Traumatic Brain Injury

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Chair of Neurosurgery

Introduction

- 4 million people experience head trauma annually
- Severe head injury is most frequent cause of trauma death

- At Risk population
  - Males 15-24
  - Infants
  - Young Children
  - Elderly

Causes

Most head injuries occur secondary to

- motor vehicle accidents
- falls
- assaults
- recreational activities
- child abuse
- gunshot injury

Anatomy & Physiology of the Head

- Scalp
  - Strong Flexible mass of
    - Skin
    - Fascia
    - Muscular Tissue
  - Highly Vascular
  - Structures Beneath
    - *Galea Aponeurotica*
      - Between scalp and skull
      - Fibrous connective sheath
    - Subaponeurotica (Areolar) Tissue
      - Permits venous blood flow from the dural sinuses to the venous vessels of scalp = Emissary Veins: potential route for Infection

Anatomy & Physiology of the Head

- Brain
  - Occupies 80% of cranium
  - Comprised of 3 Major Structures
    - Cerebrum
    - Cerebellum
    - Brainstem
  - High metabolic rate
    - Receives 15% of cardiac output
    - Consumes 20% of body's oxygen
    - Requires constant circulation
  - IF Blood supply stops
    - Unconscious within 10 seconds
    - Death in 4-6 minutes

Anatomy & Physiology of the Head

- Cerebral Perfusion Pressure
  - Pressure within cranium (ICP) resists blood flow and good perfusion to the CNS
    - Pressure usually less than 10 mmHg
  - Mean Arterial Pressure (MAP)
    - Must be at least 50 mmHg to ensure adequate perfusion
    - MAP = DBP + 1/3 Pulse Pressure
  - Cerebral Perfusion Pressure (CPP)
    - Pressure moving blood through the cranium
    - CPP = MAP - ICP

CPP=MAP-ICP

CPP: cerebral perfusion pressure

MAP: mean arterial pressure

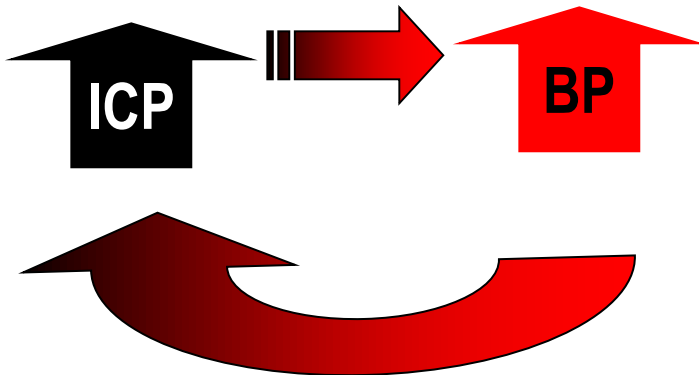
ICP: intracranial pressure

Intracranial Perfusion

- Cranial volume fixed
  - 80% = Cerebrum, cerebellum & brainstem
  - 12% = Blood vessels & blood
  - 8% = CSF
- Increase in size of one component diminishes size of another
  - Inability to adjust = increased ICP

Intracranial Perfusion

- Compensating for Pressure
  - Compress venous blood vessels
  - Reduction in free CSF
    - Pushed into spinal cord
- Decompensating for Pressure
  - Increase in ICP
  - Rise in systemic BP to perfuse brain
    - Further increase of ICP
      - Dangerous cycle



CN	Name	F	Innervation
I	Olfactory	S	Smell
II	Optic	S	Sight
III	Oculomotor	M	Pupil Const, Rectus & Obliques
IV	Trochlear	M	Superior Obliques
V	Trigeminal	S	Opthalmic (FH), Maxillary (cheek) Mandible (chin)
		M	Chewing muscles
VI	Abducens	M	Lateral rectus muscle
VII	Facial	S	Tongue
		M	Face Muscles
VIII	Acoustic	S	Hearing balance
IX	Glossopharyn-geal	S	Posterior pharynx, taste to anterior tongue
		M	Face Muscles
X	Vagus	S	Taste to posterior tongue
		M	Posterior palate and pharynx
XI	Accessory	M	Trapezius & Sternocleido. Muscles
XII	Hypoglossal	M	Tongue

Two types of brain injury occur

- Closed brain injury
- Open brain injury

Closed Head Injury

- Closed head injuries result from blunt trauma.
- The scalp remain intact so that there are no tracts connecting the intracranial contents and the atmosphere.

Open Head Injury

- The term *open head injury* indicates there is communication between intracranial contents and the atmosphere.
- Open head injuries can result from penetrating missiles or blows to the head by sharp or blunt objects with consequent lacerations and/or severe abrasions to the scalp.

Types of Trauma

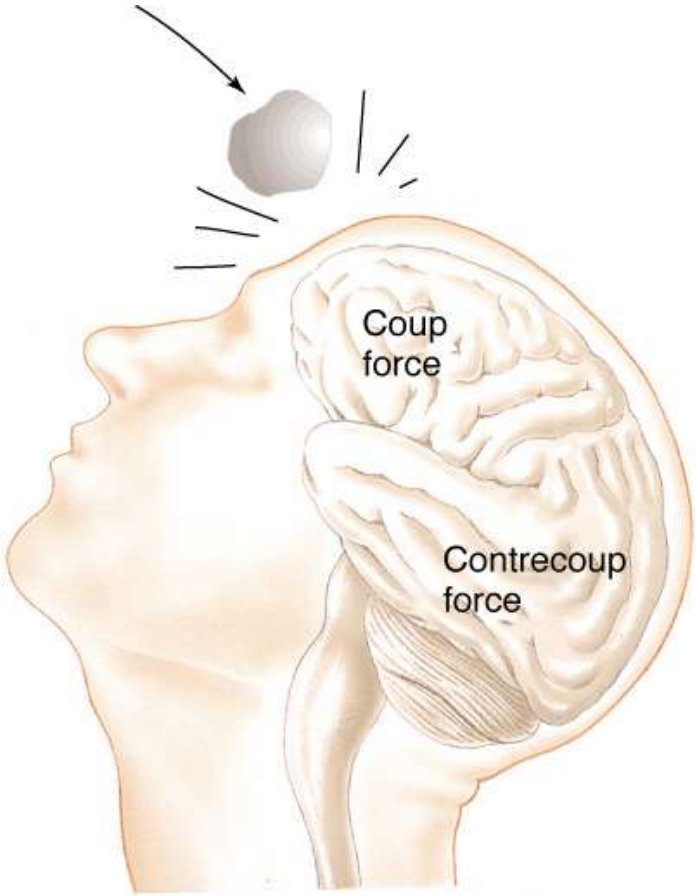
- Soft tissue
- Skull fracture
- Primary brain injuries caused by forces of trauma
- Secondary brain injuries caused by factors resulting from the primary injury

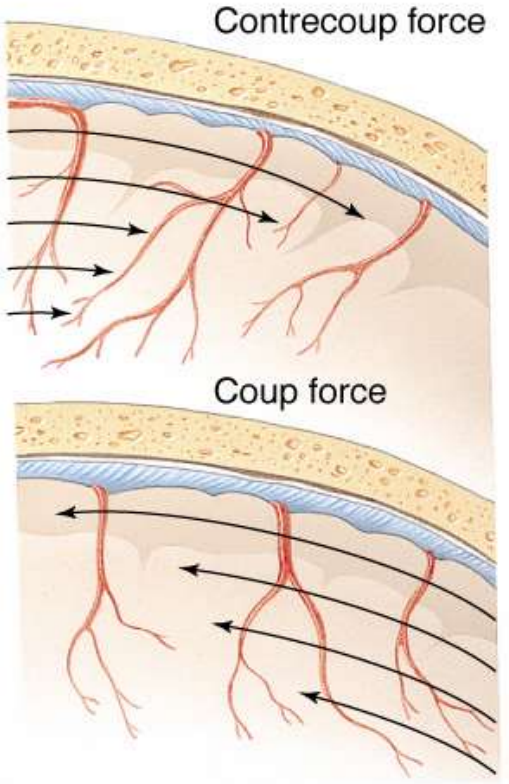
Scalp Injury

- Contusions
- Lacerations
- Avulsions
- Significant Hemorrhage

Direct Brain Injury Types

- Coup
  - Injury at site of impact
- Contrecoup
  - Injury on opposite side from impact





Signs & Symptoms of Brain Injury

- Frontal Lobe Injury
  - Alterations in personality
- Occipital Lobe Injury
  - Visual disturbances
- Cortical Disruption
  - Reduce mental status or Amnesia
    - Retrograde
      - » Unable to recall events before injury
    - Antegrade
      - » Unable to recall events after trauma
      - » “Repetitive Questioning”
- Parietal Lobe Injury
  - Hemiplegia, Weakness or Seizures

Signs & Symptoms of Brain Injury

- Upper Brainstem Compression
  - Increasing blood pressure
  - Reflex bradycardia
    - Vagus nerve stimulation
  - Cheyne-Stokes respirations
  - Pupils become small and reactive
  - Decorticate posturing
    - Neural pathway disruption

Signs & Symptoms of Brain Injury

- Middle Brainstem Compression
  - Widening pulse pressure
  - Increasing bradycardia
  - CNS Hyperventilation
    - Deep and Rapid
  - Bilateral pupil sluggishness or inactivity
  - Decerebrate posturing

Signs & Symptoms of Brain Injury

- Lower Brainstem Injury
  - Pupils dilated and unreactive
  - Ataxic respirations
    - Erratic with no pattern
  - Irregular and erratic pulse rate
  - ECG Changes
  - Hypotension
  - Loss of response to painful stimuli

Glasgow Coma Scale

Table 8-2 GLASGOW COMA SCALE

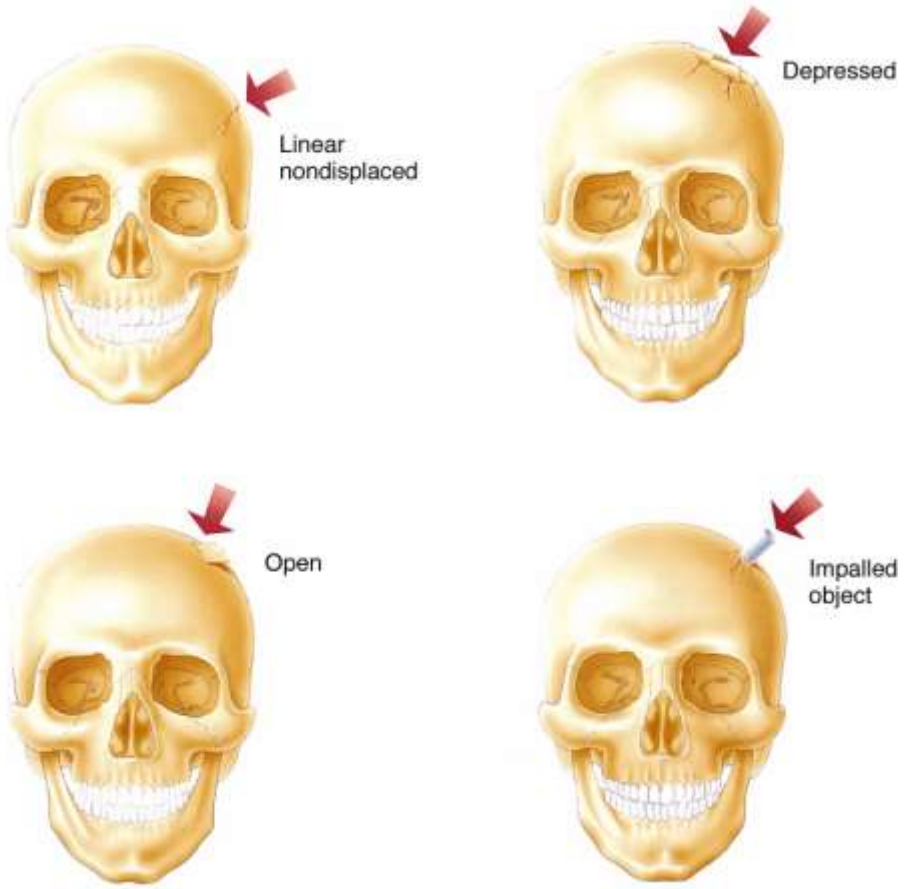
Eye Opening	
Spontaneous	4
To verbal command	3
To pain	2
No response	1
Verbal Response	
Oriented and converses	5
Disoriented and converses	4
Inappropriate words	3
Incomprehensible sounds	2
No response	1
Motor Response	
Obeys verbal commands	6
Localizes pain	5
Withdraws from pain (flexion)	4
Abnormal flexion in response to pain (decorticate rigidity)	3
Extension in response to pain (decerebrate rigidity)	2
No response	1

Head injury severity

- Severe head injury/coma if GCS < 8
- moderate head injury if GCS 9 -12
- minor head injury if GCS 13 –15

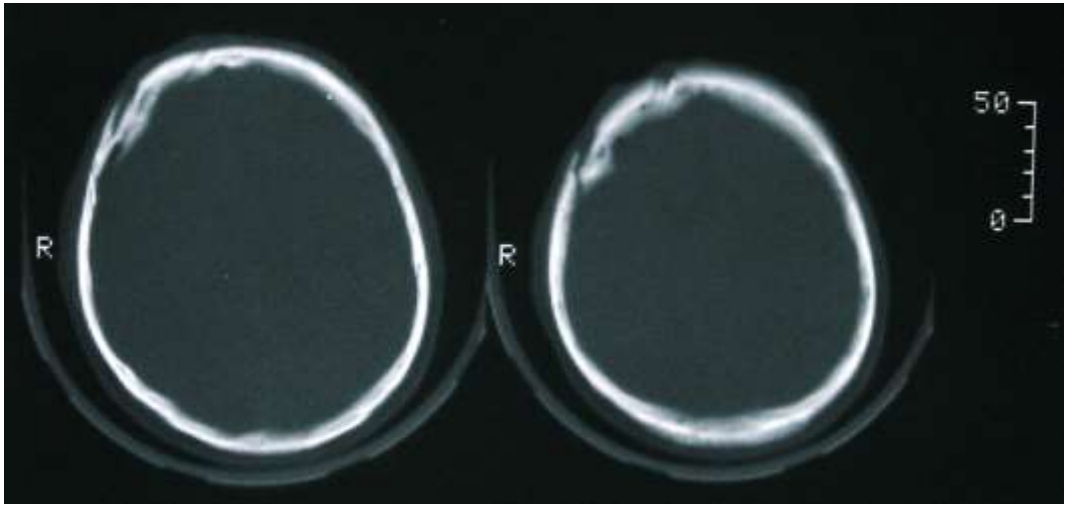
Cranial Injury

- Trauma must be extreme to fracture
  - Linear
  - Depressed
  - Open
  - Impaled Object
- Basal Skull
  - Unprotected
  - Spaces weaken structure
  - Relatively easier to fracture



Skull fracture

- The presence of cerebrospinal fluid (CSF) in the wound indicates a violation of the dura.
- Location of the fracture is important because it may cross the path of a major vessel and be associated with an intracranial bleed.


R
R
50
0


666
50M
53MM
DIST/ANGLE
DIST :
ANGLE:
150MA
3.7MS
5S

Basal Skull Fracture Signs

- Battle's Signs
  - *Retroauricular Ecchymosis*
  - Associated with fracture of auditory canal and lower areas of skull
- Raccoon Eyes
  - *Bilateral Periorbital Ecchymosis*
  - Associated with orbital fractures

Retroauricular ecchymosis (Battle's sign).

Bilateral periorbital ecchymosis (racoon eyes).

Basal Skull Fracture

May tear dura

- Permit CSF to drain through an external passageway = CSF leakage

Direct Brain Injury Categories

- Focal
  - Cerebral Contusion
  - Intracranial Hemorrhage
    - Epidural hematoma
    - Subdural hematoma
  - Intracerebral Hemorrhage
  - Subarachnoid Hemorrhage
  - Impalement injury
  - Bullet wounds
- Diffuse
  - Concussion
  - Moderate Diffuse Axonal Injury
  - Severe Diffuse Axonal Injury

Contusion

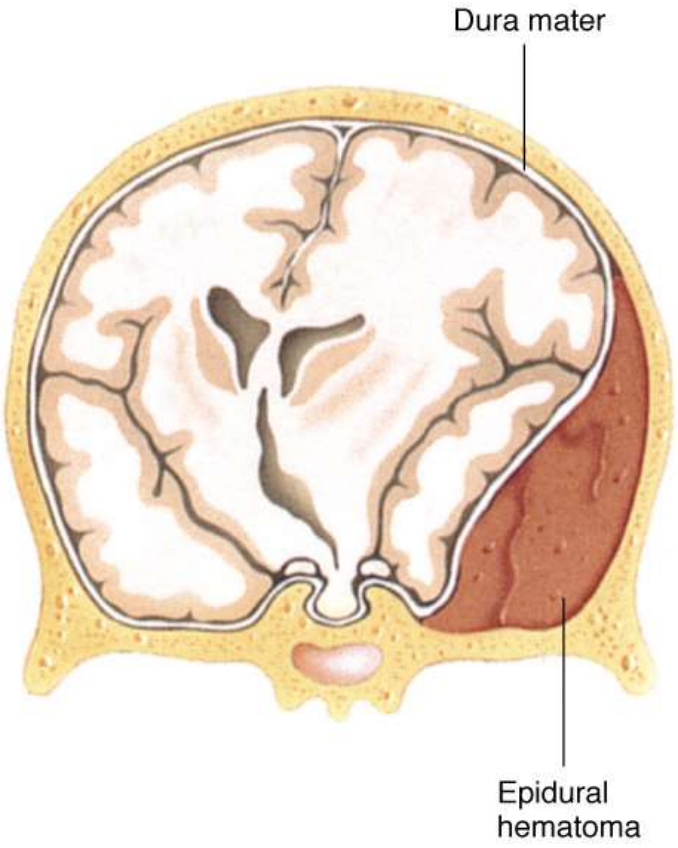
Contusions of the brain are injuries to cerebral substance, usually accompanied by hemorrhage into the substance of the brain with adjacent edema.

Contusion

- Blunt trauma to local brain tissue
- Capillary bleeding into brain tissue
  - LOC > 30 min
  - Confusion
  - Neurologic deficit
    - Personality changes
    - Vision changes
    - Speech changes
- Results from
  - Coup-contrecoup injury

Epidural Hematoma

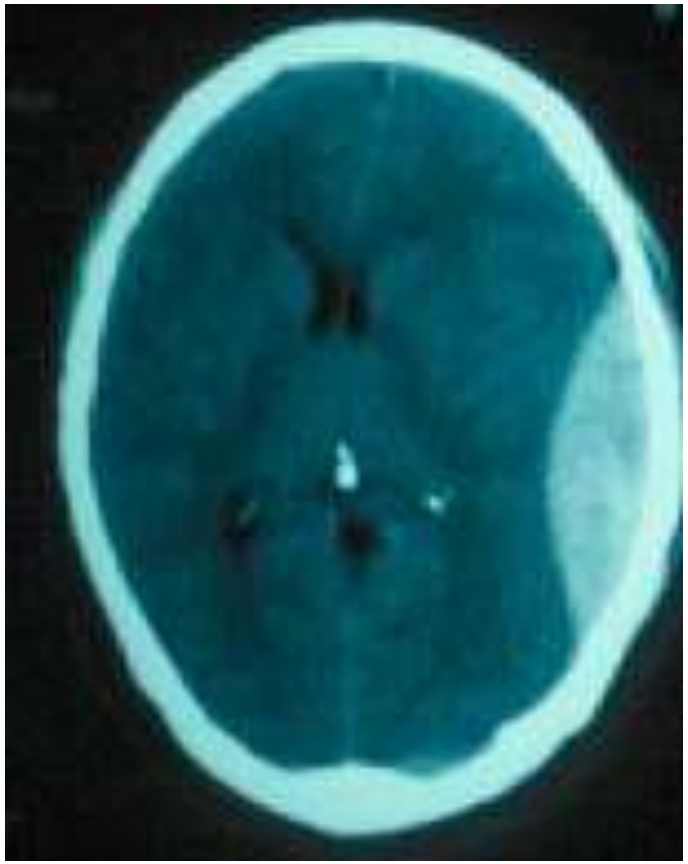
- Located between skull and dura mater
- Usually involves arterial bleeding- middle meningeal artery
- Sharply defined edges on CT
- Usually no underlying brain injury
- Classical presentation is “lucid interval”
- May quickly evolve into herniation of the brain toward foramen magnum
- Epidural haematoma develop over 4 - 6 hrs

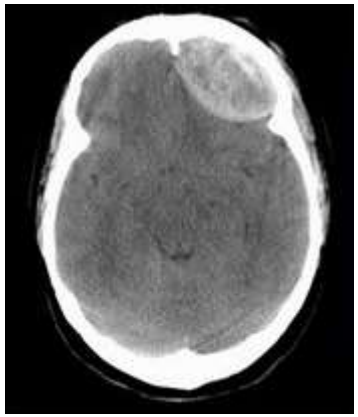


Lucid Interval

transient LOC followed by a lucid period where patient is neurologically intact followed by a secondary onset of HA and decreasing LOC, headache with progressive hemiparesis contralateral to the side of the lesion and a dilated pupil ipsilateral to the lesion.

CT scan of an acute left-sided epidural hematoma. Note the typical convex or lens-shaped appearance. The hematoma takes this shape as the dura strips from the undersurface of the cranium, limited by the suture lines. A midline shift of the ventricular system exists.

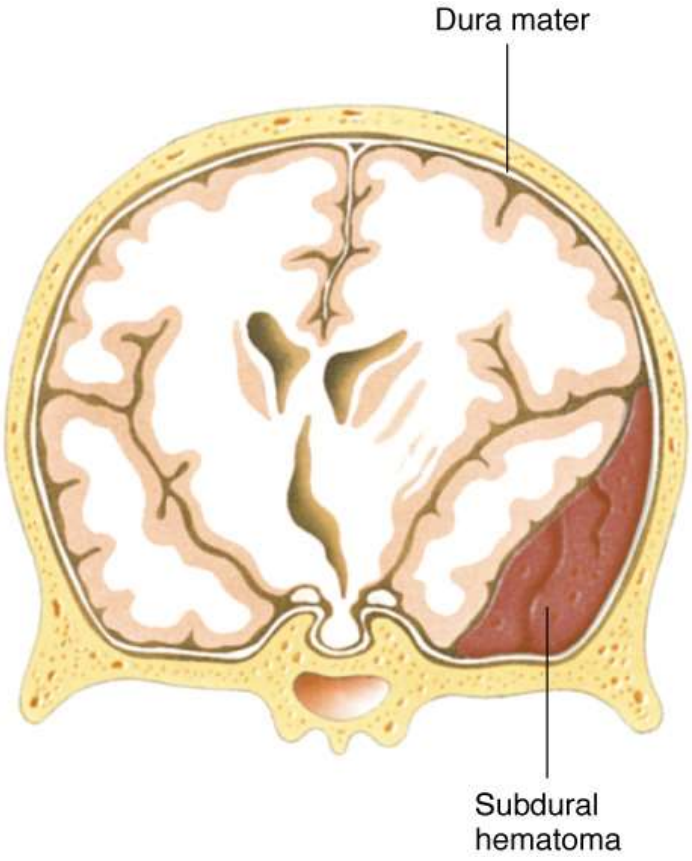




Subdural Hematoma

Subdural hematoma usually results from tears in veins bridging from the surface of the brain to the inner surface of the dura, where they connect with the sinuses.

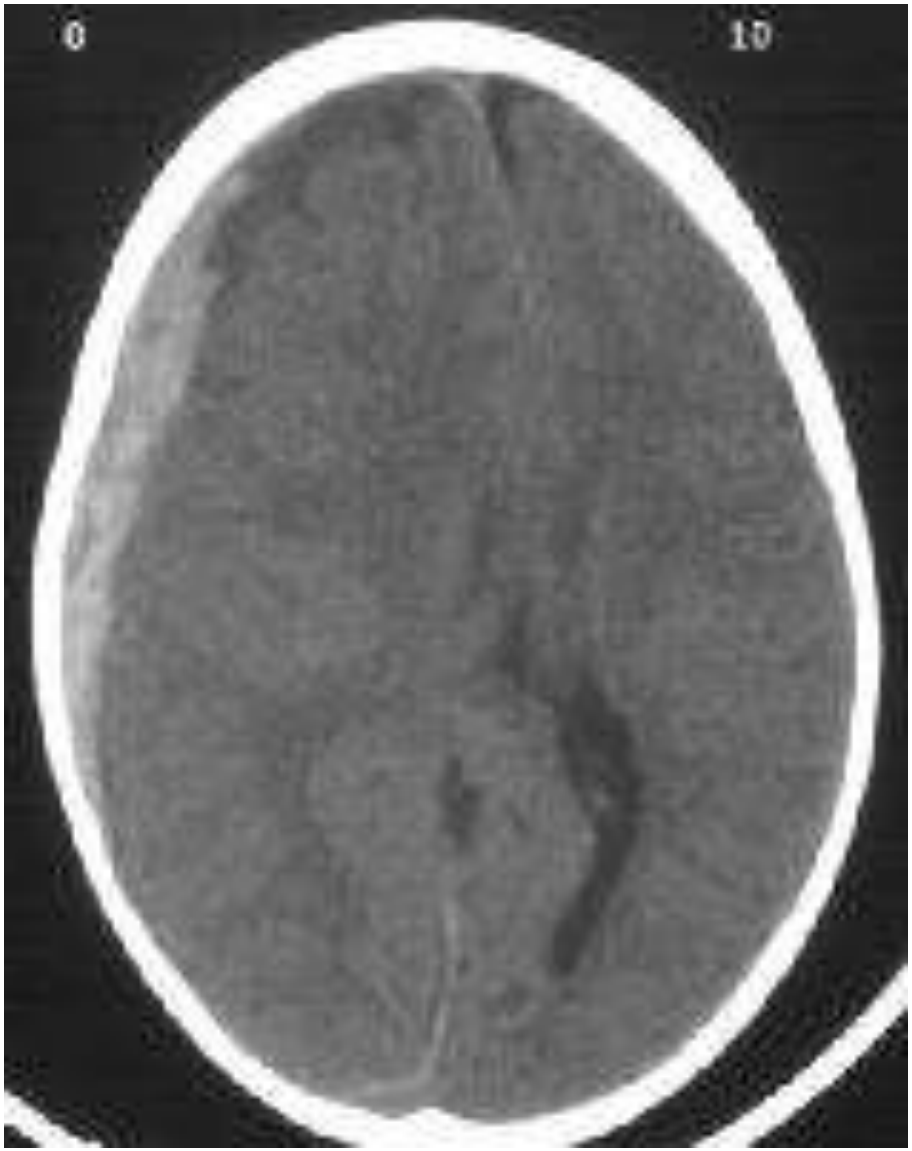
- Located between the dura mater and pia mater
- All venous bleeds, usually present with slow onset
- Indistinct on CT
- Underlying brain injury



Subdural hematoma

- Acute < 48 h
- Subacute 2 – 14 d
- Chronic > 3 w

Acute subdural hematoma: note the bright (white) image properties of the blood on this noncontrast cranial CT scan. Note also the midline shift.



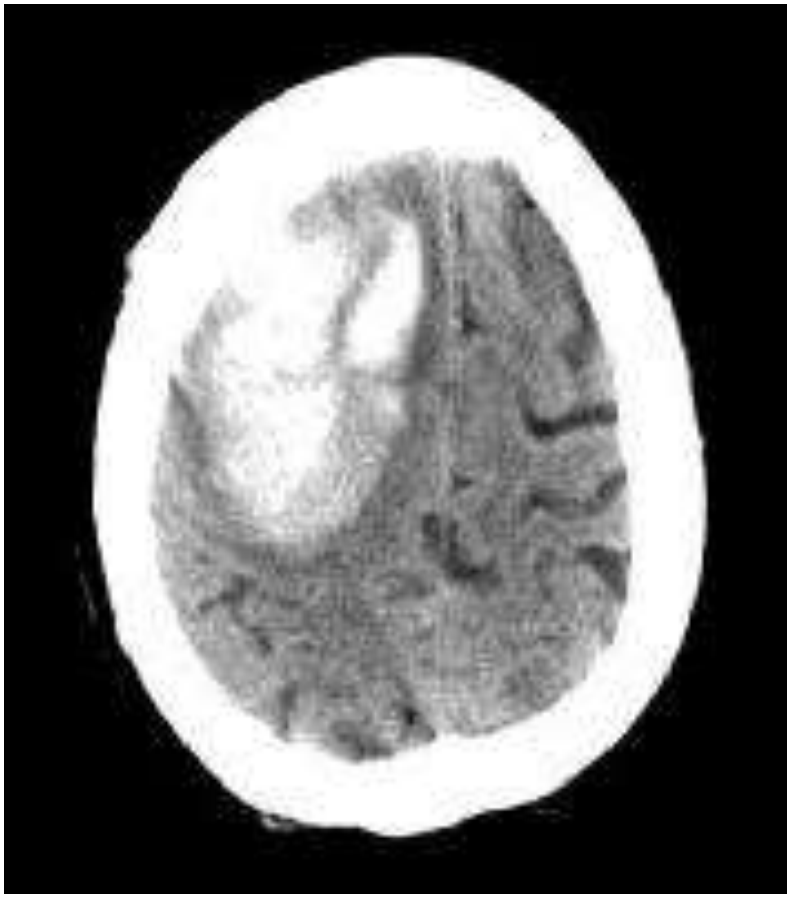
Subacute subdural hematoma: the crescent-shaped clot is less white than on CT scan of acute subdural hematoma

Intracerebral hematomas

are collections of blood within cerebral tissue, they are usually the result of a coalition of multiple petechial hemorrhages resulting from cerebral contusion or rupture blood vessel within the brain.

- Presentation similar to stroke symptoms
- Signs and symptoms worsen over time
- Difficult to distinguish from contusion

Intracranial hemorrhage. CT scan of right frontal intracerebral hemorrhage complicating hrombolysis of an ischemic stroke.



Subarachnoid Hemorrhage

- May not present with physical findings
- HA
- Stiff neck
- Nuchal rigidity
- Blood in CSF

Brain CT scan shows subtle finding of blood at the area of the circle of Willis consistent with acute subarachnoid hemorrhage.

Intraventricular hemorrhage:

Large hemorrhages could lead to obstructive hydrocephalus, especially when they are located at the level of the foramen of Monroe and the aqueduct of Sylvius, in which case surgical intervention is required.

Diffuse Brain Injury

- Due to stretching forces placed on axons
- Pathology distributed throughout brain
- Types
  - Concussion
  - Diffuse Axonal Injury

Concussion

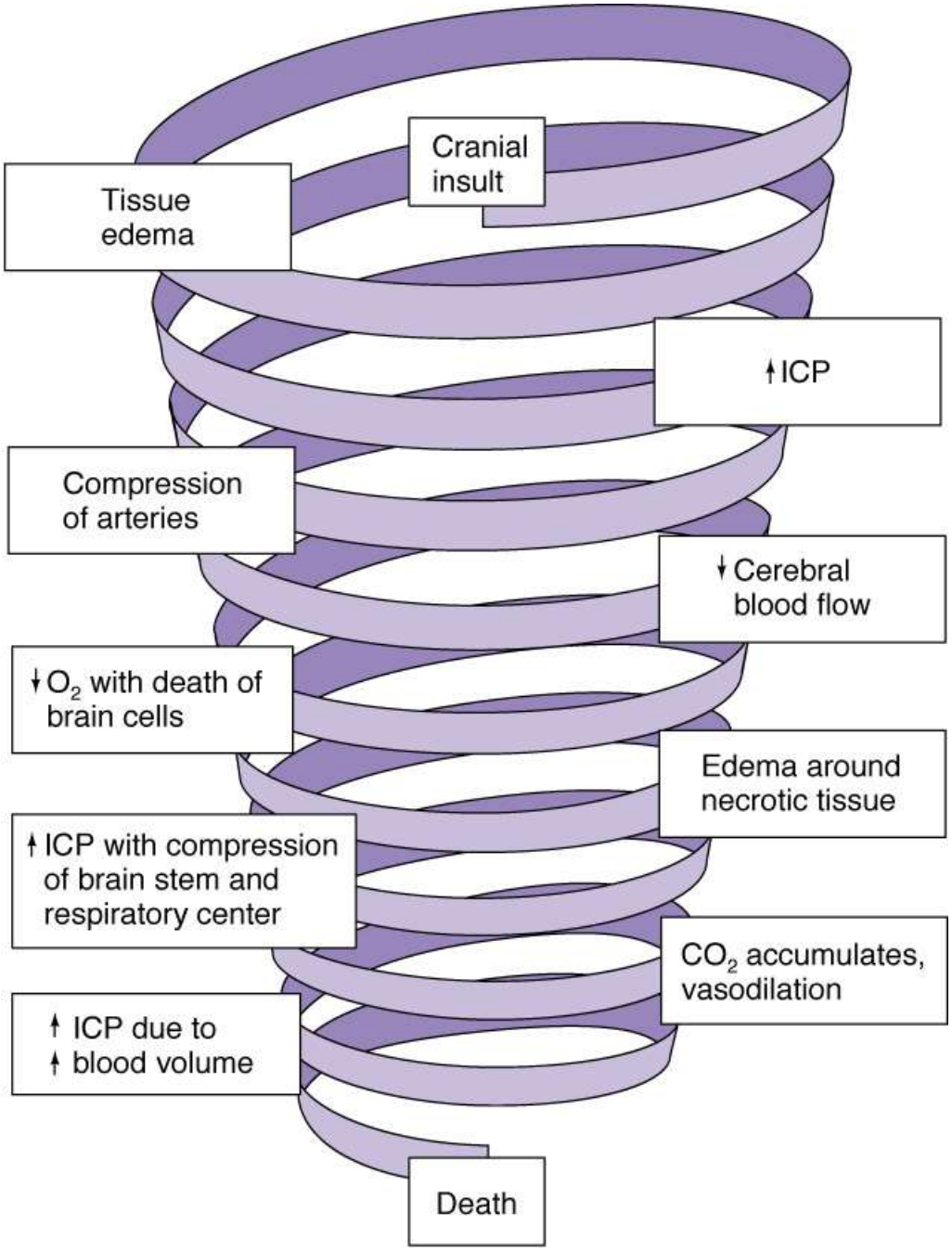
- Transient LOC < 30 min
- Nerve dysfunction without anatomic damage

- Usually complete recovery
- Mild form of diffuse injury
- Often presents with a brief period of confusion
- Patients often have normal findings on neurologic examination
- The diagnosis is usually a retrospective one
- Patients may exhibit retrograde or posttraumatic amnesia

Severe Diffuse Axonal Injury

- Significant mechanical disruption of axons (small petechial hemorrhages may be present)
  - the basal ganglia
  - thalamus
  - deep hemispheric nuclei
  - brainstem and corpus callosum - High mortality rate

- Signs & Symptoms
  - Prolonged unconsciousness
  - Cushing’s reflex
  - Decorticate or Decerebrate posturing


Cranial insult
Tissue edema
↑ ICP
Compression of arteries
↓ Cerebral blood flow
↓ O_2 with death of brain cells
Edema around necrotic tissue
↑ ICP with compression of brain stem and respiratory center
CO_2 accumulates, vasodilation
↑ ICP due to ↑ blood volume
Death

Pathway of Deterioration

- Cranial insult
- Tissue edema
- Increasing ICP
- Compression of arteries
- Decreased cerebral blood flow
- Decreased O2 with cellular death
- Edema around necrotic tissue

Pressure & Structural Displacement

- Increased pressure
  - Compresses brain tissue
    - Against & around
      - *Falx Cerebri*
      - *Tentorium Cerebelli*
  - Herniates brainstem
    - Compromises blood supply
    - Signs & Symptoms
      - Upper Brainstem
        - » Vomiting
        - » Altered mental status
        - » Pupillary dilation
      - Medulla Oblongata
        - » Respiratory
        - » Cardiovascular
        - » Blood Pressure disturbances

Herniation

- Depression of 3rd cranial nerve results in homolateral pupillary dilation- anisocoria
- Controlateral paresis
- Cushing’s triad
- Decorticate posturing
- Decerebrate posturing

Decorticate Posturing

- Results from lesions of internal capsules, basal ganglia, thalamus or cerebral hemisphere
- Interrupts corticospinal pathways
- Presents with flexed arms and extended lower extremities

Decerebrate Posturing

- Results from injury to midbrain and pons
- Indicative of brainstem dysfunction
- Presents with extended upper extremities and pronation
- Extended lower extremities
- Usually indicative of graver injury

Cushing's Reflex

- Late sign of increasing ICP

- Bradycardia
- Widening pulse pressure / increasing BP
- Changes in respiratory patterns

Secondary Brain Injury

- Hypoxia
- Hypotension
- Anemia
- Hyperglycemia
- Hypoglycemia
- Hyperthermia
- Intracranial mass
- Infection

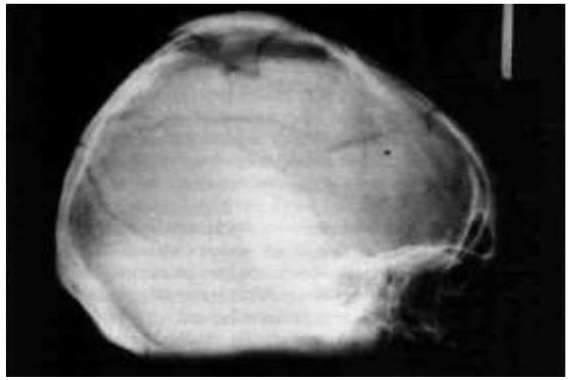
Investigations

- Skull X-rays
- CT scan
- MRI
- Lumbar puncture

Skull radiography

is not routinely indicated except in the following situations:

- Patients younger than 1 year
- Loss of consciousness for 3 minutes or longer
- Skull penetration
- Preexistent shunt
- Scalp hematoma and/or depression
- Otorrhea and/or rhinorrhea
- Hemotympanum
- Battle sign
- Raccoon eyes
- Altered mental status
- Focal neurologic examination

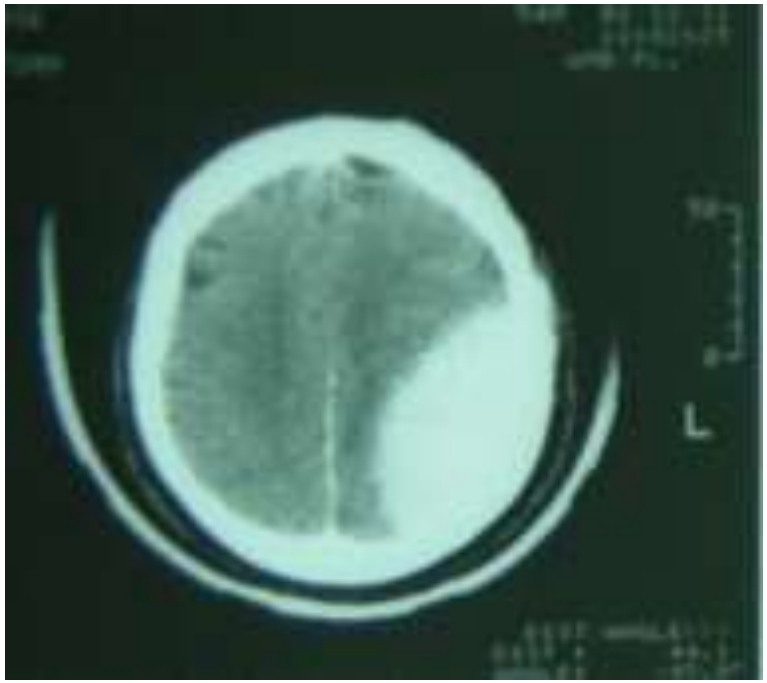


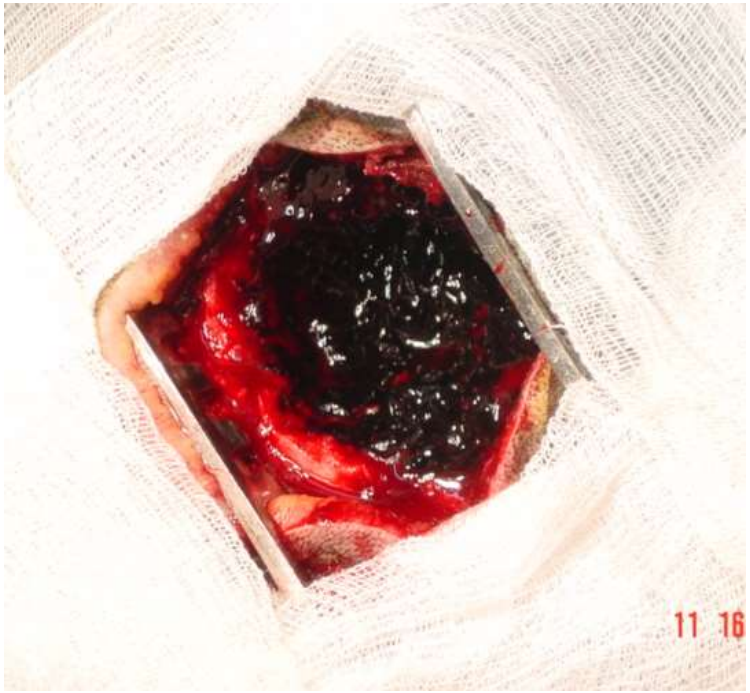
CT scanning

most useful imaging study for patients with severe head trauma

- the integrity of soft tissue and bone
- the size of the fontanel and suture lines
- the presence of foreign bodies
- the presence of hemorrhage
- and signs of edema
- Infarction
- contusion
- mass effect as indicated by midline shift
- compression of the ventricles
- hydrocephalus from intraventricular hemorrhage or blockage by mass effect.
- the presence of cerebral edema

CT scanning





Magnetic resonance imaging

MRI is not practical in emergency situations because the magnetic field precludes the use of monitors and life-support equipment needed by unstable patients.

Management of acute head injury

1. Diagnosis
2. Pre-operative management
3. Operative management

Medical Care

The goal of medical care of patients with head trauma is to recognize and treat life-threatening conditions and to eliminate or minimize the role of secondary injury. Patients with severe head trauma are at increased risk of developing cerebral edema, respiratory failure, and herniation secondary to the increased ICP.

The biggest challenge in TBI management

Prevention of secondary brain damage

Management

- secure and protect airway if necessary
- 50% oxygen
- ensure normoglycaemia
- ensure normocapnia - KIV intubate and ventilate (avoid hyperventilation)
- fluid control but maintain blood pressure
- diuretics - mannitol 1g/kg
- steroids - no role
- Seizures - iv diazepam, phenytoin(20mg/kg)
- analgesia - iv ketoralac, haloperidol
- suture of scalp wounds to prevent blood loss, infection in open skull fractures
- definitive neurosurgical management within 2 hours

Surgical Care

- Surgical decompression is required in the presence of rapidly expanding epidural or subdural hematoma causing increase in ICP and focal compression.
- Depressed skull fractures require surgical elevation if the depth of the depression is thicker than the calvarium.

Complications

- Seizures are more commonly observed with contusions (subdural hematoma more so than epidural hematoma), depressed skull fracture, and severe head injury (PGCS of 3-5).
- Leptomeningeal cyst or growing fracture represents extrusion of leptomeninges and brain tissue through a dural defect.
- Meningitis could develop secondary to basilar skull fracture.
- Cranial nerve injury may develop secondary to basilar skull fracture. Oculomotor palsy is due to injury of cranial nerves VI, III, or IV. Trauma to nerve VII leads to facial nerve palsy. Hearing loss may occur because of injury of cranial nerve VIII.
- Posttraumatic syndrome may develop following mild-to-moderate head trauma and consists of irritability, inability to concentrate, nervousness, and occasionally behavioral or cognitive impairment.

Complications

- Cortical blindness, described as an acute loss of vision following head trauma, usually resolves spontaneously within 24 hours. Several mechanisms have been implicated, including acute cerebral edema and transient vasospasm. Cortical blindness is now considered to result from minor transient alterations in the brain function triggered by the traumatic event.
- Trauma-induced migraine may begin from minutes to hours following the injury and may last from hours to days. Beta-blockers are the drugs of choice for this complication.
- Hydrocephalus results from either an obstruction caused by an intraventricular hemorrhage or decreased reabsorption of CSF due to proteinaceous obstruction of the arachnoid villi.
- Neurogenic pulmonary edema is thought to be due to medullary ischemia that leads to increased sympathetic tone with subsequent increase in pulmonary vascular pressure and a shift in blood distribution from the systemic to pulmonary bed.
- Pulmonary infections are often present in patients with head trauma because of either an initial aspiration process or prolonged mechanical ventilation.