decelerate rapidly. The brain moves slower than the skull causing the brain tissue to collide with skull. As the brain moves over the bony prominences, it can stretch, shear or tear the tissue. Acceleration injuries can occur when an object hits the head and the skull and the brain are set in motion. Acceleration-deceleration forces occur due to the rapid changes in velocity of the brain within the cranial vault. Rotational forces occur from the twisting of the head usually after impact. The degree of injury depends upon the speed and direction the brain is rotated. Rotational forces affect white matter tissue of the brain. The most common areas affected include the corpus collosum and the brain stem. Deformation forces occur when the velocity of the impact changes the shape of the skull and compresses the brain tissue. The brain tissue is cushioned within the cranial vault by cerebrospinal fluid, one of the protective mechanisms of the brain. Direct injury to the brain tissue can occur as contusions, lacerations, necrosis and hematomas with coup and contrecoup injuries. Coup injuries occur at the site of impact and the contrecoup injury occurs at the opposite side or at the rebound site of impact. Bi-polar injuries may occur from front to back or side to side. Quadra-polar injuries involve all sides of the brain—front, back, and each side. The most common area of impact of a coup injury is the occipital lobe and the contrecoup injury is the frontal lobe (29).

When a patient experiences a penetrating injury, the object causing the injury breaks through the scalp and skull and penetrates the brain. Typically, the penetrating object will cause tissue lacerations, contusions and hemorrhages, along with a range of secondary injuries (30). The injury will range in severity depending on a number of factors including size, shape, speed and location of entry. Gunshot wounds and stab wounds are especially problematic and both have a high incidence of mortality (11).

There are two classifications of head trauma:

- Primary – This type of injury occurs as a direct result of the trauma
Secondary – These injuries often develop over a period of time (typically between several hours and five days) (27)

Initial treatment will focus on repairing any primary injuries, while later treatment will transition to minimizing potential secondary injuries (31). When an individual experiences a head trauma, he or she will often incur both primary and secondary injuries (23).

The following table provides information on both types of injury:

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Injuries</td>
<td>Primary injuries are a result of acceleration-deceleration and rotational forces occurring at the time of impact. These cause coup (initial impact site) and contrecoup (rebound site of impact) injuries. The forces exerted on the brain tissue may result in shearing, tensile or compressive stresses. They can lead to ruptured blood vessels causing hemorrhage, hematomas, and/or contusions. Injuries include lacerations, bone fractures, contusions, hematomas and diffuse axonal injuries.</td>
</tr>
<tr>
<td>Secondary Injuries</td>
<td>Secondary injuries occur after the initial traumatic injury and are a consequence of the primary injury. A pathological cascade occurs due to the biochemical changes in cellular structure. These changes lead to cell death and further secondary injuries such as hypoxia, hypotension, hypercarbia, hyperexcitation, cerebral edema, pathologic changes associated with increased intracranial pressure, late bleeding and expanding intracranial lesions.</td>
</tr>
</tbody>
</table>

(29)

Open vs. Closed Injuries
Head injuries can be either open or closed. With a closed injury, the patient experiences trauma in the absence of skull penetration (5). With an open injury, the
patient’s skull is penetrated (2). Open and closed head injuries cause different symptoms and must be treated differently. The following information provides the distinctions between the two types of injuries.

Signs and Symptoms of Closed Injury:
- Altered or decreasing mental status—the best indicator of a brain injury
- Irregular breathing pattern
- Obvious signs of a mechanism of injury—contusions, lacerations, or hematomas to the scalp or deformity to the skull
- Blood or cerebrospinal fluid leaking from the ears or nose
- Bruising around the eyes (raccoon eyes)
- Bruising behind the ears, or mastoid process (Battle’s sign)
- Loss of movement or sensation
- Nausea and/or vomiting; vomiting may be forceful or repeated
- Unequal pupil size (dilated) that does not react to light (fixed) with altered mental status
- Possible seizures
- Unresponsiveness (32)

Signs and Symptoms of Open Injury:
- Obvious results of the mechanism of injury—contusions, lacerations, or hematomas to the scalp
- Deformity to the skull or obvious penetrating injury
- A soft area or depression detected during palpation
- Brain tissue exposed through an open wound
- Bleeding from an open bone injury (33)

Diffuse vs. Focal Injuries
Brain injuries are either diffuse or focal. In diffuse injuries, the damage occurs throughout various areas of the brain. The damage is microscopic and widespread and it often occurs as the result of force that is exerted on the brain tissues (34). The force causes damage to the axons, which are the parts of the brain that communicate with
each other and initiate nerve cell responses (35). Focal brain injuries are confined to one specific region of the brain. They cause localized damage and are easily identifiable (36).

**Types of Diffuse Injuries:**
- Concussion
- Brain edema.
- Diffuse axonal injury (27)

**Types of Focal Injuries:**
- contusion
- intracranial hematoma
- extradural hematoma
- subdural hematoma
- intracerebral hematoma (ICH )
- subarachnoid hemorrhage (SAH )
- intraventricular hemorrhage (IVH ) (37)

**COMMON CATEGORIES OF HEAD INJURIES**

Head trauma can produce a wide range of injuries, depending on the type of force, the object, the site of impact and the level of penetration. While a patient may experience a variety of injuries, there are some injuries that are more common than others. These include scalp wounds, skull fractures, and traumatic brain injury.

**Scalp Wounds**
Scalp wounds are very common in head trauma situations and can range in severity from very mild to severe (38). The scalp is the primary layer of the cranial region and is often injured in instances of head trauma. In most cases, scalp injuries occur when there is a skull or brain injury. However, in some instances, a scalp injury can occur independent of any other brain injury (30). While most scalp wounds are not severe, they can be alarming as the scalp is very vascular and prone to excessive bleeding (6).
In some situations, bleeding may be present between the layers of the scalp (10). While such bleeding does not require extensive treatment, it is necessary to conduct a thorough assessment of the patient’s injuries to determine the extent of damage (36). It is especially important to palpitate the patient’s scalp to determine if there is a fracture in conjunction with the wound (39). Once an assessment has been completed, the wound should be cleaned thoroughly to prevent infection (31).

The following is a list of common scalp wounds:

- Bruises
- Laceration
- Avulsion
- Hematoma (15)

**Skull Fractures**

One of the most common severe injuries is the skull fracture. Although skulls serve as the first line of defense in protecting the brain, they are actually quite prone to injury. There are two distinct types of skull fracture:

- Depressed Skull Fracture - This type of fracture is caused by pieces of the broken skull pressing into the brain tissue
- Penetrating Skull Fracture - This type of skull fracture is caused by something piercing the skull (e.g. bullet, knife, etc.). The object produces a distinct injury to the brain tissue which is localized (40).

Skull fractures rarely occur in a patient unless he or she experiences a significant force, as the skull is extremely hard (41). The skull is comprised of three layers. The inner and outer layers are quite hard, and the middle layer is comprised of a spongy material that is prone to injury (7). There are a number of different types of fractures depending on the location of the injury, the type of force and the severity of the injury.

**Linear Skull Fracture**

It is very common for patients to experience linear fractures. However, the fractures often require little to no treatment (42). Linear fractures are most common in instances
where a force spreads over a wide area (41). When the bone fractures, it may lacerate the arteries located in the region which often results in an intracranial bleed (42). In most instances, a linear fracture will heal on its own within a period of two or three months (40). However, in some rare instances, a linear fracture may progress into a growing fracture. This complication typically develops over a number of months and will cause the bone to erode (43). In addition, the fracture line will widen, thereby producing a leptomeningeal cyst.

In these instances, the patient will require surgical treatment to remove the cyst (41). The patient may also require dural repair and cranioplasty (40). In some instances, the linear fracture may cause a separation of the cranial suture. These separations are called diastatic fractures. When a patient experiences a diastatic fracture, he or she will require continuous monitoring to ensure that there is no extradural bleeding present (44).

**Depressed Skull Fracture**

Depressed skull fractures occur when a patient has experienced a significant amount of force against the head (45). Depressed fractures are more serious and severe than linear fractures (46). Depressed fractures occur when the force causes a downward displacement of the skull bones. This displacement can range in severity from a slight depression to a complete displacement of the outer hard bone layer, which will move under the inner hard bone and cause direct pressure to the brain tissue (41).

Depressed skull fractures are most common in instances of open scalp wounds (38). However, the skull will still have an intact dural membrane (28). When a patient experiences a complex depressed skull fracture, he or she will present with a laceration of the dura membrane. These lacerations are caused by bony skull fragments (38). In some complex depressed skull fractures, a patient may experience complications. The most common complications include hemorrhage and laceration of the brain tissue (47). When a patient presents with a depressed skull fracture, he or she may require surgical care to repair the damage and control bleeding (32). In many instances, the patient will
also require irrigation and debridement, dural repair, elevation, and bone fragment placement (48).

**Basilar Skull Fracture**

It is more common for a patient to experience fractures in the cranial region than at the base of the skull. However, in some instances, a patient will experience a basilar skull fracture. These fractures occur after the patient experiences a severe blow to the head (49). A basilar fracture is a break that occurs along one of the following regions:

- basilar portion of the occipital bones
- orbital plate of the frontal bones
- cribriform plate of the ethmoid, sphenoid, and petrous or squamous portions of the temporal bones (50)

It is difficult to diagnose a basilar fracture using a standard X-Ray. Instead, practitioners must rely on a standard clinical assessment to identify symptoms of the fracture (51). The presentation and clinical findings will depend on the specific location of the fracture. During a clinical examination, the provider will assess the patient’s symptoms to identify the location and type of basilar fracture. The following is a list of the signs and symptoms specific to each type:

- **Anterior Fossa**: rhinorrhea (discharge from nose), raccoon eyes (periorbital ecchymosis), anosmia (loss of smell), oculomotor palsies
- **Middle Fossa**: hemotympanum (blood in the middle ear), otorrhea, vertigo, Battle’s sign (mastoid ecchymosis), unilateral hearing loss
- **Posterior Fossa**: hypotension, tachycardia, alteration in respirations due to compression of the brainstem (49)

Basilar skull fractures rarely cause complications and they do not require extensive treatment and repair. Most fractures only require an observation for 24 – 48 hours (41). However, in some rare instances, the patient may experience a complication in the form of a cerebral spinal fluid leak (CSF). As the result of a skull fracture, a patient may experience tears in the membranes that cover the brain. These tears can result in leaks of cerebral spinal fluid (19).
When a patient experiences a tear between the dura and the arachnoid membrane, which is referred to as a CSF fistula, cerebral spinal fluid will often leak out of the subarachnoid space into the subdural space. This type of leaking is referred to as a subdural hygroma (24). In some instances, cerebrospinal fluid may leak out of the nose and ears (52). When a patient has tears that cause CSF to leak from the brain cavity, they are at an increased risk of developing infections such as meningitis, which is caused by air and bacteria entering the cavity (24). Patients are also at risk of developing pneumocephalus from air entering the intracranial cavity and becoming trapped in the subarachnoid space (24).

If there is a chance of a CSF leak, the patient must be monitored and assessed for leaks on a continuous basis, over a period of several days. CSF assessment should begin at the time of admission and continue throughout the duration of the patient’s treatment, especially as the patient increases mobility (31). CSF leaks are more common when patients begin moving around and can change positions or move from the bed to a chair (24). In most instances, CSF leaks will resolve on their own and will not require any intervention or treatment (36).

The presence of a CSF leak can be identified through an assessment of the patient’s symptoms. In a conscious patient, the nurse will work with the patient to identify any of the following symptoms:

- a salty or sweet taste in the patient’s mouth
- post-nasal drip
- coughing or clearing of throat
- visible drainage from ear or nose (19)

When a patient experiences a CSF leak, the fluid should be able to flow freely. The flow should not be blocked using any artificial means. When the CSF is blocked, the patient is at risk of developing an increase in intracranial pressure, as well as an infection (53). Patients who experience a CSF leak are at an increased risk of developing meningitis. While meningitis is a rare complication in instances of a CSF leak, it is still important to understand the risk and identify any present symptoms. Meningitis is an infection of the
meninges. Meningitis will occur when a CSF leak is present in a tear in the meninges (54).

It is important to treat patients with a CSF leak immediately. In some instances, patients will be treated with antibiotics. However, some situations will not warrant the use of antibiotics (24). The patient should refrain from the following activities if a CSF leak is present:

- Drinking with a straw
- Drinking hot fluids
- Blowing his or her nose
- Using the incentive spirometer (19)

The above activities pose the risk of creating a vacuum, which will increase pressure in the cranial area and may result in the introduction of bacteria or viruses into the cranial region (24).

**Cranial Nerve Injuries**

Patients will often experience cranial nerve injuries as the result of skull fractures, especially when the fracture occurs at the base of the skull (18). These cranial nerve injuries often result in compressive cranial neuropathies. The brainstem contains twelve cranial nerves, with nine of them projecting out toward the head and face. Therefore, cranial nerve damage often results in partial paralysis of facial muscles (19).

**Traumatic Brain Injury (TBI)**

Traumatic Brain Injury (TBI) is one of the most common trauma related injuries, and is the most severe form of head trauma. According to the Center for Disease Control, approximately 1.7 million traumatic brain injuries occur each year (60). Many of these injuries occur along with other injuries. While traumatic brain injury is considered one type of head trauma, it is sometimes used to refer to most head injuries that a patient experiences. In fact, some providers use the term traumatic brain injury interchangeably with head trauma. Therefore, many of the symptoms and complications included in the traumatic brain injury section overlap with those found in
other sections of this course. However, for the purpose of this section, we use Traumatic Brain Injury to refer to one specific type of head trauma.

Traumatic brain injury is commonly referred to as either TBI, acquired brain injury, or head injury (37). It is caused by a sudden trauma to the head that causes damage to the brain. Depending on how the trauma occurs, the resulting damage may be focal, or it can be diffuse (31). Traumatic brain injury can result from either a closed head injury or from a penetrating head injury (60).

Traumatic brain injury is the direct result of a blow to the head. However, not all forces to the head cause traumatic brain injury. Depending on a number of factors, such as the level of impact and the type of object, the severity of the injury may range from non-existent to severe (54). In instances where the force actually causes some level of trauma, the injury will range from mild to severe (60). Mild injuries typically cause a minor, or brief, change in mental status. Mild injuries may result in a temporary loss of consciousness, but there will be no long term adverse affects (61). Severe injuries can result in full, extended loss of consciousness. They may also cause short or long-term amnesia (62). Throughout all levels of injury, TBI produces a range of functional and sensory changes. These changes impact the patient’s movement, thinking, sensation, language, and emotions (60).

Many of the symptoms of traumatic brain injury develop over time and may not appear for a number of days or weeks. In some rare cases, the symptoms may not appear for months (27). Many patients with mild traumatic brain injury will recover within a number of weeks or months, although some symptoms may persist for longer (31). In patients who experience moderate to severe traumatic brain injury, the recovery time is greater. In fact, many moderate to severe TBI patients never fully recover (52). Many TBI symptoms are life long complications. According to the Center for Disease Control, approximately 5.3 million Americans are living with a TBI-related disability (60).

A majority of traumatic brain injuries cases (approximately half) occur as the result of transportation accidents, which includes automobiles, motorcycles, bicycles, and
pedestrian accidents. These accidents are the major cause of TBI in people under age 75 (37). For those 75 and older, falls cause the majority of TBIs (63). Approximately 20% of TBIs are due to violence, such as firearm assaults and child abuse, and about 3% are due to sports injuries (27).

The cause of the TBI plays a role in determining the patient’s outcome. For example, approximately 91% of firearm TBIs (two-thirds of which may be suicidal in intent) result in death, while only 11% of TBIs from falls result in death (27). Civilians and military personnel in combat zones are also at increased risk for TBIs. The leading causes of such TBI are bullets, fragments, and blast; falls; motor vehicle-traffic crashes; and assaults. Blasts are a leading cause of TBI for active-duty military personnel in war zones (40).

Traumatic brain injuries can cause a number of complications that may occur during the onset of the injury, as well as after the injury has been treated and resolved. In some instances, these complications may be mild and easily treatable and manageable. In other instances, these complications can pose a significant threat to the individual. Some complications can be life threatening, while others may cause long term disability (27).

A traumatic brain injury can cause some significant initial complications within the following categories:

- Arousal
- Consciousness
- Awareness
- Alertness
- Responsiveness (54)

The above conditions are complications that are specific to traumatic brain injury. However, there are also conditions that can occur immediately after a traumatic brain injury that are not specific to TBI, but that occur as a direct result of the injury. These complications increase in prevalence in direct correlation to the severity of the injury.
Complications of TBI are outlined and further elaborated on below:

- Immediate seizures
- Hydrocephalus or posttraumatic ventricular enlargement
- CSF leaks
- Infections
- Vascular injuries
- Cranial nerve injuries
- Pain
- Bed sores
- Multiple organ system failure in unconscious patients (47)

Seizures

It is common for approximately for patients with TBI to experience seizures. In fact, 25% of patients with brain contusions or hematomas will experience seizures, while approximately 50% of patients with penetrating head injuries will experience seizures (64). In these patients, seizures typically occur within the first 24 hours of the injury (65). While some patients who experience immediate seizures will have an increased risk of developing seizures that occur within hours or days of the injury, there is no risk of the patient developing posttraumatic epilepsy. Typically, patients who experience immediate or early seizures are treated with anticonvulsants if the seizures are persistent and recurring (64).

Hydrocephalus and Posttraumatic Ventricular Enlargement

Hydrocephalus or posttraumatic ventricular enlargement is a condition that is caused by the accumulation of cerebrospinal fluid in the brain. This excess fluid causes dilation of the cerebral ventricles and an increase in intracranial pressure (ICP) (53). This condition is common during the acute stage of traumatic brain injury, but it can also occur during later stages (37). It is most common within the first year of the injury (66). It is characterized by worsening neurologic outcome, behavioral changes, incontinence, axtaxia, and impaired consciousness (67). This condition typically develops as a result of meningitis, subarachnoid hemorrhage, intracranial hematoma, or various other
injuries that have the potential to produce pressure (52). Typical treatment involves shunting and draining the fluid (31).

**Infections**

Individuals with traumatic brain injury are prone to a number of infections that can occur within the intracranial cavity. Depending on the type of injury, infections can occur in a variety of locations in the brain, including the dura, below the dura, below the arachnoid, and within the space of the brain (37). The majority of infections will develop within a few weeks of the trauma. They can result from penetrating injuries or from skull fractures. Patients are typically treated with antibiotics. However, surgery may occasionally be used to remove sections of the infected tissue (52).

**Vascular Injuries**

Traumatic brain injury patients are especially prone to vascular injuries due to the damage caused to the head and/or brain. While damage to small blood vessels rarely has a significant impact on the patient, damage to the large blood vessels can result in severe complications. For instance, damage to a major artery may result in a stroke due to bleeding from the artery or as a result of the formation of a clot (66).

Common types of vascular injuries include:

- Hemorrhagic stroke – bleeding directly from the artery
- Ischemic stroke – blocked blood flow to the brain
- Thrombus or thrombosis – the formation of a clot at the site of the injury
- Vasospasm – an exaggerated, persistent contraction of the walls of the blood vessel
- Aneurysms – blood filled sacs caused by stretching of an artery of blood vessel (51)

Patients with the above conditions may experience headaches, vomiting, partial paralysis (often on one side of the body) and semi-consciousness. These symptoms often appear several days after the injury (37). Depending on the specific complication, different treatments will be used. For example, anticoagulants are often used to treat ischemic strokes. However, surgery is typically used to treat hemorrhagic strokes (52).
The conditions included above occur immediately following the onset of a traumatic brain injury. Therefore, they are often identified and treated during the initial stage of injury (31). In addition to injuries that occur during the initial stage of injury, there are other complications that will develop over time and that will typically last throughout the individual’s lifetime, or at least for a significant period of time (54). These complications are considered TBI related disabilities.

TBI related disabilities vary depending on the location of the injury, the severity of the injury and the age and general health of the patient. The most common types of TBI related disabilities affect the following areas:

- cognition (thinking, memory, and reasoning)
- sensory processing (sight, hearing, touch, taste, and smell)
- communication (expression and understanding)
- behavior or mental health (depression, anxiety, personality changes, aggression, acting out, and social inappropriateness) (53)

It is quite common for TBI patients to develop a range of symptoms and complications as a result of the injury. In fact, approximately 40% of all TBI patients develop post concussion syndrome (PCS), which is defined simply as a collection of symptoms, within days or weeks of suffering an injury (68). PCS is common in all TBI patients, not just those who have experienced a concussion or loss of consciousness. In fact, a number of patients who are being treated for mild TBI are diagnosed with PCS (69). The following symptoms are common in patients with PCS:

- Headache
- Dizziness
- Vertigo (a sensation of spinning around or of objects spinning around the patient)
- Memory problems
- Trouble concentrating
- Sleeping problems
- Restlessness
- Irritability
- Apathy
- Depression
- Anxiety (34)

These symptoms may last for a few weeks after the head injury. Typical treatment involves the use of medicines and therapy to reduce the impact of the symptoms and help the patient cope (70).

**Cognitive Impairments**

It is common for patients with traumatic brain injury to experience cognitive disabilities, especially if they have lost consciousness. In many patients, the impairments include a loss of higher level mental skills (71). Of the different cognitive impairments, memory loss is the most common, with patients experiencing the loss of specific memories and the inability to form or store new memories. In some instances, patients may develop posttraumatic amnesia. There are two types of posttraumatic amnesia:

- Anterograde – impaired memory of events that happened after the TBI
- Retrograde – impaired memory of events that happened before the TBI (58)

It is common for patients with cognitive impairments to become confused easily or to have problems with distraction. These patients will typically experience difficulty concentrating and focusing their attention. Some patients may also experience problems with higher level functions, which includes planning, organizing, abstract reasoning, problem solving, and making judgments (71). Patients experience the greatest recovery during the first six months, after which the recovery becomes more gradual. Cognitive impairments are more common in patients with moderate or severe TBI (52).

**Sensory Problems**

Sensory impairments are common in TBI patients. The most common form of sensory impairment is with vision. It is common for TBI patients to experience difficulty registering what they are seeing or recognizing various objects (67). TBI patients are also prone to problems with hand eye coordination. Due to these impairments, TBI patients often experience difficulty maneuvering through spaces and often bump into...
objects or drop them (90). Sensory impairments produce a general instability in TBI patients. As a result, many TBI patients are unable to operate a motor vehicle or complex machinery (67). Many of these sensory issues cannot be treated and remain with the patient indefinitely. However, in some instances, optometric vision therapy has produced good results in patients with oculomotor dysfunctions (72).

While vision impairments are the most common form of sensory impairment in TBI patients, some patients will also develop problems with hearing, smell, taste, or touch. These impairments are the result of damage to the areas of the brain that controls these senses. These conditions are difficult to treat (67).

 Language and Communication Problems

Many TBI patients experience language and communication problems. Some patients only experience difficulties with subtle aspects of communication, such as body language and emotional, nonverbal signals (73). However, others will actually experience difficulty understanding and producing spoken and written language. This type of impairment is called aphasia (74). The following is a list of the different forms of aphasia:

- **Broca’s Aphasia** (nonfluent/motor) – difficulty recalling words and/or speaking in complete sentences. Characterized by broken phrases and frequent pauses. Patients often experience extreme frustration.
- **Wernicke’s Aphasia** (fluent/sensory) – Patients display little meaning in their speech, but typically speaks in complete sentences and use correct grammar. Characterized by the use of flowing gibberish and sentences that include nonessential and invented words. Patients are often unaware that they are not making sense and express frustration when others do not understand them.
- **Global Aphasia** – extensive damage to the portions of the brain responsible for language. Characterized by severe communication disabilities (73).

In some instances, TBI patients may experience difficulties with spoken language as a result of damage to the section of the brain that controls the speech muscles. This disorder is called **dysarthria**, and it affects patients differently than other impairments.
With dysarthria, the patient is able to understand and think of appropriate words/language. However, the patient is unable to speak the words because of damage to the speech muscles (93). Therefore, speech may be slurred and garbled. Some patients experience difficulty with intonation or inflection. This is called prosodic dysfunction (75).

*Emotional and Behavioral Problems*

Many TBI patients experience emotional and behavioral difficulties, which are often classified as general psychiatric issues (76). It is common for a TBI patient to exhibit personality changes and behavioral issues. The following is a list of the common psychiatric problems experienced by TBI patients:

- Depression
- Apathy
- Anxiety
- Irritability
- Anger
- Paranoia
- Confusion
- Frustration
- Agitation
- Insomnia or other sleep problems
- Posttraumatic Stress Disorder (PTSD)
- Mood swings (77)

Typically, behavioral problems include the following:

- aggression and violence
- impulsivity
- disinhibition
- acting out
- noncompliance
- social inappropriateness
- emotional outbursts
- childish behavior
- impaired self-control
- impaired self-awareness
- inability to take responsibility or accept criticism
- egocentrism
- inappropriate sexual activity
- alcohol or drug abuse/addiction (78)

Other TBI patients may experience developmental stagnation. When this occurs, the patient fails to mature emotionally, socially, or psychologically after the trauma (78). This is especially problematic for children and young adults who suffer from a TBI. Typical treatment for the various emotional and behavioral problems includes medication and both occupational therapy and psychotherapy (31).

**Coup and Contrecoup Effect**

In some instances, the patient will experience a coup or contrecoup injury to the head. These terms are used to identify a range of head injuries, but they are most commonly used in instances of cerebral contusions (80). The two terms are used to identify the specific injury pattern and the location of the damage.

The following is a description of the different types of injury:

**Coup Injury**
Damage to the brain at the point of initial impact or blow.

**Contra Coup Injury**
Damage to the brain on the side opposite the side that received the initial impact or blow.

**Coup- Contrecoup Injury**
Damage to the brain on both sides- the side that received the initial impact or blow and the side opposite the initial impact. This occurs when the force of the initial blow is great...
enough to cause brain damage at the site of initial impact between the skull and brain and is also great enough to cause the brain to move in the opposite direction and hit the opposite side of the skull, causing damage at that site. (81)

OUTCOMES AND EFFECTS OF INJURIES

Head trauma can impact the brain and other parts of the body in a number of ways. Depending on the type, severity and location of the injury, the patient will experience a range of outcomes and effects. Patients will not experience every one of the outcomes listed below, but they may experience one or more. It is important to understand the potential outcomes and effects of head injuries so that any damage can be minimized and/or prevented.

Contusion

A contusion is defined as bruising of the brain, and it is caused by bleeding and edema within the brain tissue (82). A contusion is a secondary injury, as it is caused by a primary injury that swells, bleeds and results in increased intracranial pressure (15). Contusions can occur in instances of blunt and penetrating trauma. In some patients, the contusion will appear at the site of impact. In other patients, the contusion will appear on the opposite side of the injury (80). It is most common for patients to experience a contusion in the frontal or temporal lobes (47).

Contusions can vary in shape and size, and will often produce different signs and symptoms. In many instances, contusions will produce some or all of the following symptoms:

- Change in level of consciousness
- Seizures
- Disorientation
- Headache
- Vomiting
- Increased intracranial pressure
- Deterioration of neurological status (83)
Contusions are diagnosed using a CT or MRI, either of which can identify small amounts of bleeding within the edema (84). Once bleeding has been identified, the patient will require a follow up scan twenty four hours later to determine if there has been an increase in the amount of blood or to see if the edema has developed around the bleeding (82).

The following treatments are often used for contusions:

- Supportive therapy
- Hyperventilation (when intubated)
- Osmotic diuretics
- Barbituates
- Management of intracranial pressure
- Surgery (last resort if other treatment options are not successful) (83)

Contusions to the lobe

The following table shows the effects of a contusion on the different lobes:

<table>
<thead>
<tr>
<th>Lobe</th>
<th>Blood Supply:</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal lobes</td>
<td>Lateral – MCA</td>
<td>Left – cognition, right voluntary motor function, expressive aphasia</td>
</tr>
<tr>
<td></td>
<td>Middle – ACA</td>
<td>Right – short-term memory, alteration in emotional control, motivation, inhibition; moral ethical and social value disruption; and left voluntary motor function</td>
</tr>
<tr>
<td>Parietal lobes</td>
<td>Lateral – MCA</td>
<td>Left – right sensory deficits, alteration in ability to understand written word</td>
</tr>
<tr>
<td></td>
<td>Middle – ACA</td>
<td>Right – visual disturbances left sensory deficits, spatial confusion, and alteration in ability to process emotions and behavior</td>
</tr>
<tr>
<td>Temporal Lobes</td>
<td>MCA</td>
<td>Left – receptive aphasia, alteration in interpretive area (causes difficulty in learning and re-learning)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Right – unprovoked and abrupt aggression, and alteration in hearing, taste and smell</td>
</tr>
<tr>
<td>Region</td>
<td>Function and Characteristics</td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Occipital Lobes</td>
<td>visual problems including recognition of objects, alteration in reading comprehension, and conjugate deviation of eyes/head</td>
<td></td>
</tr>
<tr>
<td>Cerebellar Lobes</td>
<td>problems including equilibrium, spatial, and locomotion, and altered posture</td>
<td></td>
</tr>
<tr>
<td>Brainstem</td>
<td>temperature regulation (hypo or hyperthermia), altered autonomic nervous system responses, thalamic syndrome (hyperthermia, tachycardia, posturing, tachypnea), involuntary motor function, may have pupillary dilation (CN III – indication of herniation) or pin point pupils (indication of hemorrhage in the pons), altered eye movements, respiratory alterations, uncontrolled vomiting, and altered swallowing abilities (CN IX)</td>
<td></td>
</tr>
</tbody>
</table>

**Hematoma**

A hematoma is the result of damage to one of the major blood vessels in the head. There are three types of hematomas that affect the brain:

- **Epidural Hematoma** – this type of hematoma is identified by the bleeding that occurs between the skull and the dura.
- **Subdural Hematoma** – In this type of hematoma, the blood is confined between the dura and the arachnoid membrane.
- **Intracerebral Hematoma** – this type of hematoma is characterized by bleeding that occurs within the brain itself.

**Epidural Hematomas**

Epidural hematomas are collections of blood that are commonly located in the temporal area of the brain (85). An epidural hematoma is typically caused by a laceration of the middle meningeal artery, and it will often expand rapidly and cause shifting in the medial brain tissue (86). When this occurs, surgical intervention will be required immediately.
If the hematoma does not receive immediate treatment, it can result in brain death. Patients who experience an epidural hematoma will experience an initial period of lucidity, which will be followed by rapid neurological deterioration.

The symptoms of an epidural hematoma include:
- Ipsilateral (same side) pupil dilation (due to direct lateral pressure on cranial nerve III from shifting brain tissue)
- Change in the level of consciousness
- Posturing
- Contralateral limb weakness
- Hemiparesis
- Hemiplegia

Subdural Hematoma

Subdural hematomas occur in the region below the dura and often venous, originating from the bilateral bridging veins. Subdural hematomas are most common in the following types of accidents:
- Falls
- Motor vehicle crashes
- Assaults
- Violent shaking

Subdural hematomas are divided into two classifications based upon the timing of the appearance of symptoms:
- Acute: 24 – 48 hours after trauma
- Subacute: 2 days to 2 weeks after trauma
- Chronic: 2 weeks to 3 months after trauma

A subdural hematoma will be identifiable on a CT scan. It will appear as a crescent shaped hematoma that will spread along the inner table of the skull. Once the hematoma is identified, it will require treatment. Standard treatment includes an elimination of the clot and minimization of bleeding. It is standard protocol to keep
the patient in a completely flat position for at least twenty four hours so that the brain tissue is able to reexpand (65).

*Intracerebral Hematomas*
An intracerebral hematoma occurs within the cerebral tissue and can occur with minimal blood. In fact, a patient can experience an intracerebral hematoma with as little as 5 cc’s of blood in the cerebral tissue (90). Intracerebral hematomas occur most frequently with depressed skull fractures, penetrating injuries, and acceleration-deceleration injuries (91). In some instances, intracerebral hematomas may occur when the patient experiences bleeding in the necrotic brain tissue (92). Patients will often experience a sudden deterioration of their neurological status (90). Depending on the severity, size and location of the hematoma, the patient may require medical and surgical interventions (86).

*Hemorrhage*
A patient will often experience a brain hemorrhage when the fragile blood vessels within the skull rupture (15). The type of bleeding will be classified based upon the location. The layers of the meninges are used as a guide to determine the type of bleeding (85). The type of brain bleed depends on how and where the meningeal layers capture the blood and how it is distributed.

*Epidural Hemorrhage*
An epidural hemorrhage is the least common type of hemorrhage and typically occurs in less than one percent of intracranial hemorrhage cases (42). This type of hemorrhage is typically the result of a laceration in the middle meningeal artery (30). When epidural bleeding occurs from a venous source, the bleeding will be quite slow. However, when the bleeding is from an artery, it will progress much faster (83).

Epidural hemorrhages are quite dangerous and can often be life threatening (87). When a patient experiences an epidural hemorrhage, he or she will typically follow one of two patterns of injury. Approximately fifty percent of patients with an epidural hemorrhage will experience a brief loss of consciousness immediately following the
injury, but they will regain consciousness shortly after (23). When the patient regains consciousness, he or she will be asymptomatic. However, the patient will often develop symptoms within the hours following the return to consciousness (77).

Typical symptoms include:

- Headache
- Nausea
- Vomiting
- Lethargy
- Confusion
- Altered mentation
- Unconsciousness (5)

The lucid interval stage of injury can last anywhere from two minutes to sixteen hours, with the average duration being 2 – 6 hours (93). Approximately half of the patients with an epidural hemorrhage will lose consciousness and never regain it. Of these, approximately 15 – 20% will die (94).

Subarachnoid Hemorrhage

A subarachnoid hemorrhage occurs when the cerebral blood vessels are stretched or torn during injury (95). Since there is a small amount of CSF present in this region, it can be difficult to differentiate between the two on a CT scan (96). Therefore, it is more plausible and reliable to use the patient’s clinical presentation and relevant brain injury as guides when assessing and identifying a subarachnoid hemorrhage (97).

Subarachnoid hemorrhages can cause extensive neurological deterioration and other secondary injuries, including but not limited to:

- Focal ischemia
- Localized cerebral edema
- Vasospasm
- Thrombosis of blood vessels
- Traumatic aneurysm (95)
Typically, patients who experience a subarachnoid hemorrhage will often show signs of neurological deterioration, intracranial hypertension, and meningeal irritation (26). There is no standard protocol used to treat patients. In fact, there is some controversy surrounding the best method to treat a subarachnoid hemorrhage (88). Some patients may be treated using calcium channel blockers, but this method of treatment is not widely used. Other providers will take a “wait and see” stance (47).

**Cerebral Hemorrhage**
A cerebral hemorrhage is defined as any bleeding that occurs within the actual matter of the brain. It is most common in the frontal and temporal lobes and occurs most often as the result of penetrating trauma (85). However, some patients may experience a cerebral hemorrhage after sustaining an acceleration-deceleration injury. This occurs when the force causes tears within the blood vessels within the brain (83).

In instances of cerebral hemorrhage, a patient will experience symptoms that are similar to those found in other head injuries. However, specific symptoms will vary depending on the location and severity of the injury and the bleeding. A patient may not experience symptoms immediately, but once symptoms do appear, the patient will often progress rapidly from asymptomatic to unconscious (90).

**Extradural Hemorrhage**
An extradural hemorrhage is bleeding that occurs in the region between the inside of the skull and the dura (47). The most common cause of an extradural hemorrhage is a skull fracture, especially in children and adolescents (41). In fact, extradural hemorrhages are most common in younger individuals due to fact that the membrane covering the brain is loosely attached to the skull, unlike the covering in adults, which is more firmly attached (98).

Extradural hemorrhages often occur as the result of a ruptured blood vessel, most commonly an artery. The blood released by the artery will flow into the spaces between the dura matter and the skull (86). The blood typically flows rapidly and quickly collects, thereby causing pressure on the brain, which leads to an increase in the pressure inside
the head (intracranial pressure) (53). When the hemorrhage progresses to this stage, the patient will require intervention to relieve the pressure. If the pressure is not relieved, the patient may experience additional brain damage (25).

**Diffuse Axonal Injury**

This injury, also known as shearing, is caused by contrecoup and is characterized by damage to neurons and the subsequent loss of connections among them. Once this occurs, there is the potential for the breakdown of communication among all neurons in the brain (52). Diffuse axonal injury (DAI) is common with primary head injuries and is typically caused by acceleration-deceleration and rotational forces (35). DAI causes a disruption to the neuronal transmission and occurs as a result of stretching and shearing of the neurons (99).

Diffuse Axonal Injury is identified using an MRI, but may also appear on a CT scan (4). A patient will show a variety of symptoms depending on the type and severity of diffuse axonal injury. DAI is classified using severity as the scaling agent and is diagnosed after a patient presents with a prolonged coma lasting longer than six hours (100). The following is the classification information or diffuse axonal injury:

- **Mild DAI**: Coma lasting 6-24 hours, mild to moderate memory impairment, and mild to moderate disabilities
- **Moderate DAI**: Coma lasting > 24 hours, followed by confusion and long-lasting amnesia. Withdrawal to purposeful movements, and mild to severe memory, behavioral, cognitive, and intellectual deficits
- **Severe DAI**: Deep prolonged coma lasting months with flexion and extension posturing. Dysautonomia can occur. Deficits are noted in cognition, memory, speech sensorimotor function and personality (101)

**Concussion**

A concussion is the most common and most mild form of traumatic brain injury. The Center for Disease Control defines a concussion as:

> “a type of traumatic brain injury, or TBI, caused by a bump, blow, or jolt to the head that can change the way your brain normally works. Concussions can also...”
**occur from a fall or a blow to the body that causes the head and brain to move quickly back and forth** (68).”

However, the term is commonly used to identify a mild injury to the head or brain. Concussions can range in severity and some require extensive medical treatment. If untreated, some concussions can cause more significant problems (60).

Most individuals will recover fully from a concussion over a short period of time. However, some individuals require more recovery time. For these individuals, recovery can take a number of days, weeks or even months (61). In addition, some individuals may experience severe symptoms as a result of a concussion that indicate that the patient is at risk of developing long term complications (66).

It is important that providers recognize the different symptoms of concussions so that they are able to differentiate between common symptoms and those that indicate a more significant problem. Typical concussion symptoms are identified using the following four categories:

- Thinking/Remembering
- Physical
- Emotional/Mood
- Sleep (69)

Using the categories listed above, the following table provides an overview of standard concussion symptoms:

<table>
<thead>
<tr>
<th>Thinking/Remembering</th>
<th>Physical</th>
<th>Emotional/Mood</th>
<th>Sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulty thinking clearly</td>
<td>Headache; Fuzzy or blurry vision</td>
<td>Irritability</td>
<td>Sleeping more than usual</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>Nausea or vomiting (early on); Dizziness</td>
<td>Sadness</td>
<td>Sleep less than usual</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>Sensitivity to noise or light; Balance</td>
<td>More emotional</td>
<td>Trouble falling asleep</td>
</tr>
<tr>
<td>problems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------------------</td>
<td>----------------------</td>
<td></td>
</tr>
<tr>
<td>Difficulty remembering new info.</td>
<td>Feeling tired, having</td>
<td>Nervousness or anxiety</td>
<td></td>
</tr>
<tr>
<td></td>
<td>no energy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The symptoms listed above are common concussion symptoms. However, there are some symptoms that are considered a red flag to providers and warrant immediate attention. According to the Center for Disease Control, the following warning signs should be taken seriously and should be treated immediately:

Danger Signs in Adults

- Headache that gets worse and does not go away.
- Weakness, numbness or decreased coordination.
- Repeated vomiting or nausea
- Slurred speech.

Emergency treatment should be sought immediately if the patient shows any of the following signs:

- Looks very drowsy or cannot be awakened.
- Has one pupil (the black part in the middle of the eye) larger than the other.
- Has convulsions or seizures.
- Cannot recognize people or places.
- Is getting more and more confused, restless, or agitated.
- Has unusual behavior.
- Loses consciousness (a brief loss of consciousness should be taken seriously and the person should be carefully monitored).

Danger Signs in Children

- Any of the danger signs for adults listed above.
- Will not stop crying and cannot be consoled.
- Will not nurse or eat (68)
**Grading scale**

Throughout the years, a number of classification and grading systems have been developed to assess the type and severity of a concussion. The individual care provider, based on the situation and the patient's needs, determined which grading system was used. There are over sixteen concussion-grading scales. However, the most widely used scales are the *Contu Grading System*, the *Colorado Medical Society Guidelines*, and the *American Academy of Neurology Guidelines*. The following is a list of the most common concussion grading scales:

<table>
<thead>
<tr>
<th><strong>American Academy of Neurology Concussion Severity</strong>-March 1997 Practice Parameter:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Phalin used this system in his doctoral study of different models for detecting recovery in sports concussions:</td>
</tr>
<tr>
<td><strong>Grade 1:</strong></td>
</tr>
<tr>
<td>• Transient Confusion</td>
</tr>
<tr>
<td>• No Loss of Consciousness</td>
</tr>
<tr>
<td>• Concussion Symptoms &lt; 15 Minutes</td>
</tr>
<tr>
<td><strong>Grade 2:</strong></td>
</tr>
<tr>
<td>• Transient Confusion</td>
</tr>
<tr>
<td>• No Loss of Consciousness</td>
</tr>
<tr>
<td>• Concussion Symptoms &gt; 15 Minutes</td>
</tr>
<tr>
<td><strong>Grade 3:</strong></td>
</tr>
<tr>
<td>• Any Loss of Consciousness, Brief or Prolonged</td>
</tr>
</tbody>
</table>

AAN Guidelines suggest observation for the following features of concussion:

- Vacant stare (befuddled facial expression)
- Delayed verbal and motor responses (slow to answer questions or follow instructions)
- Confusion and inability to focus attention (easily distracted and unable to follow through with normal activities)
• Disorientation (walking in the wrong direction, unaware of time, date, and place)
• Slurred or incoherent speech (making disjointed or incomprehensible statements)
• Gross observable incoordination (stumbling, inability to walk tandem/straight line)
• Emotions out of proportion to circumstances (distraught, crying for no apparent reason)
• Memory deficits (exhibited by the athlete repeatedly asking the same question that has already been answered, or inability to memorize and recall 3 of 3 words or 3 of 3 objects in 5 minutes)
• Any period of loss of consciousness (paralytic coma, unresponsiveness to arousal.

AAN Guidelines Suggest Monitoring for "Early" and "Late" Symptoms of Concussion

Early Symptoms:
• Headache
• Dizziness or vertigo
• Lack of awareness of surroundings
• Nausea or vomiting

Late Symptoms (days to weeks):
• Persistent low grade headache
• Light-headedness
• Poor attention and concentration
• Memory dysfunction
• Easy fatigability
• Irritability and low frustration tolerance
• Intolerance of bright lights or difficulty focusing vision
• Intolerance of loud noises, sometimes ringing in the ears
• Anxiety and/or depressed mood
• Sleep disturbance

Contu’s system is often used in research involving sports concussions.

Grade 1:
No Loss of Consciousness AND Post Traumatic Amnesia < 30 Minutes

Grade 2:
Loss of Consciousness < 5 Minutes OR Post Traumatic Amnesia of 30 Minutes to 24 Hours

Grade 3:
Loss of Consciousness > 5 Minutes OR Post Traumatic Amnesia > 24 Hours

In 2001 Cantu’s system was updated and included additional symptoms:

Grade 1:
No Loss of Consciousness and Post-Traumatic Amnesia < 30 minutes, and post-concussion symptoms 15-30 min.

Grade 2:
Loss of Consciousness < 1 minute or post-traumatic amnesia 30 min.- 24 hrs.

Grade 3:
Loss of Consciousness > 1 minute, Post-traumatic amnesia > 24hrs, or signs and symptoms < 1 week.

Ruff Concussion Grades

Type I:
- altered mental state or transient loss of consciousness (LOC)
- 1-60 seconds of post-traumatic amnesia (PTA)
- one or more neurological symptoms

Type II:
- definite LOC with time unknown or < 5 minutes
- 60 seconds to 12 hours of post-traumatic amnesia (PTA)
- one or more neurological symptoms

Type III:
- 5 - 30 minutes of LOC
- more than 12 hours of PTA
- one or more neurological symptoms

<table>
<thead>
<tr>
<th>American College of Sports Medicine Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I: None or transient retrograde amnesia, None to slight mental confusion, No loss of coordination, Transient dizziness, Rapid recovery</td>
</tr>
<tr>
<td>Grade II: Retrograde amnesia; memory may return slight to moderate mental confusion, Moderate dizziness, Transient tinnitus, Slow recovery</td>
</tr>
<tr>
<td>Grade III: Sustained retrograde amnesia; anterograde is possible with intracranial hemorrhage, Severe mental confusion, Obvious motor impairment, Prolonged tinnitus, Delayed recovery</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Colorado Medical Society Concussion Rating Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I: No loss of consciousness, Transient confusion, No amnesia</td>
</tr>
<tr>
<td>Grade II: No loss of consciousness, Transient confusion, Amnesia</td>
</tr>
<tr>
<td>Grade III: Loss of consciousness</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Zurich Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I: Simple, Injury resolves over 7 – 10 days</td>
</tr>
<tr>
<td>Grade II: Complex, Persistent symptoms, Specific, Specific sequelae, Prolonged loss of consciousness (more than 1 minute), Or prolonged cognitive function impairment</td>
</tr>
</tbody>
</table>

There has been a great deal of controversy surrounding the different grading scales and their usefulness over the years. Much of the controversy has focused on the inconsistency in the grading scales (103). Depending on the scale used, a patient may have a class 2 concussion or a class 3 concussion. Therefore, recent concussion
assessment guidelines have eliminated the use of classification systems in favor of a symptom-based approach to concussion assessment and identification (104). Rather than rate the concussion, practitioners are now encouraged to use basic symptom identification and objective assessment to determine whether or not a patient has a concussion (105).

**Dementia pugilistica**

Some patients who experience repeat head trauma will develop dementia pugilistica. However, it typically takes a number of years and many repeat episodes of head trauma to appear (22). It is especially common after a patient experiences numerous concussions. These concussions can cause permanent brain damage, which will impact the long term condition of the patient’s mental facilities (106). The condition is especially common in boxers and other athletes who experience repeat head trauma (22). Dementia pugilistica is permanent and cannot be cured. However, progression of the cognitive degeneration can be minimized through the use of medication and therapy (59).

The symptoms of dementia pugilistica will vary and often present as a range of mental and physical symptoms. The following is a list of the most common symptoms of dementia pugilistica:

- inhibited ability to process written or spoken language
- inability to concentrate on tasks
- difficulty remembering events
- psychotic episodes
- mood swings
- unpredictable behavior changes
- hand tremors
- speaking difficulties
- loss of motor movement coordination (61)

**Coma**
A coma is defined as a deep state of unconsciousness (102). A patient who experiences a coma is alive, but loses the ability to move or respond to the environment and external stimulation (47). Most comas last an average of two to four weeks, but some patients can remain in a coma for an extended period of time. The duration of a coma and the extent of recovery will vary depending on the cause, severity and location of the damage (107). Some patients will recover completely from a coma, while others will experience long term physical, mental, intellectual and emotional problems (102). A patient who remains in a coma for an extended period of time (months or years) is at an increased risk of developing an infection such as pneumonia, which can be life threatening (108).

During a coma, a patient is completely unconscious and cannot be aroused. The patient is also unresponsive and unaware of his or her surroundings (102). Patients will not respond to external stimuli and do not experience sleep-wake cycles (109). A coma is typically the result of severe trauma to the brain, and is most common with injuries to the cerebral hemispheres of the upper brain and the lower brain or brainstem (107). In most instances, a coma will only last for a few days or a few weeks. However, in some extreme situations, a patient may progress to a vegetative state (110).

When a patient appears to be in a coma, the trauma team will first stabilize the patient and assess the vital signs and basic neurological signs. After the vital signs and basic neurologic functions are assessed, the emergency medical provider will assess the patient’s level of consciousness and neurologic functioning (109). This assessment is done using the Glasgow Coma Scale, which is a standardized, 15 point test that measures neurologic functioning using three assessments: eye opening, best verbal response, and best motor response. A patient will be determined to be in a coma if he of she meets the criteria on the coma scale (60).

The Center for Disease Control provides the following guidelines for the Glasgow Coma Scale:

Eye Opening Response
- Spontaneous; open with blinking at baseline - 4 points
- To verbal stimuli, command, speech - 3 points
- To pain only (not applied to face) - 2 points
- No response - 1 point

Verbal Response
- Oriented - 5 points
- Confused conversation, but able to answer questions - 4 points
- Inappropriate words - 3 points
- Incomprehensible speech - 2 points
- No response - 1 point

Motor Response
- Obeys commands for movement - 6 points
- Purposeful movement to painful stimulus - 5 points
- Withdraws in response to pain - 4 points
- Flexion in response to pain (decorticate posturing) - 3 points
- Extension response in response to pain (decerebrate posturing) - 2 points
- No response - 1 point

Categorization:
Coma
- No eye opening, no ability to follow commands, no word verbalizations (3 - 8)

Head Injury Classification:
- Severe Head Injury----GCS score of 8 or less
- Moderate Head Injury----GCS score of 9 to 12
- Mild Head Injury----GCS score of 13 to 15

Disclaimer: Based on motor responsiveness, verbal performance, and eye opening to appropriate stimuli, the Glasgow Coma Scale was designed and should be used to assess the depth and duration coma and impaired consciousness. This scale helps to gauge the impact of a wide variety of conditions such as acute brain
damage due to traumatic and/or vascular injuries or infections, metabolic disorders (e.g., hepatic or renal failure, hypoglycemia, diabetic ketosis), etc. (110)

The coma is one form of altered consciousness that occurs during head trauma. If the trauma is severe enough, patients may experience one of the other types of altered consciousness. These altered states of consciousness are often considered different types of comas, even though they have different symptoms, and are explained below.

**Stupor:**
When a patient experiences a stupor, he or she is often unresponsive but is able to be aroused, if only briefly, by a strong stimulus (52).

**Vegetative State:**
When a patient is in a vegetative state, he or she is completely unaware of the surroundings. However, unlike with a coma, patients in a vegetative state continue to have a sleep-wake cycle. In addition, patients may experience periods of alertness (31). Patients in a vegetative state will often open their eyes and show other signs of movement and function, which may include groaning and some reflex responses (52). In many instances, a vegetative state is the result of trauma to the cerebral hemispheres with the absence of injury to the lower brain and brainstem (111). Most patients will only remain in a vegetative state for a few weeks, but some may progress to a persistent vegetative state, which is defined as longer than thirty days (52). Once a patient has been in a vegetative state for a year, the chances of recovery are extremely low (54).

**Locked-In Syndrome:**
With Locked-In Syndrome, the patient is unable to move or communicate normally as the result of paralysis of the body. However, the patient is fully aware and awake (60). Locked-In Syndrome is caused by damage to areas in the lower brain and brainstem, but not by damage to the upper brain (47). Typically, patients use movements and eye blinking to communicate. Ultimately, most patients do not gain their motor control back once they are in a locked-in state (52).
Brain Death:
Brain death is a newer diagnosis that has occurred due to the development of assistive devices that artificially maintain blood flow and breathing (52). Brain death is defined as a lack of measurable brain function. This is typically caused by injuries to the cerebral hemispheres and brainstem (54). There is also a loss of integrated activity within specific areas of the brain (52). This condition is irreversible. If a patient does not remain on assistive devices, he or she will experience immediate cardiac arrest and will stop breathing (2).

The various unconscious states listed above are easy to diagnose as the result of advancements in imaging and other technologies. Using these new technologies, practitioners can identify the area of the brain affected and diagnose the patient based on the level of activity present in different regions of the brain (31). Most commonly, doctors use CT and MRI to identify the affected areas of the brain. However, other diagnostic imaging tools such as cerebral angiography, electroencephalography (EEG), transcranial Doppler, ultrasound, and single photon emission computed tomography (SPECT) may be used (112).

Death
The most severe outcome of head trauma is death. While some patients may experience brain death (see: Traumatic Brain Injury section), others will fully succumb to injuries sustained during a head trauma situation. Death is most common in patients who experience moderate to severe trauma (113). The 2011 CDC Surveillance Report on Traumatic Brain Injury provides the following information regarding head injury related deaths:

<table>
<thead>
<tr>
<th>2011 CDC Surveillance Report</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Head Injury Related Deaths</strong></td>
</tr>
<tr>
<td>During 1997--2007, an annual average of 53,014 deaths (18.4 per 100,000 population; range: 17.8--19.3) among U.S. residents were associated with TBIs.</td>
</tr>
</tbody>
</table>
During this period, death rates decreased 8.2%, from 19.3 to 17.8 per 100,000 population ($p = 0.001$). TBI-related death rates decreased significantly among persons aged 0--44 years and increased significantly among those aged ≥75 years. The rate of TBI deaths was three times higher among males (28.8 per 100,000 population) than among females (9.1). Among males, rates were highest among non-Hispanic American Indian/Alaska Natives (41.3 per 100,000 population) and lowest among Hispanics (22.7). Firearm- (34.8%), motor vehicle-- (31.4%), and fall-related TBIs (16.7%) were the leading causes of TBI-related death. Firearm-related death rates were highest among persons aged 15--34 years (8.5 per 100,000 population) and ≥75 years (10.5). Motor vehicle--related death rates were highest among those aged 15--24 years (11.9 per 100,000 population). Fall-related death rates were highest among adults aged ≥75 years (29.8 per 100,000 population). Overall, the rates for all causes except falls decreased.

(1)

Head injury related death is most common in patients who experience trauma from firearms, motor vehicles, and falls (34). This is due to the severity and type of injury caused by these mechanisms. While these are the primary causes of head injury related death, any head injury can be life threatening depending on the type and location.

**TIMELINE FOLLOWING INJURY**

**Immediate**

In the period immediately following head trauma, the patient will experience a range of symptoms and conditions. The specific symptoms will depend on the type of injury, the damage incurred, and the location of the injury. Many patients will lose consciousness, at least briefly (93). Some patients may also show signs of confusion (114). The period immediately following a head injury is crucial for the identification and treatment of any conditions (36).

**Lucid interval**
A lucid interval is the period of consciousness that occurs between the initial period of unconsciousness and a subsequent period of unconsciousness (93). A patient only experiences a lucid interval if he or she becomes unconscious again immediately following the period of consciousness (115). This occurs when blood builds on the brain, producing significant pressure on the brain tissue. If a patient does not receive immediate treatment, he or she is at an increased risk of death (116).

Later in life
Many individuals who experience mild head injuries will recover completely within a few weeks of the trauma and will not experience long term complications (47). However, patients who experience moderate to severe forms of traumatic brain injury will often experience long term problems associated with the injury (13).

The following is a list of the more common long-term problems associated with head injuries.

Parkinson’s Disease
In some patients, Parkinson’s disease may develop years after TBI as a result of damage to the basal ganglia. Symptoms of Parkinson’s disease include:

- tremor or trembling
- rigidity or stiffness
- slow movement (bradykinesia)
- inability to move (akinesia)
- shuffling walk
- stooped posture (117)

Parkinson’s Disease is a rare complication of TBI, but it can occur. Other movement disorders that may develop after TBI include tremor, ataxia (uncoordinated muscle movements), and myoclonus (shock-like contractions of muscles) (118).

Alzheimer’s Disease
Alzheimer’s disease (AD) is defined as a progressive, neurodegenerative disease characterized by dementia, memory loss, and deteriorating cognitive abilities. According
to recent research, there is an association between head injury in early adulthood and the development of AD later in life. The risk of developing AD later in life is increased in direct correlation to the severity of the head injury (119).

**Chronic Traumatic Encephalopathy and ALS**
There is evidence that TBI contributes to the incidence of nerve degenerative diseases such as amyotrophic lateral sclerosis (ALS) and chronic traumatic encephalopathy (CTE). In fact, there is pathological evidence that there is a direct correlation between repeated blows to the head and the long-term development of these diseases (120).

**Posttraumatic Dementia**
Posttraumatic dementia is characterized by symptoms of both dementia and Parkinson’s and is caused by a single, severe TBI that results in a coma (78).

**Long Term Treatment for Head Trauma**
Many individuals experience long term complications and disabilities as the result of head trauma (121). Therefore, long-term treatment is often needed beyond the emergency treatment that is provided initially. Initial treatment for patients with moderate to severe traumatic brain injury is focused on stabilizing the patient and is often done within the emergency department or intensive care unit (31). Once the patient is stabilized, further treatment may be required depending on the type and severity of the injury.

Most long-term treatment involves rehabilitation, as the goal is to have the patient regain the appropriate neurologic functions. This component of treatment is often conducted in a subacute unit of the hospital or in an independent rehabilitation center (52). In addition, some long term treatment will be conducted through outpatient services (31). Treatment at this stage is diverse and is tailored to the specific recovery needs of the patient.

Most long term treatment includes physical therapy, occupational therapy, speech and language therapy, psychiatric care, psychological services, social support and life skill development, and physiatry (92). The specific rehabilitative program will utilize the
services of experts in the above areas to develop a comprehensive program that addresses the specific treatment needs of the program. Initial treatment will most likely be extensive, with longer term treatment being less frequent (122). As the patient regains the appropriate skills, treatment will be reevaluated and modified to continue to meet the needs of the patient (79).

The goal of long-term treatment is to bring the patient to a level of functioning that enables him or her to live independently and integrate with society. When patients experience a long term or permanent disability as the result of a head injury, the rehabilitation team will provide treatment and therapy that focuses on adapting to the disability and developing new skills that will enable the patient to function within the constraints of the disability (121). Long-term rehabilitation will typically be conducted in a variety of settings, including hospital outpatient programs, inpatient rehabilitation centers, day treatment programs, hospital outpatient programs and independent living centers. The specific setting will be determined based on the rehabilitation needs of the patient and the specific services available in the geographic area (71).

SYMPTOMS

An individual will experience a variety of symptoms as the result of a head injury. Each patient will experience symptoms differently, and symptoms will vary depending on the type and severity of the injury. The following are the most common symptoms of mild and moderate/severe head injuries.

Mild head injury:

- Raised, swollen area from a bump or a bruise
- Small, superficial (shallow) cut in the scalp
- Headache
- Sensitivity to noise and light
- Irritability
- Confusion
- Lightheadedness and/or dizziness
• Problems with balance
• Nausea
• Problems with memory and/or concentration
• Change in sleep patterns
• Blurred vision
• "Tired" eyes
• Ringing in the ears (tinnitus)
• Alteration in taste
• Fatigue/lethargy

Moderate to severe head injury (requires immediate medical attention) - symptoms may include any of the above plus:

• Loss of consciousness
• Severe headache that does not go away
• Repeated nausea and vomiting
• Loss of short-term memory, such as difficulty remembering the events that led right up to and through the traumatic event
• Slurred speech
• Difficulty with walking
• Weakness in one side or area of the body
• Sweating
• Pale skin color
• Seizures or convulsions
• Behavior changes including irritability
• Blood or clear fluid draining from the ears or nose
• One pupil (dark area in the center of the eye) looks larger than the other eye
• Deep cut or laceration in the scalp
• Open wound in the head
• Foreign object penetrating the head
• Coma (a state of unconsciousness from which a person cannot be awakened; responds only minimally, if at all, to stimuli; and exhibits no voluntary activities)
• Vegetative state (a condition of brain damage in which a person has lost his thinking abilities and awareness of his surroundings, but retains some basic functions such as breathing and blood circulation)
• Locked-in syndrome (a neurological condition in which a person is conscious and can think and reason, but cannot speak or move) (11)
The above is a list of general symptoms of mild to severe head injuries. The following section will provide more detailed information on each of the most common symptoms.

**Bleeding**

Bleeding is common with head injuries. With penetrating head injuries, bleeding can occur externally or internally (59). Internal bleeding is most common in the brain tissue or between the cranial layers (47). In blunt trauma injuries, bleeding typically occurs internally, although there may be minimal bleeding at the site of impact (28). Bleeding is not always apparent when it is internal. Therefore, it is important to utilize radiologic imaging to identify any internal areas of bleeding (4).

**Bruising**

Bruising is common in instances of blunt head trauma (38). Most patients will experience external bruising at the site of impact (15). External bruises can range in severity and appearance, depending on the amount of force used and the area of the head that is bruised. Some patients will experience internal bruising, otherwise known as contusions (82).

A contusion is defined as bruising of the brain, and it is caused by bleeding and edema within the brain tissue (83). It is a secondary injury, as it is caused by a primary injury that swells, bleeds and results in increased intracranial pressure (15). Contusions can occur in instances of blunt and penetrating trauma (28). In some patients, the contusion will appear at the site of impact as a coup injury. In other patients, the contusion will appear on the opposite side of the injury as a contrecoup injury (80). It is most common for patients to experience a contusion in the frontal or temporal lobes (37).
Neurological deficits

Many patients will experience cognitive deficits as a result of head trauma. The specific deficits will vary depending on the location and severity of the injury. The following is a list of the most common cognitive deficits experienced by head trauma patients:

- Arousal or over-stimulation
- Attention and filtering issues
- Information coding and retrieval (memory) issues
- Learning, both using old information and acquiring new information
- Problem solving
- Higher-level thinking skills also known as “executive skills” (67)

Some of the cognitive deficits listed above will be short-term problems and will be eliminated over time with the aid of therapy and rehabilitation services (122). However, other cognitive deficits will persist long term and may not ever resolve themselves (59). In some instances, persistent cognitive deficits can be minimized or eliminated through the use of more intensive rehabilitation services (123).

Cognitive deficits have a direct correlation with neurobehavioral problems (71). Therefore, it is important to discuss the two together. Neurobehavioral problems are directly related to specific components of head trauma. Depending on the injury, the patient may experience neurobehavioral problems that cause changes in behavior and attitudes.

The following is a list of the common neurobehavioral problems experienced by head trauma patients:

- Reduced inhibitions and judgment
- Difficulty with self-regulation or self-control
- Impulse control
- Over-arousal
- Frustration tolerance
- Problems in perception
- Overreaction to situations
- Anger without provocation
- Socially inappropriate behaviors (124)

Treatment for neurobehavioral problems includes therapy, medication, and behavior modification (77).

Some patients will experience neuromotor problems. These are also a direct result of specific head injuries and will vary depending on the type and location of injury. Neuromotor problems affect the patient’s physical movement and ability to control the body (125). The following is a list of the most common neuromotor problems:

- Initiating or starting a movement
- Maintaining muscle control
- Sustaining a movement
- Executing a complex movement, such as walking (61)

If a patient experiences neuromotor problems, he or she will be treated using specific therapies and strategies that will help improve motor functions and regain skills (105).

**Amnesia**

Patients who sustain head injuries may experience some degree of amnesia. Amnesia is defined as a loss of memory for any period of time (126). Amnesia is broken into two categories, depending on the way that it presents itself.

**Retrograde Amnesia**

The patient loses memories of events that occurred prior to the injury. Some patients may only lose a few seconds or a minute of memory (114). In these instances, the patient may remember part of the accident, but not the entire accident. Other patients may experience the loss of a longer duration of time, up to days or years (127).

In some instances, patients may not remember the accident at all, or even the year prior to the accident (59). Most patients will recover their memories as the damage heals.
However, there is no standard time period or pattern that the return of memories will follow (126).

**Anterograde Amnesia**
Patients who experience anterograde grade amnesia will lose memories of the events that occurred following the injury. In these instances, the will continue to lose new memories, while still retaining memories of events that occurred prior to the injury (127).

**Changes in Pupil Shape and Size**
Different complications of head trauma can cause changes in the shape and size of the pupil. Therefore, a standard examination should include an assessment of the patient’s pupils. Any changes should be noted and used to determine the extent of injury. The following table provides information on the areas of the pupil that may experience changes:

<table>
<thead>
<tr>
<th>Area of Change</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupil Size and Equality</td>
<td>Pupil size is reported as the width or diameter of each pupil in millimeters. A standardized pupil gauge should be used to report the pupil size in millimeters. The use of this gauge aids in decreasing subjectivity, particularly when serial assessments are performed. The normal diameter of the pupil is between 2 and 5 mm, with the average pupil measuring 3.5 mm. Although both pupils should be equal in size, a 1-mm discrepancy is considered a normal deviation. This condition is known as anisocoria and is present in 15% to 17% of the population without any known clinical significance. Pupil size should be assessed both before and after the pupil responds to direct light.</td>
</tr>
<tr>
<td>Pupil Shape</td>
<td>Pupil shape is reported as round, irregular, or oval. The normal shape of the pupil is round. An irregular-shaped pupil</td>
</tr>
</tbody>
</table>
may be the result of ophthalmological procedures such as cataract surgery or lens implants, and this should be noted on the initial assessment and confirmed with the patient or family. A pupil that is oval in shape may indicate the early compression of cranial nerve III due to increased intracranial pressure (ICP), and thus should be addressed immediately. If an oval pupil is detected, measures should be taken to decrease ICP. As ICP is reduced, the oval-shaped pupil should resolve. However, if ICP continues to rise or is not treated, the oval-shaped pupil will become further dilated and will eventually become nonreactive to light.

**Pupil Reactivity**

Pupil reactivity is reported as the response or reflex of each pupil to direct light. Shining a low-beam flashlight inward from the outer canthus of each eye assesses reactivity. Each eye should be checked separately. The light should not shine directly into the pupil because the glare or reflection may obscure visualization. The reaction that each pupil has to the light stimulus should be recorded. The speed of pupillary reactivity is recorded as brisk, sluggish, or nonreactive. Normally, pupils should constrict briskly in response to light. A sluggish or slow pupillary response may indicate increased ICP, and nonreactive pupils are often associated with severe increases in ICP and/or severe brain damage.

A complete pupillary reactivity examination also includes assessment of the consensual pupillary response and accommodation. The consensual pupillary response is the constriction that normally occurs in a pupil when light is shown into the opposite eye.6 Because of this response, the trauma nurse should wait for several seconds before
assessing pupillary light reflex in the second eye, as that pupil may be temporarily constricted. Accommodation is the constriction of pupils that occurs when a conscious patient is focusing on a close object. Pupils should normally constrict bilaterally when an object is held within 4 to 6 inches of a patient's nose.

| General Pupil Abnormalities | When performing pupillary examinations in patients with TBI, trauma nurses may detect abnormalities, such as an irregular pupil size, shape, or a sluggish or nonreactive pupil. When an abnormality is detected, the trauma nurse should first identify whether the abnormality was present on the previous pupillary examination. If an abnormal pupil is present on the initial pupillary examination, it should be clearly documented, and a physician should be immediately notified. Immediate notification of a physician should occur with changes in pupillary response. Comparing the current examination with the previous to provide time-oriented data for the physician is wise but should never delay immediate physician notification. |
| General Indications | A complete neurologic examination should be performed and any changes in the patient's condition should be noted and reported to a physician. An abnormal pupil in a patient with TBI is often indicative of increasing ICP due to progression of the hematoma/hemorrhage or cerebral edema. However, the trauma nurse should be aware of other clinical factors that may cause an abnormal pupil response. Table 2 highlights abnormal pupils that may be seen in TBI patients and identifies both physiologic and clinical factors contributing to the abnormalities. Regardless of the cause of an abnormal pupil, the trauma nurse should always notify a physician immediately when an abnormal |
pupil is detected. A CT scan and continuous ICP monitoring will aid in definitively identifying the cause of the abnormal pupil.

(128)

**Stiff neck**
Within the twenty-four hours following a head injury, a patient may experience a stiff neck. This is often indicative of a more serious complication and should be monitored closely (36).

**Severe headache**
It is common for a patient to experience a headache immediately after experiencing a blow to the head. Most patients will experience headaches within the first few weeks following a head injury (129). However, most headaches should stop within four weeks of the injury (130). Headaches are not cause for concern as long as they do not get worse over time (36). Headaches are classified using three distinct categories:

- **Mild:** A mild headache improves or goes away completely with home treatment, medication, or rest. It may return when the medication wears off.
- **Moderate:** A moderate headache improves with home treatment, medication, or rest, but it never completely goes away. The patient is always aware that the headache is present.
- **Severe:** A severe headache is incapacitating. Home treatment, medication, and rest do not relieve this headache (130).

If a patient experiences a continuous headache that gets worse over time, it should be taken into consideration. These headaches are often indicative of swelling and/or bleeding on the brain, or within the areas surrounding the brain (131). In some instances, the blood and swelling will occur between the brain and the covering of the brain. The bleeding may occur rapidly, or it may slowly develop (130). Some patients will display symptoms within minutes of hours of the injury, while other patients will not experience symptoms until weeks after the injury (132).
If a patient reports a new and persistent headache that does not develop immediately following the injury, he or she may have a blood clot. Along with the headache, the patient may experience confusion and sleepiness (59).

While most headaches are not cause for alarm, any headache that is persistent and accompanies by other symptoms (e.g. drowsiness and personality changes) is concerning and must be assessed immediately. This type of headache is often indicative of an increase in pressure around the brain, which can be life threatening if left untreated (133).

Physical Deficits
Many patients will experience physical deficits as a result of head trauma. The most common physical deficits and correlating symptoms experienced after head trauma include:

- Hearing loss
- Tinnitus (ringing or buzzing in the ears)
- Headaches
- Seizures
- Dizziness
- Nausea
- Vomiting
- Blurred vision
- Decreased smell or taste
- Reduced strength and coordination in the body, arms, and legs (21)

Vomiting/Nausea
Vomiting and nausea are common symptoms in instances of head trauma and can occur with mild to severe trauma. When a patient experiences vomiting or nausea, it is important to make sure he or she is comfortable and that there is no chance of asphyxiation (134).

Loss of Consciousness
It is common for head trauma patients to experience loss of consciousness immediately following a head injury. Some patients will only lose consciousness for a few seconds, while others may remain unconscious for hours or days (135). Loss of consciousness can affect the patient even after he or she awakens. The following is a list of the most common side effects a patient will experience after a loss of consciousness:

- Drowsiness
- Confusion
- Restlessness
- Agitation upon waking
- Vomiting
- Seizures
- Impaired balance
- Lack of coordination
- Impaired ability to think
- Inability to control emotions
- Difficulty moving
- Inability to feel things
- Difficulty with speech
- Loss of vision
- Hearing impairment
- Memory impairment or loss (115)

**DIAGNOSIS**

Assessment and treatment of head trauma should begin as soon as possible. Therefore, emergency personnel are often the first individuals who assess and treat the injury (52). Typically, treatment begins as soon as emergency responders arrive on the scene or as soon as an individual arrives at the emergency room. Initial brain damage that is caused by trauma cannot be reversed. So, initial treatment involves stabilizing the patient and administering treatment that will prevent further damage (31).
The key components of the trauma assessment are as follows:

1. **ABC’s:**
   Assess the airway with stabilization of the cervical spine, breathing, circulation, heart rate and blood pressure before the neurological exam.

2. **Examination of the Skull:**
   Assess for periorbital and postauricular ecchymosis, cerebrospinal fluid otorrhea and rhinorrhea, hemotympanum, penetrating injury or depressed fracture, and lacerations.

3. **History:**
   Gather information related to the mechanism of injury and care prior to hospitalization.

4. **Neurological Exam:**

<table>
<thead>
<tr>
<th>Function</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerebral function</td>
<td>Assess the level of consciousness, mental status, awareness, arousal,</td>
</tr>
<tr>
<td></td>
<td>cognitive function, and behavior.</td>
</tr>
<tr>
<td>Cranial Nerve and pupillary</td>
<td>This reflects brainstem function.</td>
</tr>
<tr>
<td>examination</td>
<td>Assess the pupils, eye movements, cough reflex, corneal reflex and gag</td>
</tr>
<tr>
<td></td>
<td>reflex.</td>
</tr>
<tr>
<td>Motor and cerebellar function</td>
<td>Assess strength, movement, gait, and posture. Each extremity must be</td>
</tr>
<tr>
<td></td>
<td>assessed separately. It is important to document the degree and type of</td>
</tr>
<tr>
<td></td>
<td>stimulus applied to elicit the motor activity. Central stimuli include</td>
</tr>
<tr>
<td></td>
<td>sternal rub, trapezius pinch and/or supraorbital pressure. Abnormal</td>
</tr>
<tr>
<td></td>
<td>findings include abnormal posturing, flaccidity, and focal motor</td>
</tr>
<tr>
<td></td>
<td>movements.</td>
</tr>
</tbody>
</table>
Sensory examination | Assess tactile and pain sensations.
--- | ---
Reflex examination | Assess superficial and deep tendon reflexes.
Glasgow Coma Scale | This is a valuable component of the neurological exam because it is nationally and internationally recognized. It is only one part of the neurological exam. Severe Head Injury: GCS # 8 or a decrease in 2 points or more after admission. Moderate Head Injury: GCS 9-12 Mild Head Injury: GCS 13-15

Due to the diverse causes of head trauma and the differing needs of patients, initial contact with the patient involves an assessment of the cause of the injury and a screening to determine the extent of the injuries (31). This is important, as the mechanism of injury will determine the type of treatment needed. For example, blast trauma related head trauma is more complex than other forms of head trauma (136). Due to the complexity of blast related head injury, the assessment and treatment can be difficult to administer and determine. Therefore, in combat, it is more common to evaluate all service members who have been exposed to a blast and identify those that present symptoms of head injury (136). However, in civilian instances of head trauma, it is more common to assess each patient individually based on the symptoms present as non blast related causes of head trauma tend to be less complicated (31).

Prior to conducting a full assessment of an individual who is suspected of having a traumatic brain injury, the primary concern is ensuring that the patient is stabilized and that any further injury is prevented. During the initial stage of contact, medical personnel are primarily concerned with ensuring that the patient has a proper supply of oxygen to the brain and the rest of the body (48). Another priority is to maintain an
adequate blood flow while controlling blood pressure. This will help stabilize the patient while minimizing further damage to the brain (31).

Once a patient is stabilized, medical personnel will assess the patient and determine the extent of the injury. Primary assessment includes measuring vital signs and reflexes, as well as administering a thorough neurological exam. The initial exam includes checking the patient’s temperature, blood pressure, pulse, breathing rate, pupil size and response to light (26). After the vital signs and basic neurologic functions are assessed, the emergency medical provider will assess the patient’s level of consciousness and neurologic functioning. This assessment is done using the Glasgow Coma Scale, which is a standardized, 15 point test that measures neurologic functioning using three assessments: eye opening, best verbal response, and best motor response. These measures are used to determine the severity of the brain injury (137).

The Center for Disease Control provides the following guidelines for the Glasgow Coma Scale. Medical responders should use the scale to assess the level of severity of trauma.

**Glasgow Coma Scale**

**Eye Opening Response**
- Spontaneous--open with blinking at baseline - 4 points
- To verbal stimuli, command, speech - 3 points
- To pain only (not applied to face) - 2 points
- No response - 1 point

**Verbal Response**
- Oriented - 5 points
- Confused conversation, but able to answer questions - 4 points
- Inappropriate words - 3 points
- Incomprehensible speech - 2 points
- No response - 1 point

**Motor Response**
- Obeys commands for movement - 6 points
- Purposeful movement to painful stimulus - 5 points
- Withdraws in response to pain - 4 points
- Flexion in response to pain (decorticate posturing) - 3 points
- Extension response in response to pain (decerebrate posturing) - 2 points
- No response - 1 point

Categorization:
Coma:
- No eye opening, no ability to follow commands, no word verbalizations (3-8)

Head Injury Classification:
- Severe Head Injury----GCS score of 8 or less
- Moderate Head Injury----GCS score of 9 to 12
- Mild Head Injury----GCS score of 13 to 15)

Disclaimer: Based on motor responsiveness, verbal performance, and eye opening to appropriate stimuli, the Glasgow Coma Scale was designed and should be used to assess the depth and duration coma and impaired consciousness. This scale helps to gauge the impact of a wide variety of conditions such as acute brain damage due to traumatic and/or vascular injuries or infections, metabolic disorders (e.g., hepatic or renal failure, hypoglycemia, diabetic ketosis), etc. (110)

After the Glasgow Coma Scale is administered, further testing is conducted to determine the level of damage and the severity of the injury. Imaging tests are used to assist with the diagnosis of the patient as well as make a determination about the prognosis of the patient (31). Skull and neck x rays are used to check for bone fractures and spinal instability in patients with mild to moderate injuries (138). In patients with mild head trauma, a diffusion tensor imaging is sometimes used. This device can reliably detect and track brain abnormalities and is sensitive enough to be used on patients with mild injury (61). In some cases, a magnetoencephalography may be used to obtain further information regarding a mild case of head trauma (97).
Additional diagnostic imaging is used in cases of moderate to severe head trauma. In these instances, patients will be assessed using a computed tomography (CT) scan. This scan creates cross sectional x-ray images of the head and brain and is used to identify any bone fractures that might be present in the skull. The CT scan also indicates if there is the presence of hemorrhage, hematomas, contusions, brain tissue swelling, and tumors (139).

Once the initial assessment is complete, additional imaging may be conducted. In these instances a magnetic resonance imaging (MRI) is often used to determine if there is additional damage beyond the scope of the initial assessment. The MRI is used to determine if there have been any subtle changes in the brain tissue and are used when more detail is needed than standard x-rays can provide (20). MRI’s are not used during the initial emergency assessment as they require a significant amount of time and are not always available during the initial assessment (9). However, an MRI is an important diagnostic tool and should be used when appropriate and available.

**Examination**

When a patient presents with head trauma, he or she will undergo a complete examination, with the purpose of assessing the trauma and identifying specific injuries. While the examination will vary depending on the patient’s needs, there are standard examination methods that are typically used during the initial examination.

Regardless of the type of injury (blunt or penetrating, open or closed) the initial examination will be conducted as soon as possible and will often occur in conjunction with resuscitation (140). It is important to conduct the initial assessment as soon as possible to identify any life threatening injuries and minimize any additional damage. Early identification of any complications will reduce the likelihood of the patient developing secondary injuries (70).

While it is important to manage any damage caused by an open head wound, it should not interfere with the initial stabilization of the patient. Therefore, the initial stage of the
patient examination will include assessing and managing the airway, breathing, circulation, and related components (36). Once that is complete, the emergency provider will begin the primary survey. The primary examination will focus on identifying any complications or secondary injuries (106). The following guidelines are provided for the primary and secondary examination of the patient:

### Primary Examination

As part of the primary survey, the pupillary size and reactions are noted and the conscious state is assessed. Disturbances of consciousness may follow focal damage to the reticular formation, which extends from the rostral midbrain to the caudal medulla. It receives input from all sensory pathways and projects widely to the cerebral cortex and limbic system. Focal cortical lesions do not affect consciousness, but coma may result from general depression of the cerebral cortex.

Using purely descriptive methods to assess conscious state is problematic. One observer’s “somnolent” is another’s “drowsy”. When is a person stuporous and when are they obtunded? What is semi-conscious and when does a clouded conscious state become coma? Consciousness is a continuum and the Glasgow Coma Scale (GCS) is used as a measure (albeit crude) of level of consciousness.

### Secondary Examination

Once the primary survey is complete, the secondary survey should include a more thorough neurological examination, starting with a reassessment of the Glasgow Coma Scale, and an examination of the head, face and neck. The head and face should be examined for lacerations and fractures. Scalp lacerations can be palpated with a gloved finger. If there is an underlying depressed fracture, surgery will be required. Profuse bleeding may occur from a scalp laceration and this can be controlled with a pressure dressing or by a few temporary full-thickness sutures.

The nose and ears are inspected for leaks of cerebrospinal fluid (CSF). This is usually mixed with blood and results in a thinner discharge that will separate on blotting paper. If this is not available, the separation can also be observed on a sheet
or pillowcase. If there is CSF rhinorrhea or otorrhoea, a basal skull fracture is present (regardless of whether it can be seen on radiographs).

Bilateral periorbital hematomas (raccoon eyes) and subconjunctival hemorrhages where the posterior margin cannot be seen are both indicators of anterior fossa fracture. Haemotympanum or bruising over the mastoid (Battle’s sign) suggests a middle fossa fracture. Battle’s sign usually takes several hours to develop. The nose, mid face and orbits should also be palpated for fractures that may require treatment later. When the patient is log-rolled, the back of the head and cervical spine should also be examined. The neurological examination will be limited because of the lack of cooperation of the patient, but it should still be possible at least to determine if there are lateralizing signs such as a hemiparesis or a third cranial nerve palsy.

Higher functions are assessed first. Most often this will be limited to level of consciousness and, in particular, the “voice” component of the GCS. In a relatively cooperative patient with a focal injury it may be possible to assess language further, but in the early period after a head injury it will be difficult to differentiate dysphasia from confusion.

Memory becomes important later and the period of post-traumatic amnesia is used as an indicator of injury severity.

Cranial nerves
Many of the cranial nerves can be assessed even in the unconscious patient.

I (olfactory): Assessment obviously requires cooperation, but this nerve should be examined when possible, as it is the most commonly affected cranial nerve after head injury and is often ignored. Anosmia may seem trivial but it has significant effects beyond enjoyment of food and wine. Anosmic patients will not be able to smell smoke from a fire or leaking gas, both of which may potentially put them at risk.

II (optic): The pupillary reactions to light depend on the integrity of the optic and oculomotor nerves, as well as their connections. Normally both pupils should
constrict when light is shone in either eye or when the patient looks at a near object (accommodation reflex). A pupil that responds to direct light implies that the ipsilateral optic and oculomotor nerves are intact. If it responds to direct light, but not consensually, this implies damage to the contralateral optic nerve. A pupil reacting only consensually suggests ipsilateral optic nerve damage. An oculomotor nerve injury will produce an ipsilateral dilated pupil, which does not respond directly or consensually, but the contralateral pupil will constrict when light is shone in either eye. One must remain aware that the commonest cause of a dilated pupil after head injury is traumatic mydriasis due to local ocular trauma. This should be suspected if the dilated pupil was present right from the time of injury and there is local trauma to the globe or orbit.

During examination of the eyes the fundi are assessed. One would not expect to see papilledema in the early hours after a head injury, and funduscopy is done more for the purpose of assessing the integrity of the eye itself (checking for retinal detachment or hemorrhage, vitreous hemorrhage, corneal laceration, etc.). Contact lenses should be looked for and removed. Visual fields can be checked by confrontation in a cooperative patient or by menace in an uncooperative patient. They are not clinically assessable in the unconscious patient.

*III, IV and VI (oculomotor, trochlear and abducens):* The pupils are assessed as above. Ptosis (III) is difficult to assess in patients who are unconscious. Ocular movements can be observed and any dysconjugate movements noted. If the patient is cooperative this is easy. An alert but uncooperative patient can be made to look at objects quite readily by placing them in their field of vision. This also applies to children. Oculocephalic reflexes test the third, fourth and sixth cranial nerves and their connections. Movement of the head from side to side or up and down will be accompanied by movement of the eyes in the opposite direction, resulting in a constant point of fixation.

The term “doll’s eyes” is often used to describe oculocephalic reflexes but this frequently leads to confusion. Whether doll’s eyes are normal or abnormal depends
on the sophistication of the doll. One with eyes painted on would describe the abnormal and one with eyes free to rotate would better approximate the normal situation. It is preferable to avoid the term altogether and describe oculocephalic reflexes as being normal or abnormal. It is not usually recommended to test oculocephalic reflexes in a head-injured patient owing to the high risk of associated cervical spinal injury. If it is important to know if these reflexes are intact (e.g., in assessing brain death), caloric testing is usually undertaken.

V (trigeminal): The motor component of the trigeminal nerve can be tested in a cooperative patient, but the sensory part can be assessed even in the unconscious. Painful stimuli applied to the supraorbital nerve should usually produce a response and the corneal reflex tests trigeminal function as well as facial nerve function.

VII (facial): Facial movements are readily assessed in the cooperative patient, but can also be observed when painful stimuli are applied and as part of the corneal reflex. Facial nerve palsies are often seen with middle fossa fractures and this nerve should be assessed early in any patient with CSF otorrhea or Battle’s sign. Taste is not usually tested. Patients often complain of loss of taste after a head injury but this is usually due to anosmia.

VIII (acoustic): This is hard to test clinically in the unconscious patient. An alert but uncooperative patient can be observed for reaction to sudden noises. Assessment in the unconscious usually requires brainstem auditory evoked potential monitoring. This nerve is also often injured in middle fossa fractures.

IX (glossopharyngeal), X (vagus): There is usually little more to do than observe swallowing and test the gag reflex, either directly or by moving an endotracheal tube.

XI (accessory): Sternomastoid and trapezius function can be tested, but it is unusual for the accessory nerve to be injured intracranially.

XII (hypoglossal): A hypoglossal nerve injury will force the protruded tongue to the ipsilateral side. Over time the ipsilateral side of the tongue becomes wasted.
Motor function
The sophistication of motor testing depends on the level of cooperation of the patient. At the least, it is possible to detect asymmetry in movement or responses to pain as described above in assessing the GCS. Reflexes are often brisk but may be absent with associated spinal cord injury (spinal shock). Plantar reflexes will usually be extensor after a significant head injury. Priapism and loss of anal tone are other indicators of spinal cord injury that should be sought.

Sensory function
The same applies as for motor function. If there is a response to pain, this can be compared in different areas. This is important when a spinal cord injury is suspected and one is attempting to determine at what level. Sometimes there can be movement of limbs through local spinal cord reflexes; hence, when assessing a patient for brain death, it is mandatory that the painful stimulus is applied to a cranial nerve distribution.

(140)

The two most commonly used diagnostic assessments are the Non-contrast CT and the MRI (112).

Non-contrast CT
Computed tomography (CT scan) is a diagnostic imaging procedure that produces horizontal, or axial, images of the body. These images are often called “slices.” (45) The CT scan uses a combination of X Ray imaging and computer technology to obtain the images in a noninvasive format (142). A CT scan is an important diagnostic tool as it is able to provide detailed images of different parts of the body. It is especially useful in obtaining images of the bones, muscles, fat and organs (143).

CT scans are used more frequently than standard X Rays because the images are more detailed (139). Standard X Rays use a single beam of energy that is aimed at the specific body part being analyzed. The image is captured on a plate that is placed behind the body, once the beam of light passes through the various body parts (skin,
bone, muscle, and tissue) (4). X Rays are limited in their ability to provide detailed imaging, as they cannot capture images of internal organs and other structures of the body. Therefore, a CT scan is often the primary assessment used. A CT scan uses a moving X Ray beam to capture the images. The beam circles around the body, thereby capturing a number of different views of the same body part (142). The information is transmitted to a computer, which then interprets the data and creates a two dimensional form. The form is displayed on a monitor, which is then reviewed by the radiologist (144).

CT scans are conducted in two ways, as described below:

**Contrast CT**
Patients ingest a substance orally, or receive an injection intravenously. The contrast solution enables the radiologist to view the specific body part or region more clearly (45).

**Non-Contrast CT**
The CT scan is conducted without the use of any solution. In instances of head trauma, the patient will undergo a non contrast CT scan (145).

CT scans are especially useful in instances of head trauma as they provide detailed images of the brain structure and brain tissue. CT scans can help the treating physician identify any underlying injuries or infections of the brain, especially when other examinations of images are inconclusive (143). The scan is often used to identify the following complications of head trauma:

- Intracranial bleeding
- Structural anomalies
- Infections
- Clots (96)
The following are the CDC Guidelines for using a CT scan with patients with mild traumatic brain injury. The guidelines provide recommendations for determining which patients with a known or suspected mild brain injury requires a head CT and which may be safely discharged.

### CDC Brain Injury Guidelines for Adults: Fact Sheet

- A noncontrast head CT is indicated in head trauma patients with loss of consciousness or posttraumatic amnesia in presence of specific symptoms.
- A noncontrast head CT should be considered for head trauma patients with no loss of consciousness or posttraumatic amnesia in presence of specific symptoms.
- Even without a loss of consciousness or amnesia, a patient could still have an intracranial injury. Identifying those patients at risk is key.
- A patient with an isolated mild TBI and a negative CT is at minimal risk for developing an intracranial lesion and may be safely discharged.
- Discuss discharge instructions with patients and give them a discharge instruction sheet to take home and share with their family and/or caregiver. Be sure to:
  - Alert patients to look for post concussive symptoms (physical, cognitive, emotional, and sleep) since onset of symptoms may not occur until days after the initial injury.
  - Instruct patients on what to expect, what to watch for, and when it is important to return immediately to the emergency department.
  - Emphasize that getting plenty of rest and sleep is very important after a concussion, as it helps the brain to heal. Patients should gradually return to their usual routine only after they start to feel better.
The CDC also provides leveled recommendations for determining which patients in the emergency department should undergo a non-contrast CT scan; which are included below:

### CDC Brain Injury Guidelines for Adults: Fact Sheet

**Level A recommendations:**
A noncontrast head CT is indicated in head trauma patients with loss of consciousness or posttraumatic amnesia only if one or more of the following is present: headache, vomiting, age > 60 years old, drug or alcohol intoxication, deficits in short-term memory, physical evidence of trauma above the clavicle, posttraumatic seizure, GCS score < 15, focal neurologic deficit, or coagulopathy.

**Level B recommendations:**
A noncontrast head CT should be considered in head trauma patients with no loss of consciousness or posttraumatic amnesia if there is a focal neurologic deficit, vomiting, severe headache, ≥ 65 years old, physical signs of a basilar skull fracture, GCS score < 15, coagulopathy, or a dangerous mechanism of injury.*

* Dangerous mechanism of injury includes ejection from a motor vehicle, a pedestrian struck, and a fall from a height of > 3 feet or 5 steps.

**Level C recommendations:** None specified.

(146)

### MRI

Magnetic Resonance Imaging (MRI) is a radiologic scan produces images of various body structures using a combination of magnetism, radio waves and computer technology. The MRI is conducted using a large circular magnet that surrounds a scanner tube (147). Images are obtained after placing the patient on a movable surface, and then inserting him or her into the magnetic tube. Once the patient is in the tube, a strong magnetic field is created. This magnetic field aligns the protons of the
hydrogen atoms. Once the hydrogen atoms are aligned, they are exposed to a beam of radio waves. The radio waves impact the protons within the body, causing them to spin, thereby producing a faint signal, which is easily detected by the MRI receiver. The information obtained by the scanner is sent to a computer, where it is processed to produce an image (142).

An MRI utilizes high resolution technology, which allows it to produce highly detailed images that will show changes in many of the structures in the body (148). In some instances, additional agents will be used to enhance the accuracy of the images. It is most common to use contrast agents such as gadolinium (20). Due to the MRI's high level of sensitivity, it is able to detect many brain injuries that are undetectable using other methods (9). In fact, an MRI is often used to identify asymptomatic brain damage in patients who appear to be normal (148).

While an MRI and CT scan both use the slicing technique for obtaining images, the process is different for each. The MRI uses a magnetic field while the CT scan uses X-rays (96). As a result, the MRI provides more detailed images than a CT scan and is able to detect damage that is as small as 1 – 2 mm; a CT scan cannot detect damage this small (142). The CT scan is more appropriate for identifying fresh blood in and around the cranial region (149). However, an MRI better detects old blood that has been hemorrhaged into the cranial cavities (9). Whether or not to use an MRI will depend on the type, cause and location of the head injury.

Other Diagnostic Imaging Procedures
While the CT scan and the MRI are the most widely used forms of diagnostic imaging for head trauma, there are a number of other procedures that are being used more frequently as the technology is developing and as the diagnostic needs of the patient and the provider are changing. The following table provides a list of the more commonly used alternate forms of diagnostic imaging.
<table>
<thead>
<tr>
<th>Diagnostic Procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUSCEPTIBILITY WEIGHTED IMAGING (SWI) MRI</td>
<td>This is a software program that enables an MRI to more accurately show tiny hemorrhages known as microhemorrhages. These small white dots actually show up on the MRI because of the iron content left behind after blood has been in an area through injury. These tiny capillaries in the brain are torn and the small amounts of blood can be seen on SWI-MR. In persons fifty or older, there are white dots, which can often be from aging. In the younger person, or in an older person, where these abnormalities are clustered at the grey-white junction (where the grey matter meets the white matter) these are generally traumatically caused. If a patient is undergoing a MRI after a trauma, especially a trauma involving a high-speed collision or a fall from a height, the provider should prescribe an SWI MRI so that these abnormalities can be detected. There can be as many as several hundred of these small injuries throughout the brain, but they are an objective unarguable type of evidence for brain injury and are exceedingly helpful in any brain injury litigation. They can also identify the areas of the brain that have been shaken and can aid in rehabilitative</td>
</tr>
</tbody>
</table>
Diffusion Tensor Imaging (DTI) is a type of MRI that uses special software to view parts of the brain a normal MRI cannot. The interesting premise of this new technology is that it measures the movement of water molecules in relation to the white track fibers of the white matter of the brain. If the fibers are healthy and untorn, then the water molecules will show parallel movement along those tracks as they slide along them. Torn or missing white matter fiber will allow perpendicular movement of the water molecules.

This new technology allows for visualization of natural damage to the white matter. It is a very impressive technology and will be impressive to jurors and others involved in TBI litigation. Most radiology groups do not have this software and it tends to be available only in larger tertiary or teaching-hospital centers. DTI will be especially helpful in cases involving high velocity change injury, such as high-speed car accidents, falls from a height, and other accidents in which the injury is suspected to be Diffused Axonal Injury (DAI).
| **MRA (MAGNETIC RESONANCE ANGIOGRAPHY)** | MRA, or magnetic resonance angiography, is a means of visualizing the carotid and vertebral arterial systems in the neck and brain without having to inject contrast into the bloodstream. The resolution is not as good as with conventional arteriography, but the patient is spared the risks of catheterization and allergic reactions to the dye. (In conventional arteriography, a catheter is threaded from the femoral artery in the groin backward up the aorta into a carotid or vertebral artery in the neck, and then dye is injected up the catheter. As the dye flows into the brain, x-rays are taken of the cerebral vasculature.) |
| **EEG (ELECTROENCEPHALOGRAM)** | Monitors the brain's electrical activity by means of wires attached to the patient's scalp. These wires act like an antenna to record the brain's electrical activity. Normally, the resting brain emits signals at a frequency of 8 to 13 cycles per second (cps), called alpha activity, which is best seen in the occipital regions. Anything faster than 8-13cps is called beta activity. Slower rhythms include theta activity (6-7 cps) and delta activity (3-5 cps). |
Theta and delta activity occur in the normal brain as the patient descends into sleep. If the patient is awake, any slowing of electrical activity in a focal area of the brain may indicate a lesion there. Similarly, widespread slowing indicates a widespread disturbance of brain function, often due to a blood borne insult like low blood sugar, drug intoxication, liver failure, etc. "Spiking" (sharp waves of electrical activity) discharges indicate an irritable area of cerebral cortex. If allowed to spread, the spikes can produce a seizure.

It is not uncommon for an EEG to be normal between seizures in patients with bonafide seizures. During a seizure, however, the EEG is almost invariably abnormal. Conversely, 15% of the population shows mild abnormalities on EEG, representing old head trauma, old strokes, migraine, viral infections, and most of the time for unknown reasons.

**QUANTITATIVE EEG (QEEG, BEAM, BRAIN MAPPING)**

This test is performed in a way similar to EEG. Brain wave activity varies throughout the day depending on the state of alertness. Each area of the brain normally spends a characteristic amount of time in alpha, beta, theta, and delta
activity. Brain mapping computers are now capable of creating a map of the brain’s electrical activity depicting how long each area of the brain spends in each of the basic rhythms. By comparing the patient's map with that of a control population, it is possible to localize areas of focal slowing of electrical activity. Alone, a QEEG is insufficient to diagnose brain damage but in conjunction with other neurologic tests, QEEG can be confirmatory.

**PET SCAN (POSITRON EMISSION TOMOGRAPHY)**

PET scanning (positron emission tomography) is based on the fact that the brain uses glucose for energy. By labeling a glucose molecule with a radioactive "tag," and then inhaling radioactive glucose and placing the patient's head under a large geiger counter, one can identify abnormal areas of the brain that are underutilizing glucose. Because cyclotrons are needed to generate the radioactive gas, PET scanning is not widely available.

**SPECT SCAN (SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY)**

SPECT scanning (single photon emission computed tomography) is similar to PET scanning in that a radioactive chemical is administered intravenously to the patient, but the radioactive chemical remains in
the bloodstream and does not enter the brain. As a result, the SPECT scan maps the brain's vascular supply. Because damaged brain tissue normally shuts down its own blood supply, focal vascular defects on a SPECT scan are circumstantial evidence of brain damage. The advantage of a SPECT scan over a PET scan is its ready availability and relatively cheap cost. Recent studies have demonstrated abnormal SPECT scans after head trauma when the CAT and MRI were normal, suggesting that the SPECT scan is more sensitive to brain injury than either CT or MRI scans. Because the radioactive chemicals used in SPECT and PET scans are carried to all parts of the body by vascular tree, SPECT scans and PET scans are used judiciously in patients of reproductive age.

<table>
<thead>
<tr>
<th>EVOKED POTENTIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evoked studies take advantage of the fact that each time a sensory system of the body -- vision, hearing, touch -- is stimulated, an electrical signal is generated in the brain. These electrical signals can be detected with electrical wires on the scalp. Thus, visual evoked recordings (VER) are recorded over the occipital lobes; brainstem auditory evoked recordings (BAER) over the temporal...</td>
</tr>
<tr>
<td>LUMBAR PUNCTURE</td>
</tr>
<tr>
<td>MAGNETIC RESONANCE SPECTROSCOPY (MRS)</td>
</tr>
</tbody>
</table>

**TREATMENT**

The initial assessment and diagnostic imaging is used to determine the level of severity of the injury and to determine any specific complications. Once this information is obtained, and the patient is stabilized, medical personnel can begin to treat the specific injuries. Treatment is individualized based on the specific injuries and the severity of the damage.
In some instances, a patient with head trauma may require initial surgical interventions. These surgical interventions are conducted immediately following the initial assessment and treatment stage, as they are used as immediate treatment to minimize some of the initial complications that are most threatening to the success of the patient (37). When a patient requires an initial surgical intervention, he or she is typically admitted to the intensive care unit for further treatment and monitoring. Initial surgical interventions are used to remove or repair hematomas and contusions (52).

In many instances, a patient will experience swelling in the brain. When this occurs, fluids accumulate within the brain and pressure begins to build. This causes additional swelling and disruptions to the fluid balance (60). With other injuries, swelling and fluid accumulation is normal and poses little risk. However, when this occurs within the brain, it can be extremely dangerous. The skull limits the space for expansion, so the brain is unable to expand. Therefore, the accumulation of fluid causes unnecessary pressure on the brain, which is known as intracranial pressure (ICP) (14).

When a patient presents with swelling in the brain, it is necessary to monitor the swelling to ensure that it does not cause additional damage. This is accomplished using a probe or catheter (52). The instrument is inserted into the skull and is placed at the subarachnoid level to ensure accurate measurements. Once the instrument is properly placed, it is connected to a monitor that displays information regarding the patient’s ICP. This information is closely monitored so that action can be taken if the ICP reaches an alarming level (31). If this occurs, the patient may have to undergo a ventriculostomy. This procedure is used to drain cerebrospinal fluid as a way to reduce pressure on the brain (32). In some instances, pharmacological agents may be used to decrease ICP. These drugs include mannitol and barbituates (52).

While the above information provides an overview of the different types of treatment a patient may receive, it is important to note that the treatment for head injury will differ depending on the severity and type of injury. A patient will require different care for a penetrating head injury than a blunt head injury. In addition, a mild head injury will be
treated differently than a severe head injury. It is important to understand the treatment
goals for each type of injury.

**Mild Head Injury**

When a patient experiences a mild head injury, he or she will require minimal treatment. Most mild head injuries will resolve on their own and will not progress in severity (146). However, there is a chance that the head injury can progress to a more serious injury (61). During the initial assessment, the risk level of the head injury will be assessed and it will be categorized as either low risk or moderate risk (21).

Low Risk injuries typically include the following symptoms:

- Headaches
- Dizziness
- Nausea (3)

Patients who display symptoms of low risk injuries will not require extensive treatment. They rarely require the level of assessment that moderate or high risk patients require, and it is not common to utilize radiologic imaging to evaluate the injury (150). In most instances, patients will be released and will require monitoring at home until the window for developing additional injuries has passed (151). When the patient is released, he or she should be given thorough instructions for monitoring the injury at home. The home caregiver should wake the patient every two hours to provide a thorough assessment. Caregivers should watch for the following symptoms in the patient:

- Severe headaches
- Persistent nausea
- Vomiting
- Seizures
- Confusion
- Unusual behavior
- Watery discharge from the nose or ear (76)

Moderate Risk injuries typically include the following symptoms:
- Persistent emesis
- Severe headache
- Anterograde amnesia
- Loss of consciousness
- Signs of intoxication (152)

When a patient shows signs of a moderate risk head injury, he or she must be assessed using a CT scan. Once the CT scan findings are reviewed, the patient is eligible for release, assuming the findings were clear. However, patients must be observed for at least eight hours prior to being released (70).

Patients who have moderate to severe brain injuries will require treatment beyond an initial observation and release. Treatment will depend on the type, location and severity of the injury. However, in most instances, treatment will follow an initial standard set of procedures before being tailored to the specific needs of the patient.

**SHAKEN BABY SYNDROME**

Shaken Baby Syndrome (aka Shaken Impact Syndrome) is a head injury that typically occurs as the result of abuse toward a child (159). In most instances, shaken baby syndrome is a direct result of an individual (parent or caregiver) shaking an infant severely due to anger or frustration. It is especially common in situations when an infant will not stop crying (160). Shaken baby syndrome occurs due to the physical composition of the infant. Infant’s neck muscles are quite weak, making them unstable under the weight of the infant’s head. When an individual shakes an infant back and forth, the head moves back and forth without full support of the neck. This causes damage to the brain, which can be fatal (160).

When an infant is shaken violently, the following may occur:
- Subdural hematoma is a collection of blood between the surface of the brain and the dura (the tough, fibrous outer membrane surrounding the brain.) This occurs
when the veins that bridge from the brain to the dura are stretched beyond their elasticity, causing tears and bleeding.

- Subarachnoid hemorrhage is bleeding between the arachnoid (web-like membrane surrounding the brain filled with spinal fluid) and the brain.
- Direct trauma to the brain substance itself when the brain strikes the inner surfaces of the skull.
- Shearing off or breakage of nerve cell branches (axons) in the cortex and deeper structures of the brain caused by violent motion to the brain.
- Further irreversible damage to the brain substance from the lack of oxygen if the child stops breathing during shaking.
- Further damage to the brain cells when injured nerve cells release chemicals which add to oxygen deprivation (161) to the brain.

Other injuries related to this abuse include:

- Retinal hemorrhages ranging from a few scattered hemorrhages to extensive hemorrhages involving multiple layers of the retina.
- Skull fractures resulting from impact when the baby is thrown against a hard or soft surface.
- Fractures to other bones, including the ribs, collarbone, and limbs; bruising to the face, head and entire body. (162)

Shaken baby syndrome is most common in infants under the age of two. However, the majority of cases involve infants under the age of one, with most instances occurring in infants between the ages of three to eight months (159). While shaken baby syndrome is most common in infants under the age of two, it can occur in children up to the age of four, although it is quite rare (163). According to the National Center on Shaken Baby Syndrome, there are approximately 600 – 1400 cases of shaken baby syndrome each year. Shaken baby syndrome is the leading cause of death and disability in infants and children (159).
Few infants will show external signs when they have sustained head injury as the result of shaken baby syndrome (160). In most instances, the injuries will not appear immediately, as caregivers and providers will disregard many of the symptoms as being due to general fussiness or a virus of some sort (163). Once a patient shows signs of head injury, the brain has swelled as a secondary response to the trauma (162). In some instances, the symptoms will appear immediately following the injury. However, many patients will not show signs until approximately 4 – 6 hours after the injury (160).

The following signs and symptoms may be present with shaken baby syndrome:

- Altered level of consciousness
- Drowsiness accompanied by irritability
- Coma
- Convulsions or seizures
- Dilated pupils that do not respond to light
- Decreased appetite
- Vomiting
- Posture in which the head is bent back and the back arched
- Breathing problems and irregularities
- Abnormally slow and shallow respiration
- Cardiac arrest
- Death
- Physical findings upon medical examination
- Retinal hemorrhages
- Closed head injury bleeding (subdural, epidural, subarachnoid, subgaleal)
- Lacerations
- Contusions
- Concussions
- Bruises to the face, scalp, arms, abdomen, or back
- Soft tissue swelling which may indicate a fracture to the skull or other bones
- Abdominal injuries
- Chest injuries
- Abnormally low blood pressure
- Tense fontanel (soft spot) (162)

When an infant or child shows any of the symptoms above, it is crucial to conduct a thorough assessment to determine the level of damage (if any) that is present. The following is a list of the suggested assessments that should be administered in the case of shaken baby syndrome:

- Complete patient history
- Optic fundus exam for retinal hemorrhages
- Computed tomography scan (CT or CAT scan) of the head and abdomen
- Magnetic resonance imaging (MRI) in select cases
- Lumbar puncture with precautions
- Skeletal survey
- Nuclear scan
- Drug screening
- Routine blood samples (161)

When a patient experiences shaken baby syndrome, the prognosis is poor. Most cases of shaken baby syndrome are fatal, and those that are not will often result in severe neurological deficits (163). Shaken baby syndrome will most likely be fatal if the patient experiences any of the following:

- Uncontrollable increased intracranial pressure from cerebral edema
- Bleeding within the brain
- Tears in the brain tissue (161)

When shaken baby syndrome is not fatal, the child may experience the following long-term complications or disabilities:

- Cerebral palsy
- Paralysis
- Vision loss or blindness
- Mental retardation
HEAD INJURY AND THE LINK TO ALZHEIMER’S DISEASE

Alzheimer’s disease (AD) is defined as a progressive, neurodegenerative disease characterized by dementia, memory loss, and deteriorating cognitive abilities. According to recent research, there is an association between head injury in early adulthood and the development of AD later in life. The risk of developing AD later in life is increased in direct correlation to the severity of the head injury (119).

The link between head injury and the risk of Alzheimer's disease (AD) is indicated by data from the MIRAGE study (Multi-Institutional Research in Alzheimer Genetic Epidemiology). Patients with AD were nearly ten times more likely to have a history of head injury that resulted in loss of consciousness. The study suggests that "head injury with loss of consciousness and, to a lesser extent, head injury without loss of consciousness, increased the risk of AD.

Research led by Dr. Douglas H. Smith at the University of Pennsylvania supports previous epidemiological links between a single episode of brain trauma and the development of AD later in life. In animal studies, scientists induced brain injury without direct impact, similar to what humans often experience in automobile accidents. Analysis of damaged brain cells revealed extensive amyloid beta and tau accumulation, as well as plaque formation – all typical findings in Alzheimer's disease. These changes were evident as early as 3 to 10 days after the injury.

An analysis of injured World War II veterans links serious head injury in early adulthood with Alzheimer’s disease in later life. The study by researchers at Duke University and the National Institute on Aging also suggests that the more severe the head injury, the greater the risk of developing AD. While the findings do not demonstrate a direct cause-and-effect relationship between head injury in early life and the development of dementia, they show an association between the two that needs to be studied further.
SUMMARY

Head trauma is one of the most common injuries sustained during a trauma situation. In fact, approximately fifty percent of individuals who experience trauma show signs of a head injury. Head trauma can range from minor bumps that cause slight discomfort to a serious injury that results in permanent disability or impairment, or even death. Head trauma is a serious matter that affects people of all ages. Sports, auto accidents, and physical abuse are some of the leading causes of head trauma, but while the cause may be obvious, the effects are not always readily seen. In fact, sometimes head trauma may manifest over a period of days, weeks, or even years. For this reason, it’s important to closely monitor any incidence of head trauma and adjust treatment according to changing symptoms.

Health care providers must be familiar with the different causes and types of head injury to adequately treat trauma patients. In many instances, head injury will accompany other trauma-induced injuries. Therefore, all trauma patients must be evaluated for head injuries, even if no signs are present. Many head injuries will not produce immediate symptoms, even if significant damage has occurred. A patient should be evaluated using standard guidelines and diagnostic imaging, if appropriate. When a head injury is detected, treatment should begin immediately to avoid further complications. The goal of head trauma care is detection, treatment, and prevention of long-term problems. Many of the effects of head trauma can be reduced or prevented with proper treatment and management.
References:


38. Sharkey EJ, Cassidy M, Brady J, Gilchrist MD, NicDaeid N. Investigation of the force associated with the formation of lacerations and skull fractures. Int. J. Legal


98. Grubenhoff JA, Kirkwood MW, Deakyne S, Wathen J. Detailed concussion symptom analysis in a paediatric ED population. Brain Inj. [Internet]. Informa UK,


123. Masel BE, DeWitt DS. Traumatic brain injury: a disease process, not an event. J. Neurotrauma [Internet]. Mary Ann Liebert, Inc. 140 Huguenot Street, 3rd Floor


146. CDC. Updated Mild Traumatic Brain Injury Guidelines for Adults.

147. Articles: New MRI techniques for imaging of head trauma: DWI, MRS, SWI on Applied Radiology Online [Internet]. [cited 2013 Sep 15]. Available from:


