Acute disorders of consciousness. Brain death.

Consciousness is defined as being awake and aware of both one's self and one's surroundings, OR it is the human awareness of both internal and external stimuli.

Altered level of consciousness

Lethargy: is a mild depression in level of consciousness, person can be aroused with little difficulty.

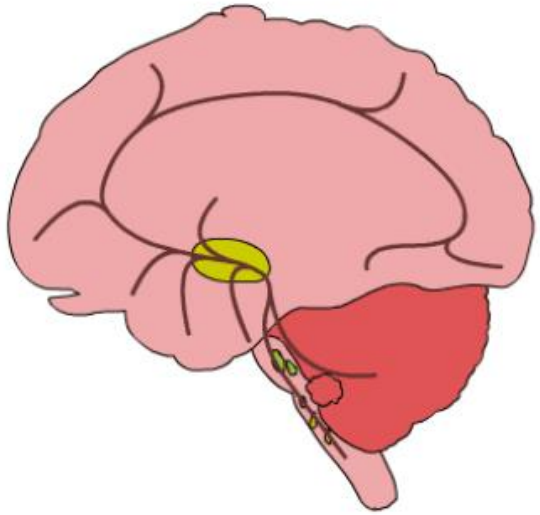
Stupor: Patient can not be aroused from a sleep like state (only responds by grimacing or drawing away from painful stimuli).

Coma: More depressed level of consciousness, patient is unable to make any purposeful response.

Pathophysiology

Reticular formation is known to play a role in alertness, wakefulness and arousal.

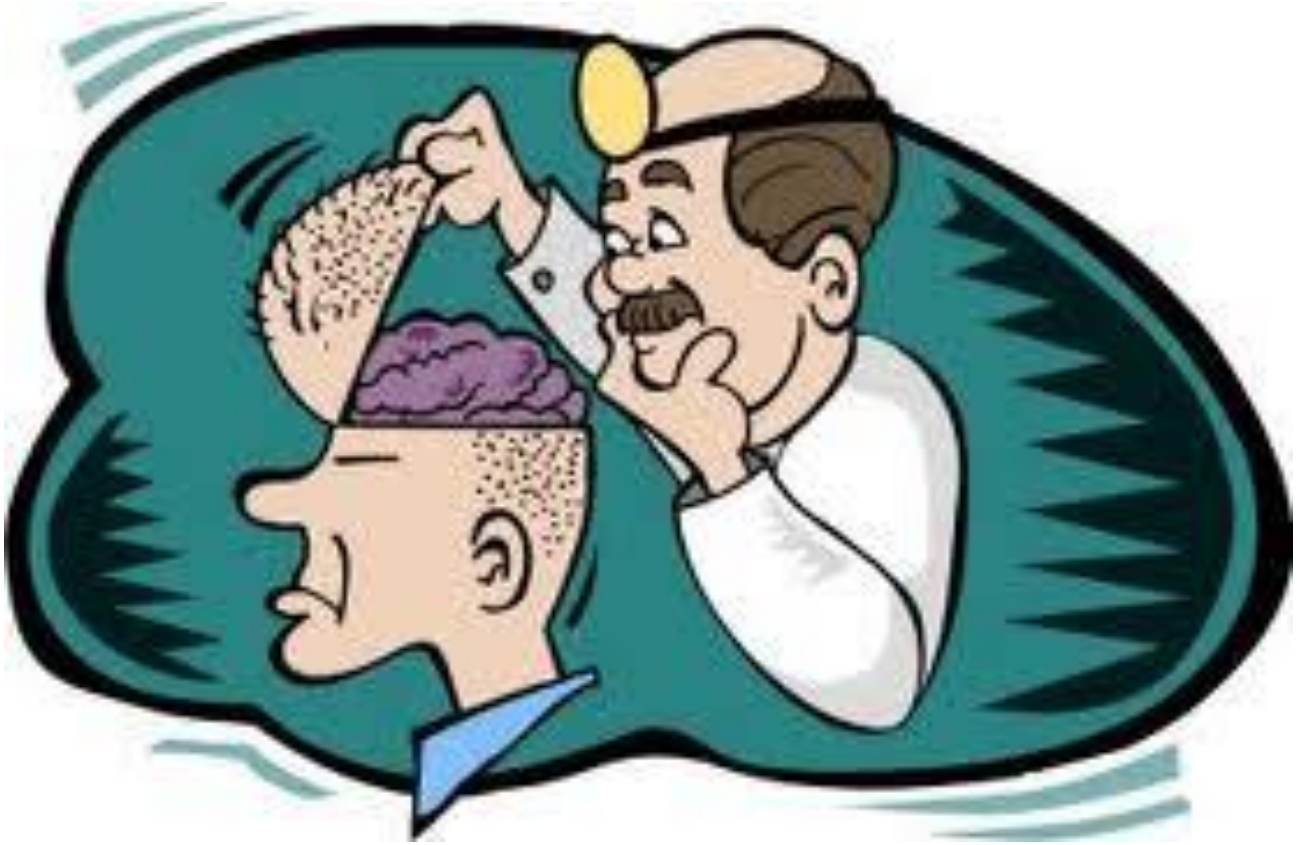
Maintaining alertness requires intact function of the cerebral hemispheres and preservation of arousal mechanisms in the reticular activating system.



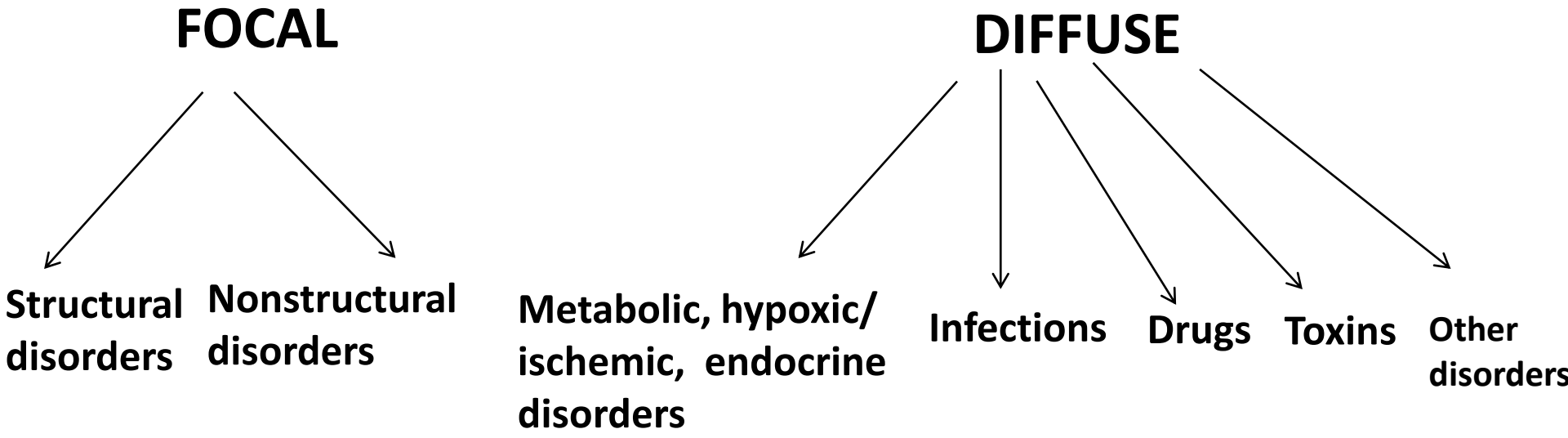
Causes of acute disorders of consciousness

1. Diffuse bilateral hemisphere damage
2. Failure of the ascending reticular activating system
3. Both

Causes



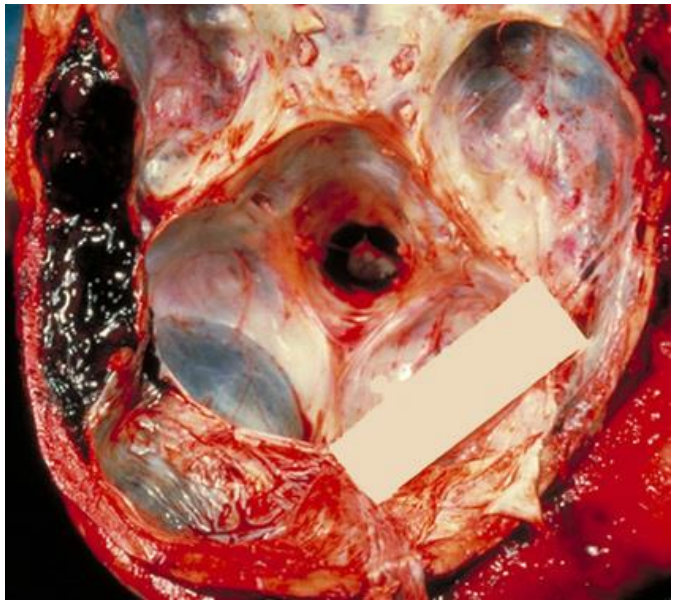
Causes of acute disorders of consciousness

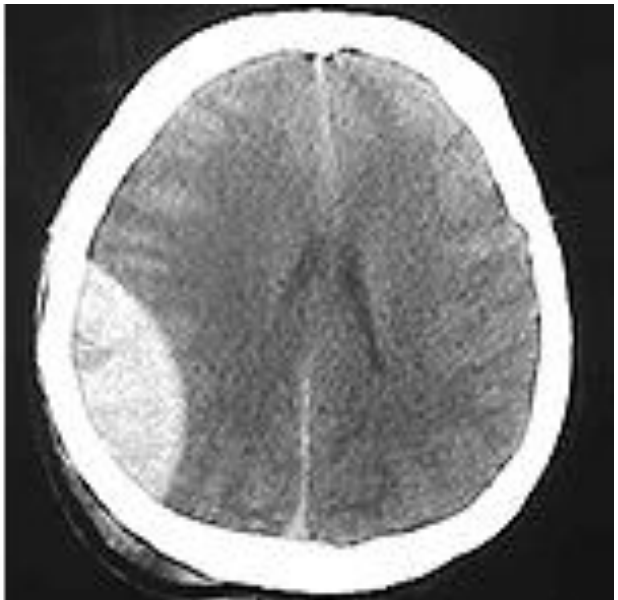


FOCAL: Structural disorders

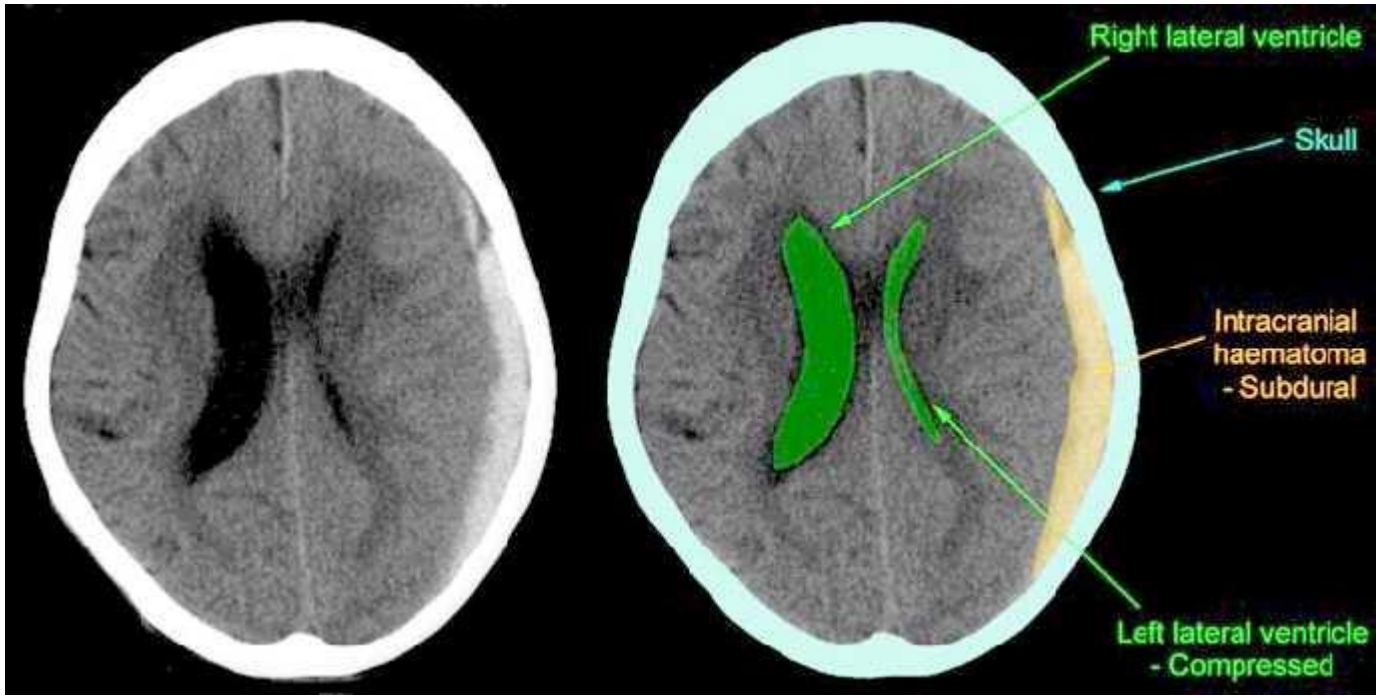
Epidural hematomas

- Lens shaped
- Caused by arterial rupture
- Skull fracture present in 85% of cases





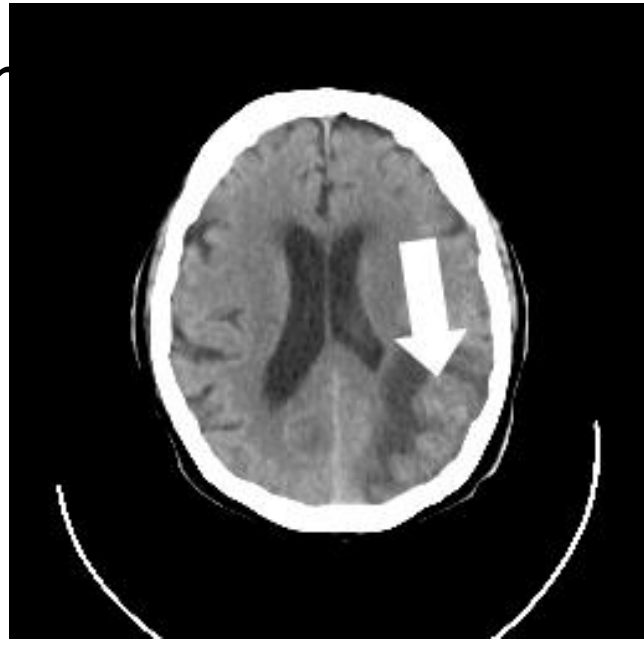
FOCAL: Structural disorders
Subdural hematomas



Crescent shaped
Caused by tearing of bridging veins through dura and arachnoid

FOCAL: Structural disorders
Intracerebral hematomas

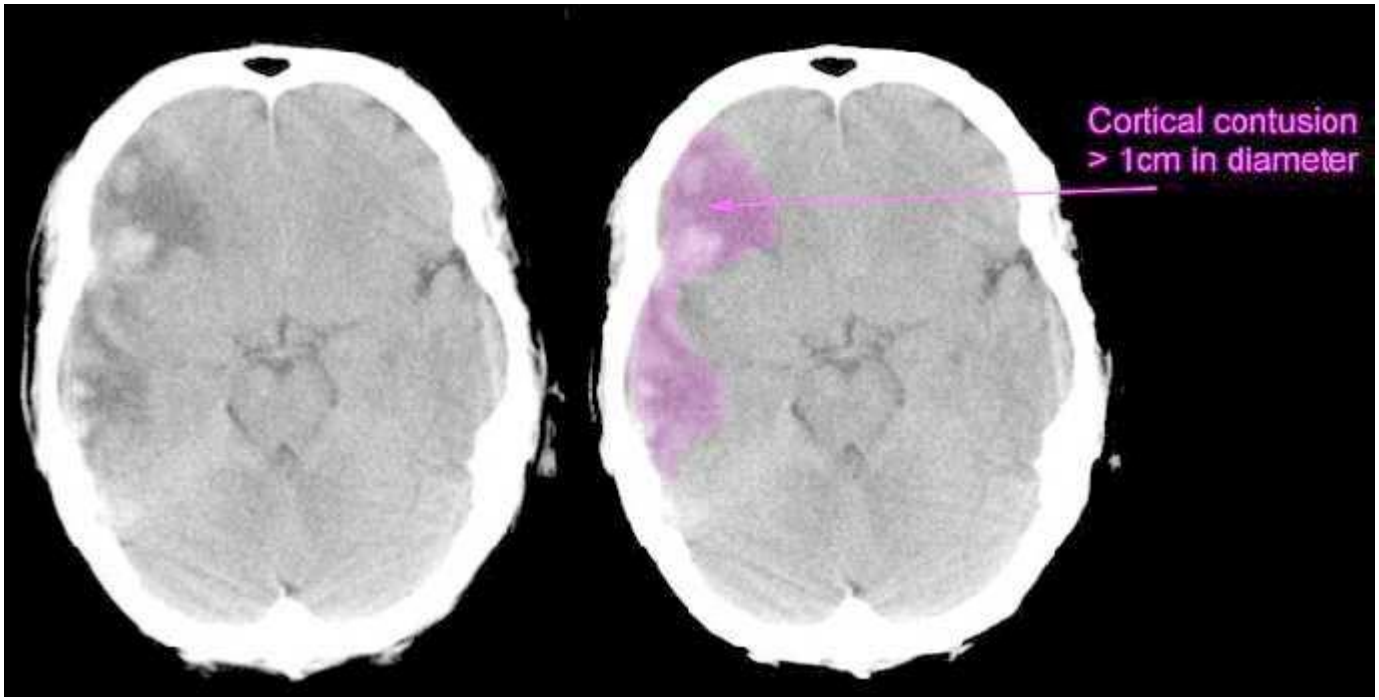
- is usually due to aneurysm
  - Severe headache
- Arteriovenous malformation or cavernous hemangioma
  - Low flow and less acute symptom



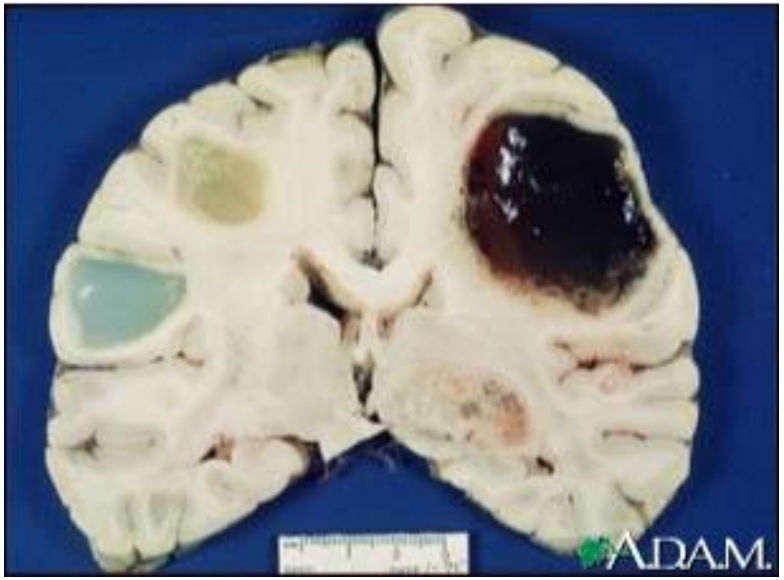
FOCAL: Structural disorders

Cerebral Contusion

Can lead to increased ICP



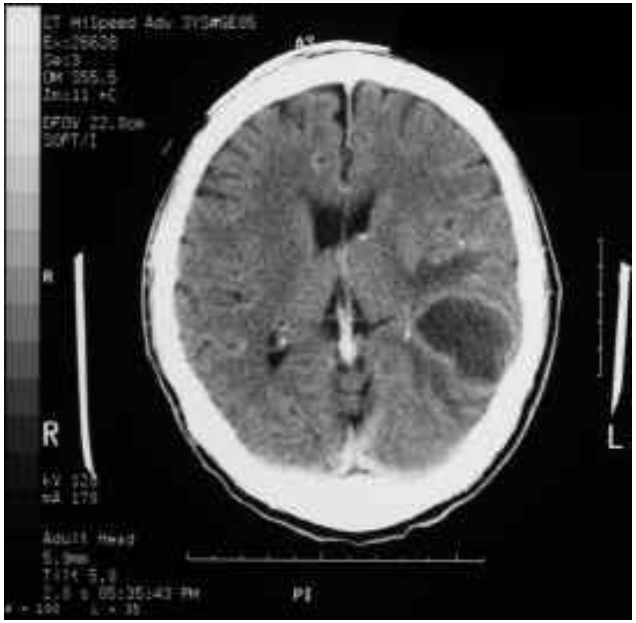
FOCAL: Structural disorders
Brain tumor



FOCAL: Structural disorders
Brain Abscess

Risc factors:

a) chronic sinusitis
b) chronic otitis
c) dental infection
d) endocarditis

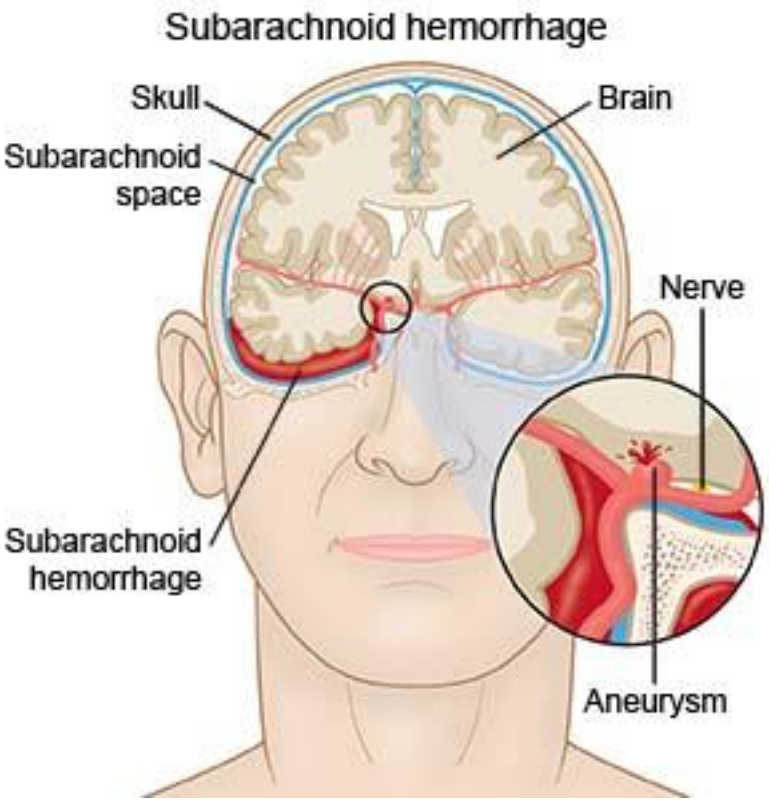


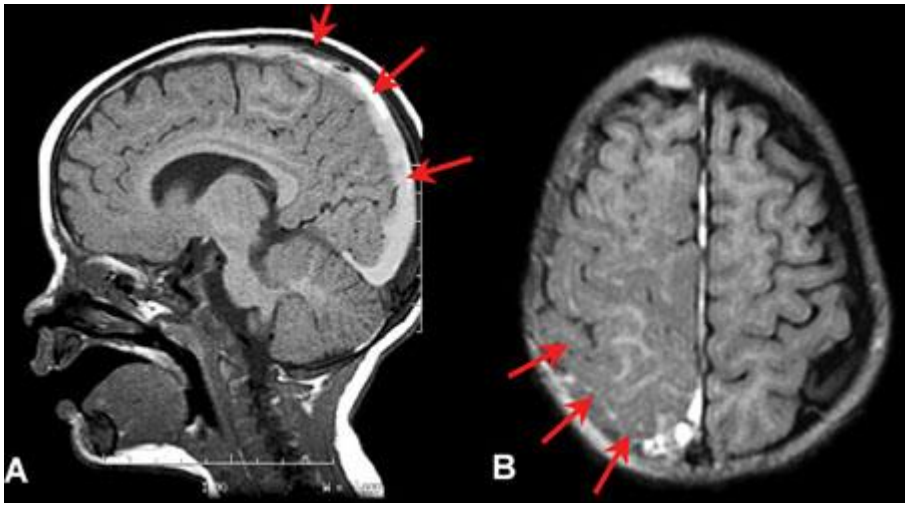
FOCAL: Structural disorders Vascular Occlusion

Atrial fibrillation or valvular heart disease

- atherosclerotic disease in the extracranial cervical carotid or vertebral artery
  - Occlusion of anterior, middle or posterior cerebral artery will NOT cause coma
  - Infarcts eventually lead to increased ICP
  - Basilar Artery infarcts cause rapid coma due to brainstem damage

FOCAL: Structural disorders
Subarachnoid hemorrhage





Focal: Nonstructural disorders

- seizures (eg, nonconvulsive status epilepticus)
- a postictal state caused by an epileptogenic focus

DIFFUSE:
Metabolic and endocrine disorders

- Hyperglycaemia (Diabetic ketoacidosis)
- Hypoglycemia
- Hypoxia
- Hypercapnia
- Hyper- , Hyponatremia
- Hypercalcemia
- Hypothyroidism
- Hepatic encephalopathy
- Uremia
- Thiamine Deficiency

FIFFUSE: INFECTIONS
Encephalitis

- Encephalitis – inflammation of the brain parenchyma usually due to viral infection
  - Herpes simplex viruses – most common devastating cause
    - Death or permanent neurologic damage in 70% of cases
    - Affects temporal lobes causing seizures, parenchymal swelling and uncal herniation

DIFFUSE: INFECTIONS
Meningitis

- Bacterial
  - Most common infection severe enough to cause profound ALOC
- Non-bacterial
  - Slower onset of symptoms

DIFFUSE: INFECTIONS

TOXINS

- Carbon monoxide

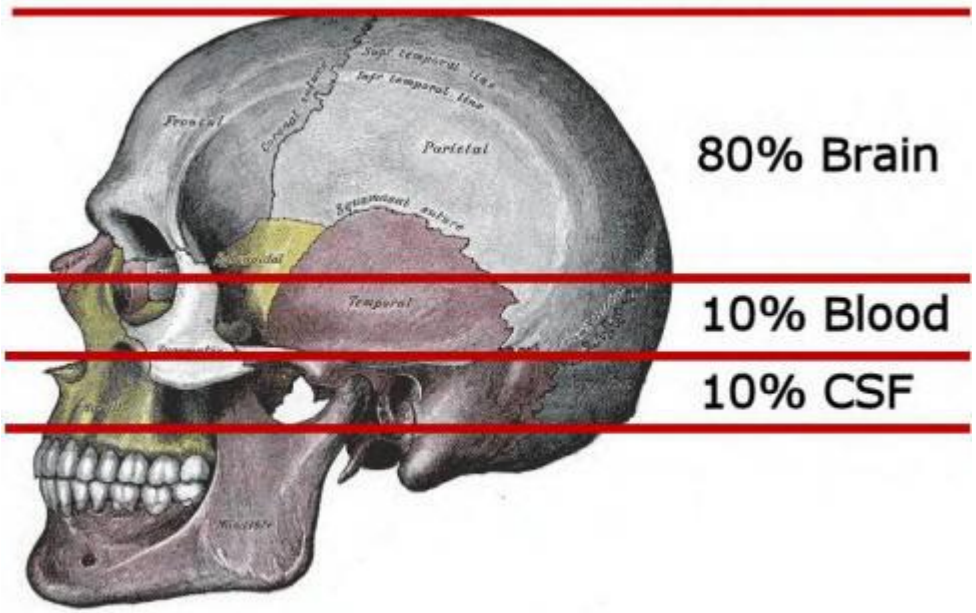
DRUGS

- Alcohol
- Opioids
- Sedatives
- Dissociative Agents

OTHER DISORDERS

- Diffuse axonal injury
- Hypertensive encephalopathy
- Hyperthermia or hypothermia

Key concepts of neurointensive care

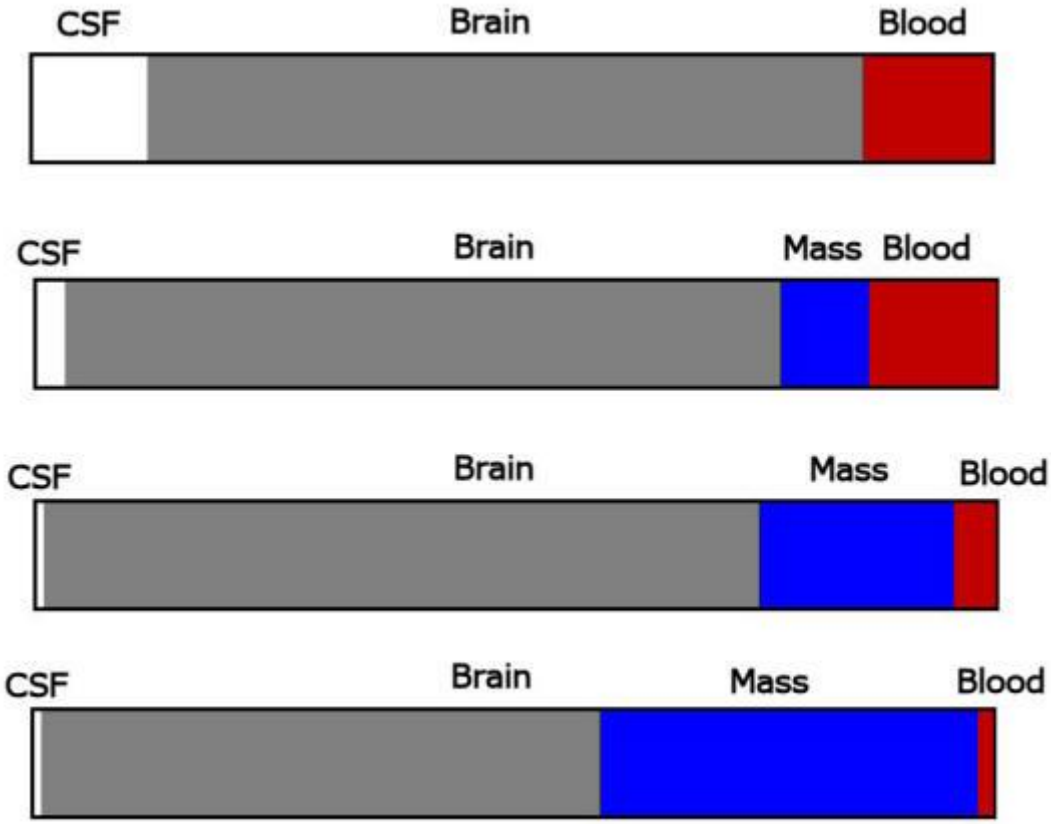


- Brain parenchyma—1200-1600 ml
- Cerebrospinal fluid—100-150 ml
- Blood— 100-150 ml

- ESF <75 ml

Monro-Kellie doctrine:

- sum of volumes of brain, CSF, and intracranial blood is constant.
- Because the overall volume of the cranial vault cannot change, an increase in the volume of one component (brain, blood, or cerebrospinal fluid) will elevate pressure and decrease the volume of one of the other elements.


CSF
Brain
Blood
CSF
Brain
Mass
Blood
CSF
Brain
Mass
Blood
CSF
Brain
Mass
Blood

Rapid changes in volume need to be evacuated in order to keep ICP down since:

Cerebral perfusion pressure=MAP-ICP

MAP= (SP + 2 DP)/3

MAP normal range (70-100 mm Hg)

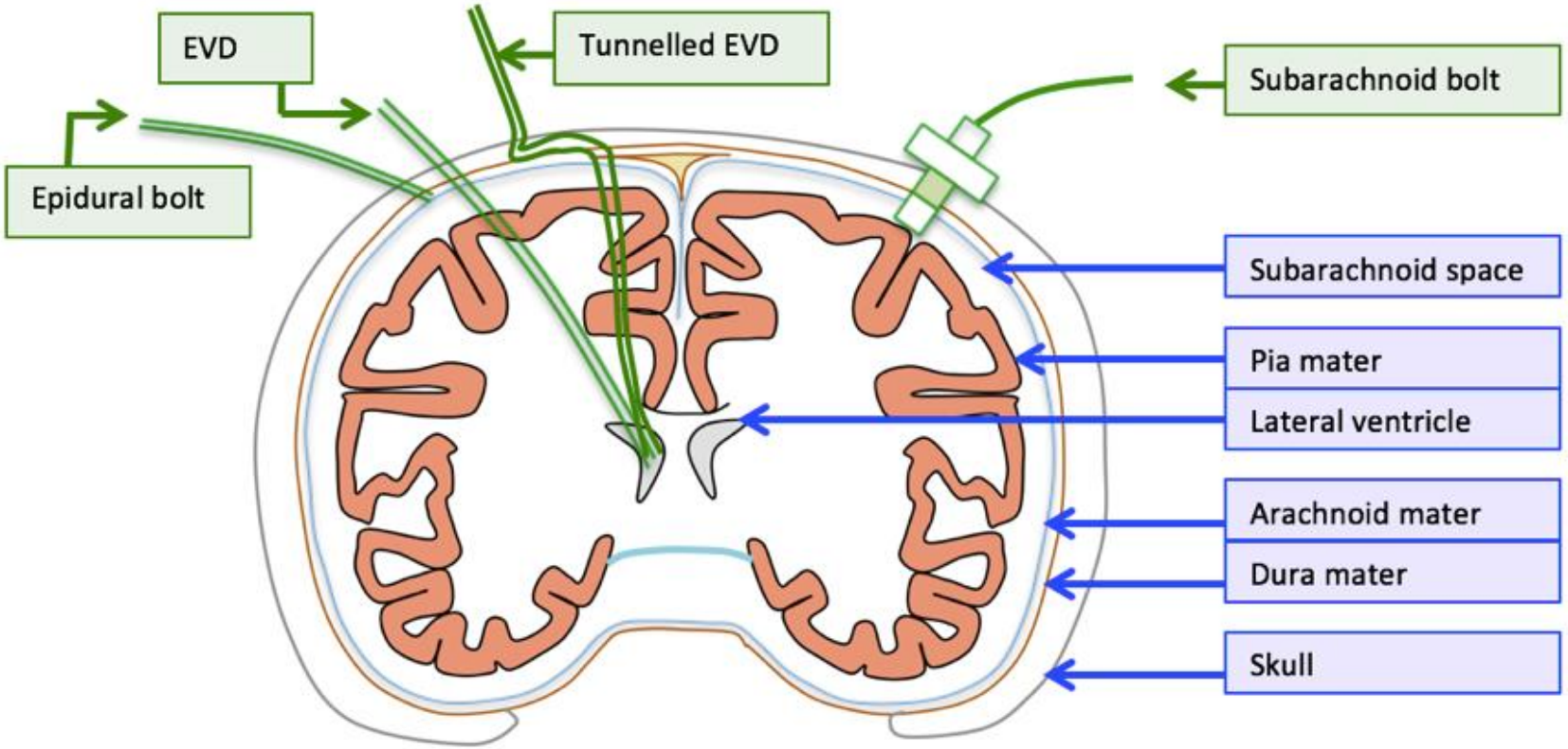
- A MAP ≥ 60 mmHg is believed to be needed to maintain adequate tissue perfusion.
- A MAP ≥ 65 mmHg is recommended in patients with severe sepsis and septic shock by the **Surviving Sepsis Campaign Guidelines Committee**

ICP - 5-15 mm Hg

Current **Brain Trauma Foundation guidelines** recommend intervention for ICP >22 mmHg

Normal **CPP =60–80 mmHg**

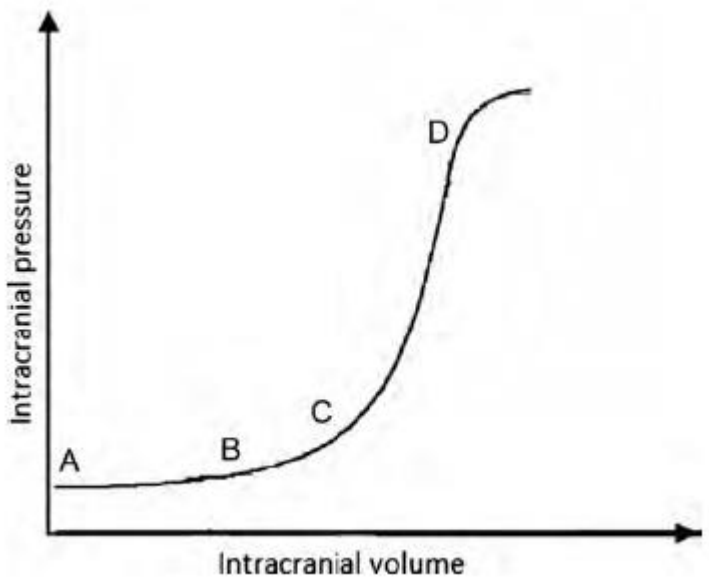
ICP monitoring



Control of intracranial pressure

A and B - Compensation phase—ICP nearly constant with increase in intracranial volume initially.

C and D Decompensation phase—ICP increases rapidly with increasing intracranial volume as the buffers are exhausted.



Intracranial compliance curve.

Control of cerebral blood flow

- Autoregulation
- $PaCO_2$
- PaO_2

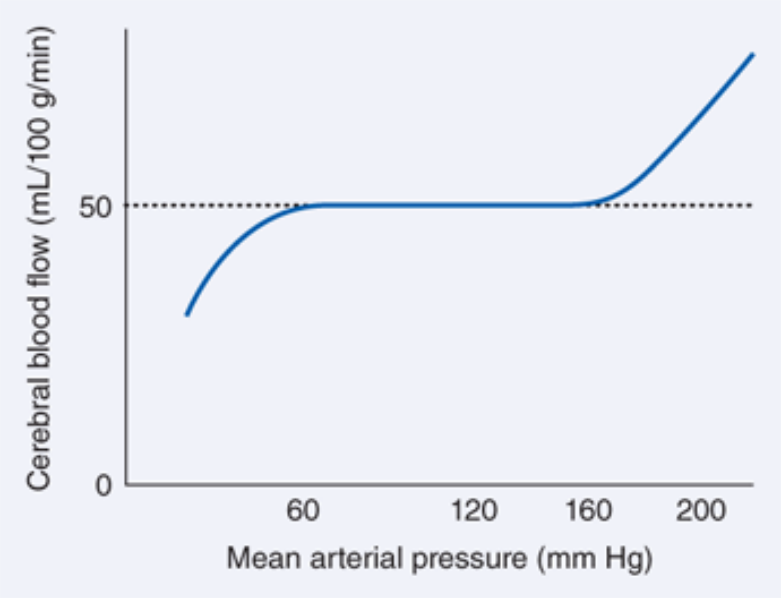
Control of CBF: autoregulation

The process of cerebral autoregulation maintains CBF between a CPP range of approximately 60 - 160 mmHg.

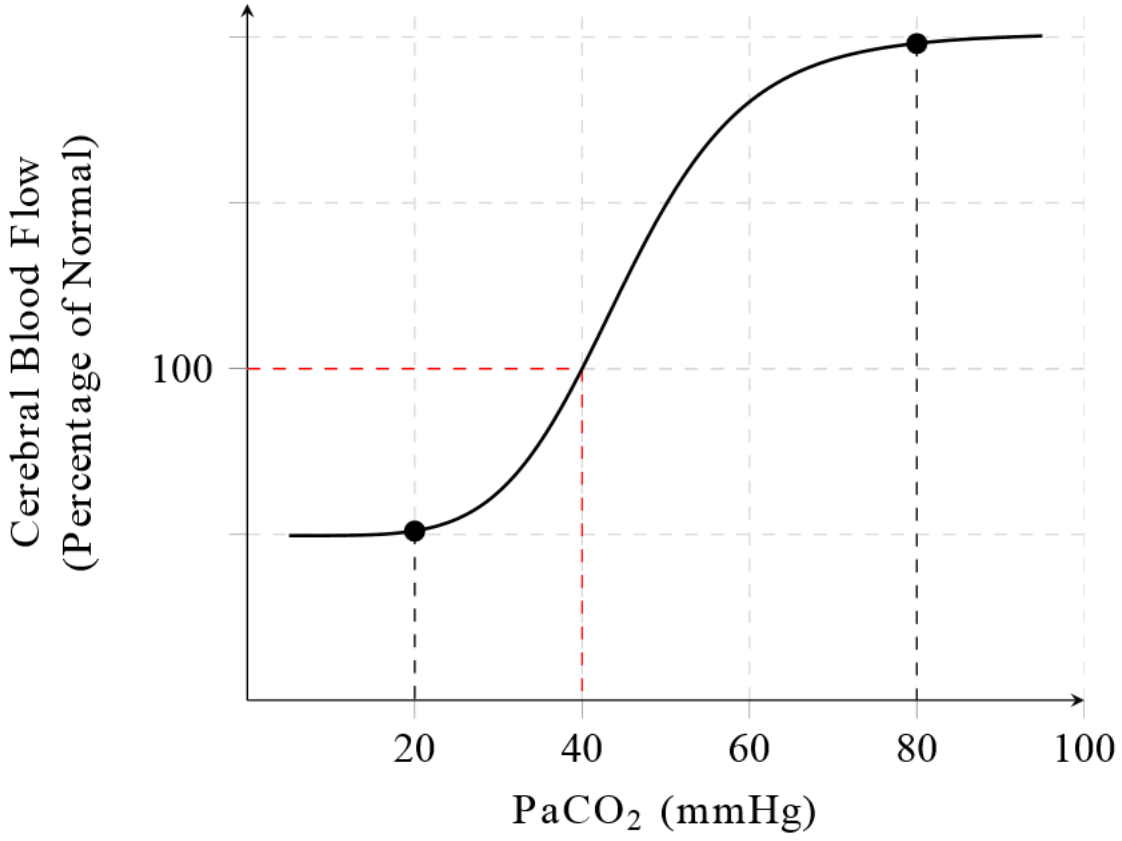
Outside these limits CBF becomes pressure-dependent.

High MAPs could greatly increase CBF and lead to cerebral edema or hemorrhage.

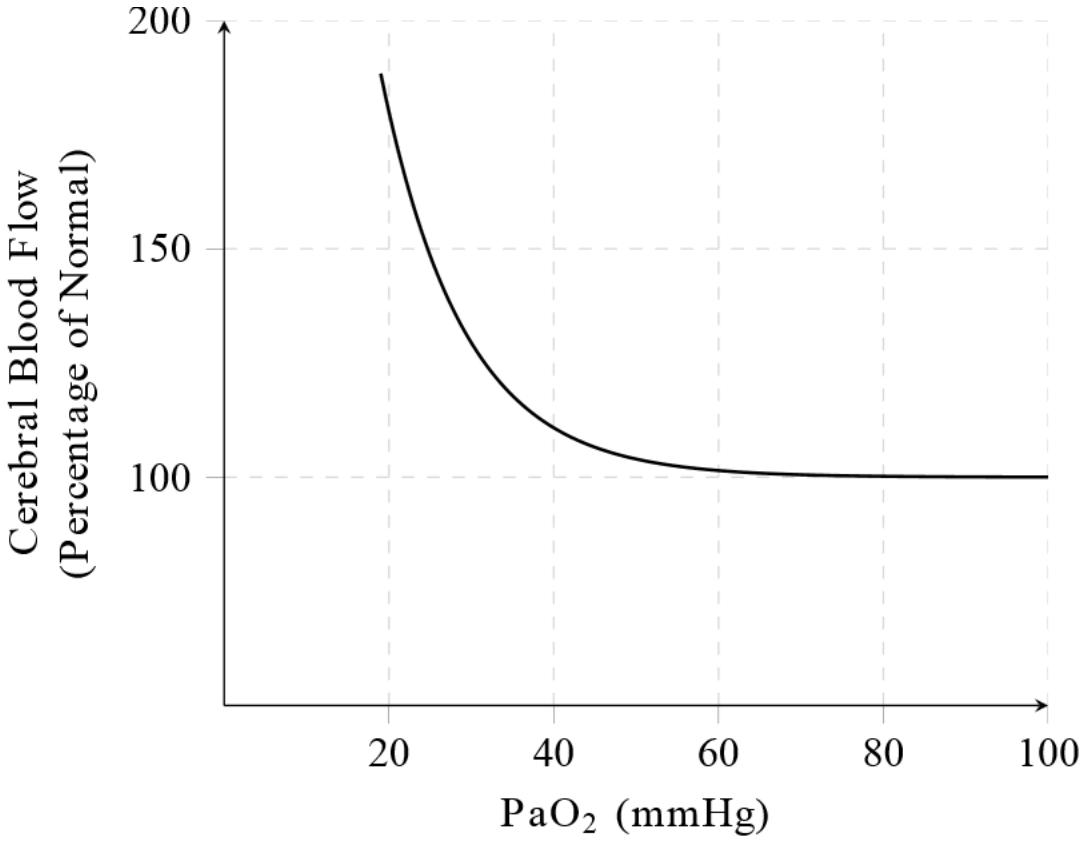
Low MAPs may greatly decrease CBF and lead to injury from hypoxia/anoxia.



Control of CBF: carbon dioxide tension



Control of CBF: arterial *o*xygen tension



Cerebral edema

is defined as an increase in brain water content.

1.vasogenic edema

2. cytotoxic edema - cellular injury

Vasogenic edema

- Vasogenic edema results when increased permeability of capillary endothelial cells permits fluid to escape into the extracellular space
- Neurons are not primarily injured
- Vasogenic edema is seen with tumors, intracranial hematomas, infarcts, abscesses, and central nervous system infections
- Therapy to decrease the edema may prevent secondary ischemic injury to surrounding brain tissue since neurons are not primarily injured
  - Steroid therapy may be beneficial for vasogenic edema that occurs in the setting of mass lesions

Cytotoxic edema

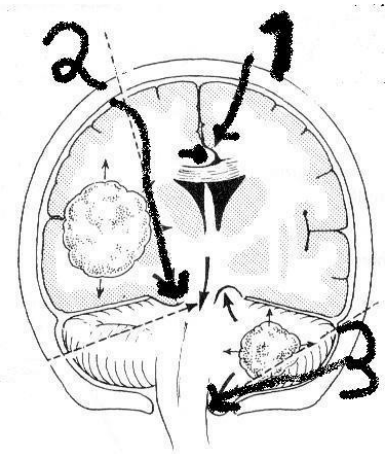
- Cytotoxic edema is caused by intracellular swelling secondary to direct cell injury
- can result from almost any insult to the brain, including trauma, hypoxia, toxic or metabolic perturbation.
- is the result of cells being unable to maintain ATP-dependent sodium/potassium (Na+/K+) membrane pumps which are responsible for high extracellular and low intracellular Na+ concentration .
- When energy fails, as is the case in cerebral ischemia, these pumps cease to operate and Na+ accumulates within the cell, drawing with it chloride (Cl-) and water along an osmotic gradient.

Brain edema

Brain edema causes impaired nerve function, may increase ICP, and eventually may lead herniation.

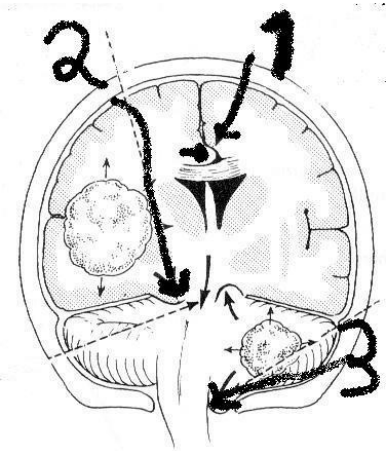
Herniation Syndromes

- Herniation of brain tissue can cause injury by compression or traction on neural and vascular structures
- Herniation results when there is a pressure differential between the intracranial compartments, and can occur in three areas of the cranial cavity
  - Transtentorial (2)
  - Subfalcian (1)
  - Foramen magnum (3)



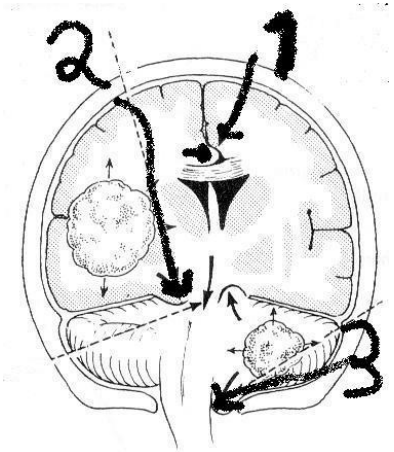
Herniation Syndromes: Transtentorial (2)

- Most common type
- Results from downward displacement of supratentorial brain tissue into the infratentorial compartment, and can be caused by supratentorial mass lesions, diffuse brain swelling, focal edema, or acute hydrocephalus.
- Can cause compression of the third cranial nerve, the upper brainstem, and the cerebral peduncles, as well as distortion or traction of the superior portion of the basilar artery.



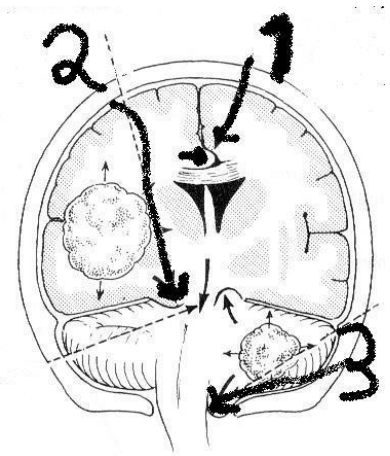
Herniation Syndromes: Subfalcian (1)

- Occurs when increased pressure in one hemisphere displaces brain tissue under the falx cerebri
- Can cause compression of the anterior cerebral artery and extensive infarction of the frontal and parietal lobes



Herniation Syndromes: Foramen Magnum (3)

- Occurs when downward pressure forces the cerebellar tonsils into the foramen magnum, where they compress the medulla oblongata and upper cervical spinal cord → impaired consciousness, decerebrate posturing, apnea, blood pressure instability, death.



Consequences of elevated ICP

Cushing's Triad

↑ **Intracranial pressure** → ↓ **perfusion** pressure within the brain → compensatory activation of the sympathetic nervous system to maintain cerebral perfusion → **↑ systolic blood pressure** → stimulation of aortic arch baroreceptors → activation of the **parasympathetic nervous system** (vagus) → **bradycardia**

- ↑ Pressure on brainstem → **dysfunction of respiratory center** → **Bradypnea (irregular).**

Examination of the comatose patient – a clinical approach

Acute depression in level of consciousness is a critical, lifethreatening emergency that requires a systematic approach for evaluation of etiology.

Initial stabilization

- securing the patients airway (with attention to the cervical spine)
- breathing
- circulation

Assessment of comatose patient

1. History—through friend, family or emergency medical personnel
2. General physical examination
3. Neurological assessment—to define the nature of coma

HISTORICAL FEATURES

Acute Onset of coma may indicate a:

- cerebral vascular etiology (i.e., subarachnoid hemorrhage, intracerebral hemorrhage, or hemispheric or brain stem stroke)
- generalized epileptic activity
- traumatic brain injury
- drug overdose

A subacute deterioration may point to:

- systemic illness
- evolving intracranial mass
- a degenerative disorder
- paraneoplastic neurologic disorder.

General examination

1.Hypothermia: Environmental exposure, near-drowning, sedative overdose, Wernicke encephalopathy, or, in the elderly, sepsis

2.Hyperthermia: Heatstroke

3. Fever, petechial or purpuric rash, hypotension: Sepsis or CNS infection

4. Hypotension or pulse abnormalities: Cardiac dysfunction with hypoperfusion

5. Breath odor (alcohol, other drug intoxication, diabetic ketoacidosis, fetor hepaticus)

6. Needle marks: Drug overdose (eg, of opioids or insulin)

7. A bitten tongue: Seizure

Neurological examination

- determines whether the brain stem is intact and where the lesion is located within the CNS.

The examination focuses on the following:

- Level of consciousness
- respiratory pattern
- pupillary size and reactivity
- eye position and movements
- corneal reflexes
- motor function

Assessment of the depth of the coma

The GCS is based on 3 measures:

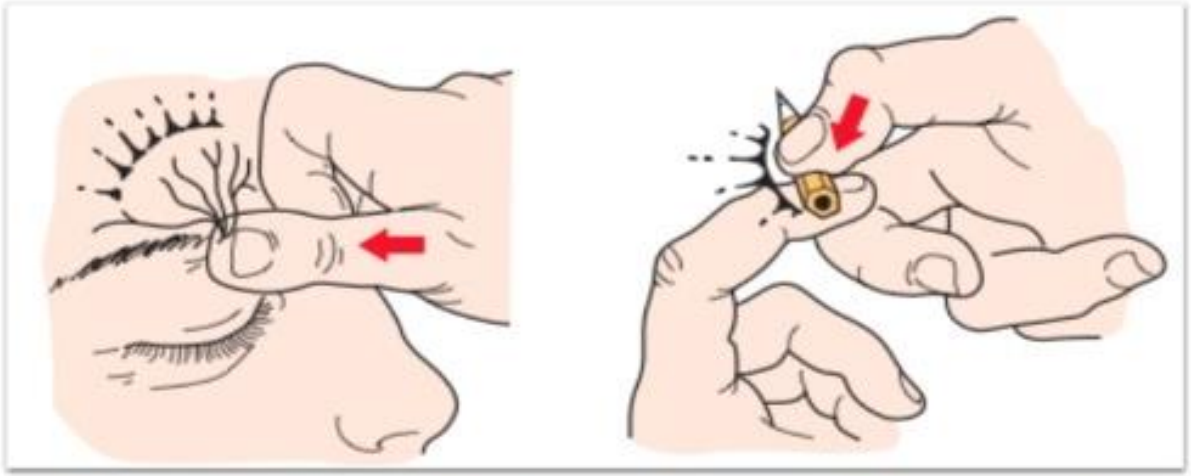
1) eye opening
2) verbal response
3) motor response

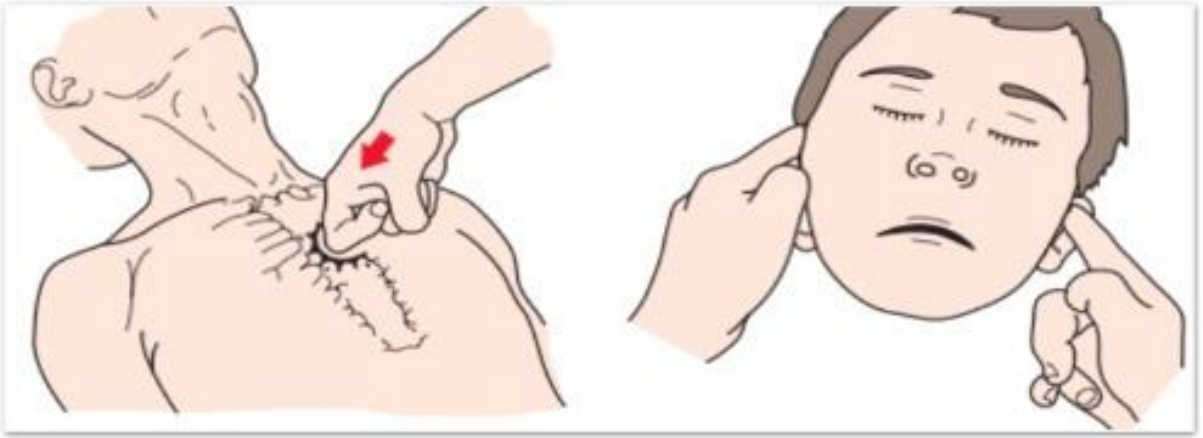
Level of conciousness Glasgow Coma Scale

Best eye response (E)	Best verbal response (V)	Best motor response (M)
4 Eyes opening spontaneously	5 Oriented	6 Obeys commands
3 Eye opening to speech	4 Confused	5 Localizes to pain
2 Eye opening in response to pain	3 Inappropriate words	4 Withdraws from pain
1 No eye opening	2 Incomprehensible sounds	3 Flexion in response to pain
	1 None	2 Extension to pain
		1 No motor response

Patients with GCS scores of 3 to 8 are comatose

Painful Stimuli





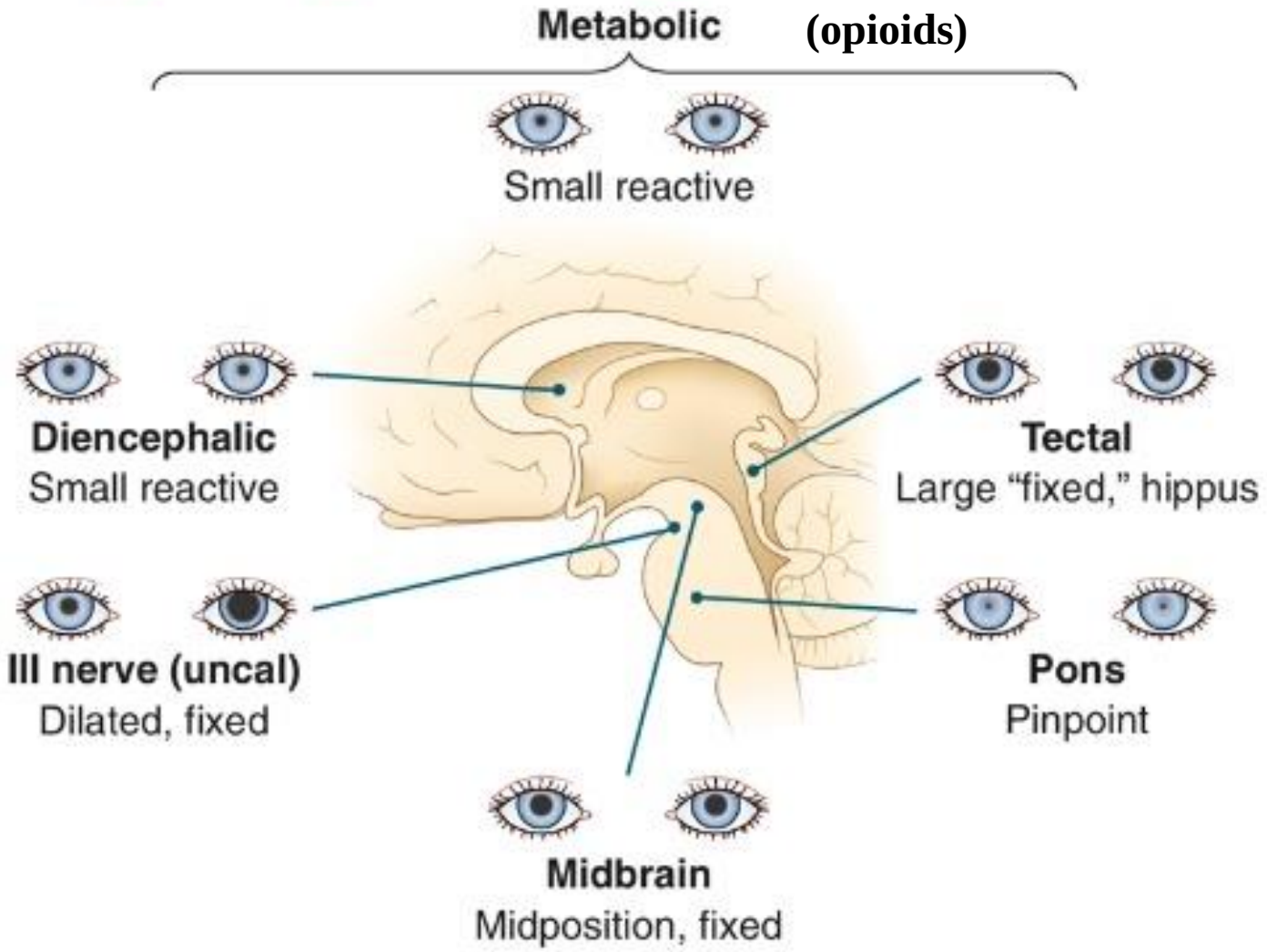
Respiratory patterns

Lesion Location	Terminology	Respiratory Patterns
Bilateral Cortical & Forebrain	Cheyne-Stokes	
Midbrain-Upper Pons	Central Hyperventilation	
Mid-Lower Pons	Apneustic	
Dorsomedial Medulla	Ataxic	

Pupils

- Size, inequality, reaction to a bright light.
- An important general rule: most metabolic encephalopathies give small pupils with preserved light reflex.
- Atropine, and cerebral anoxia tend to dilate the pupils, and opiates will constrict them.

Pupillary Finding in Comatose



Lesions above the thalamus and below the pons preserve pupillary reactions

Eye position and movements

- **In diffuse cerebral disturbance** but intact brainstem function, slow roving eye movements can be observed

- **Frontal lobe lesion** may cause deviation of the eyes *towards* the side of the lesion

Eyes deviate to the side of lesion
• Left frontal lobe lesion

- **Lateral pontine lesion** can cause conjugate deviation to the *opposite* side

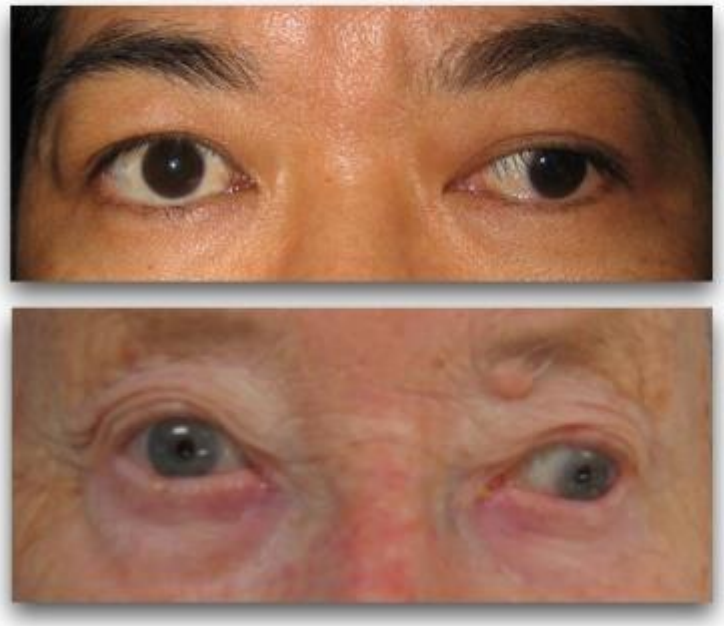
Eyes deviate away from the lesion
• Left pontine lesion

- **Midbrain lesion** Conjugate deviation *downwards*

Eyes deviate downward
• Midbrain pretectal lesion

Structural brainstem lesion

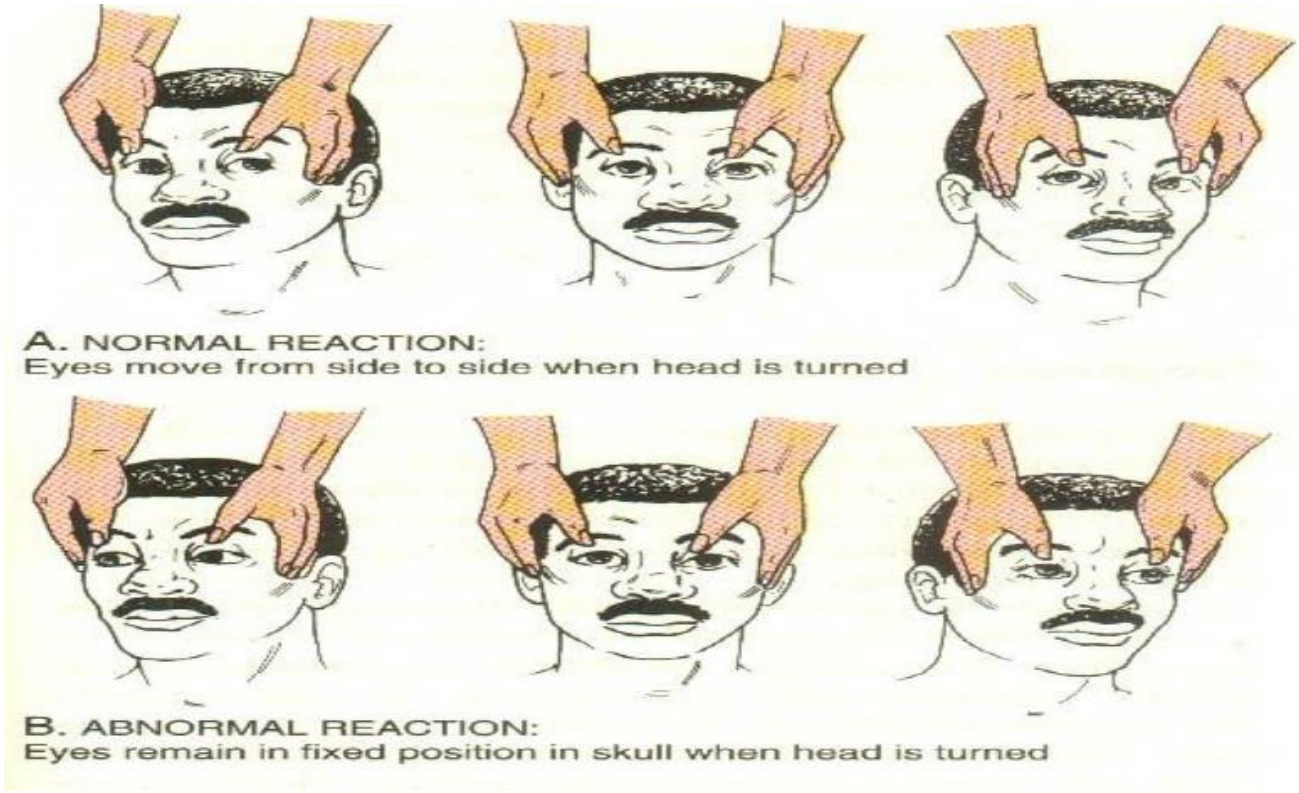
disconjugate ocular deviation



The oculocephalic (doll's head) response

Briskly rotating the head from side to side and observing the position of the eyes.

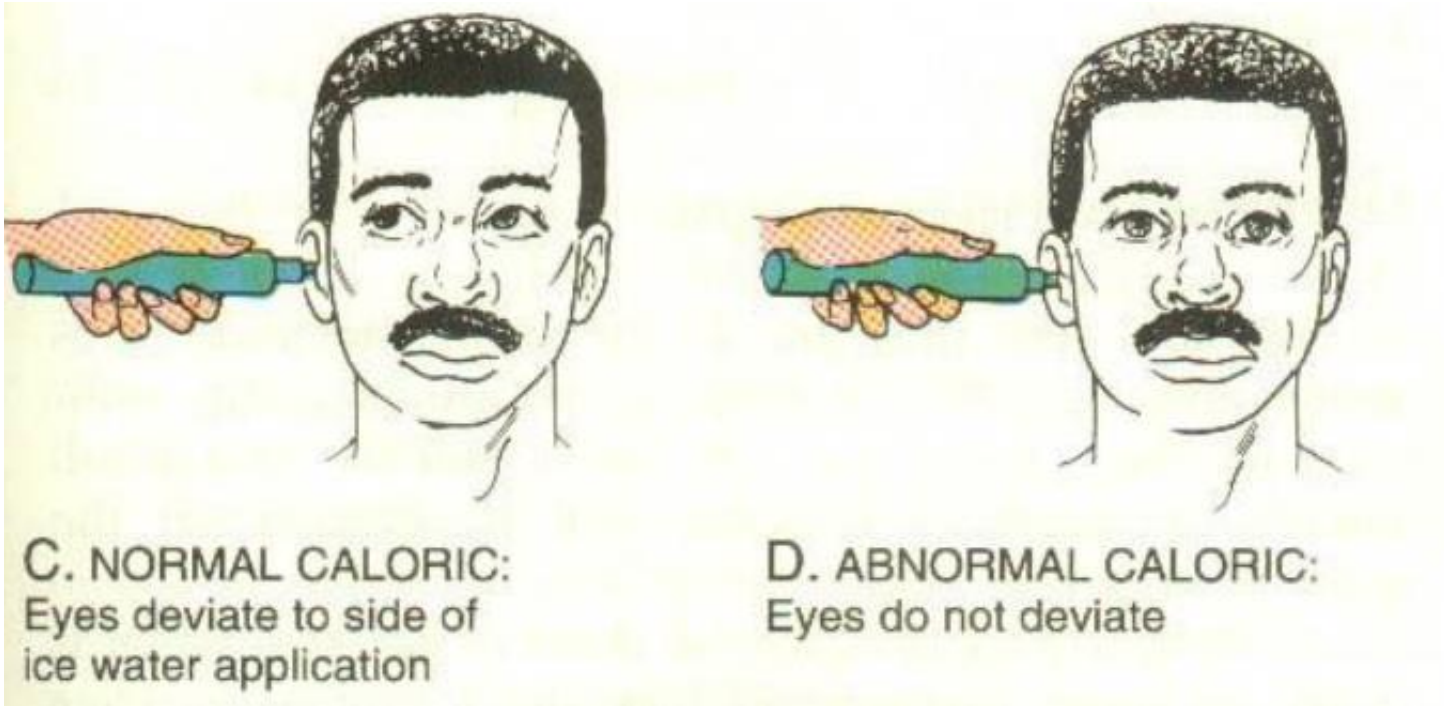
- If the eyes move *conjugately* in the *opposite direction* to that of head movement, the response is positive and indicates an *intact pons* mediating a normal vestibulo-ocular reflex



Caloric oculovestibular responses

These are tested by the instillation of ice-cold water into the external auditory meatus, having confirmed that there is no tympanic rupture.

- A normal response in a conscious patient is the development of *nystagmus* with the *quick phase away* from the stimulated side. This requires intact cerebropontine connections



Corneal reflex

The corneal reflex is an important protective mechanism for the cornea.

Afferent limb - via the trigeminal nerve (CN V),

&

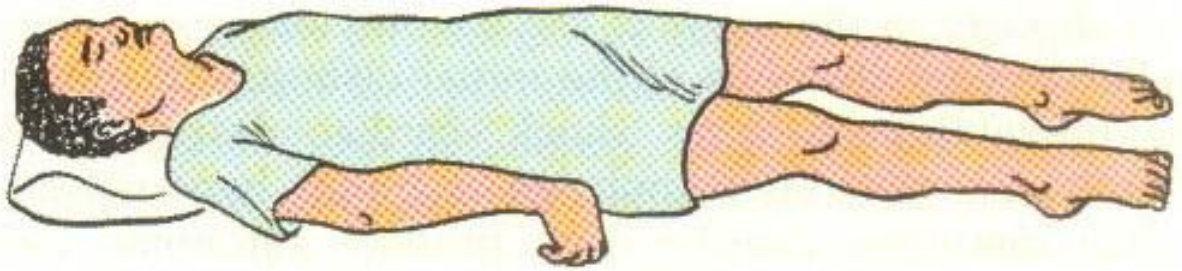
efferent limb - via the facial nerve (CN VII)

corneal reflexes assess brain stem function

Motor function

- Limb movements
- Posturing (decerrebrate/decorticate)
- Muscle tone
- Tendon reflexes and plantar responses

Posturing



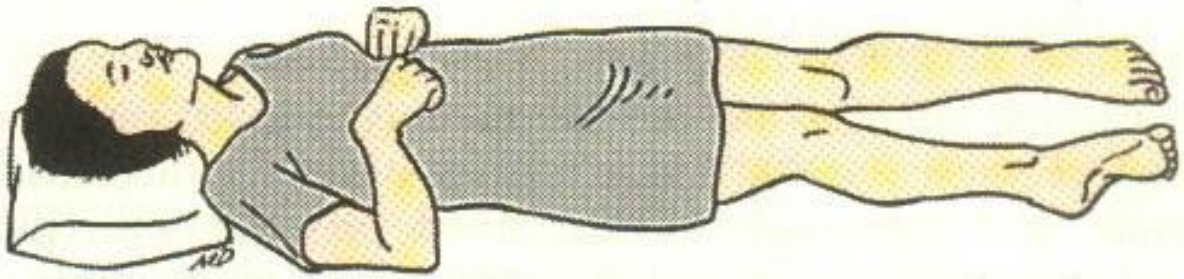
A. Extension posturing (decerebrate rigidity)

bilateral mid-brain or pontine lesions

Decerebrate rigidity - consists of opisthotonos, clenching of the jaws, and stiff extension of the limbs, with internal rotation of the arms and plantar flexion of the feet.

Posturing

Decorticate rigidity, with arm in flexion and adduction and leg(s) extended, signifies lesions **at a higher level, in cerebral white matter or internal capsule and thalamus, also upper midbrain.**



B. Abnormal flexion (decorticate rigidity)

TESTING

- pulse oximetry
- fingerstick plasma glucose measurements
- cardiac monitoring
- Blood tests (serum electrolytes, blood urea nitrogen, creatinine, calcium levels), liver function tests, and ammonia level.
- Complete blood count (CBC) with differential and platelets
- Arterial blood gases
- Blood and urine should be obtained for culture and routine toxicology screening;

  serum ethanol level
- Other toxicology screening panels and additional toxicology tests (eg, serum drug levels)
- ECG (12-lead) - to check for myocardial infarction and new arrhythmias.
- Chest x-ray - to check for new lung disease that may affect brain oxygenation.

Neurological investigations

- CT imaging - test of first choice
- Magnetic resonance imaging
- The electroencephalography
- LP

TREATMENT

- Immediate stabilization (airway, breathing, circulation)
- Admission to an ICU
- Supportive measures, including, when necessary, control of ICP
- Treatment of underlying disorder

TREATMENT

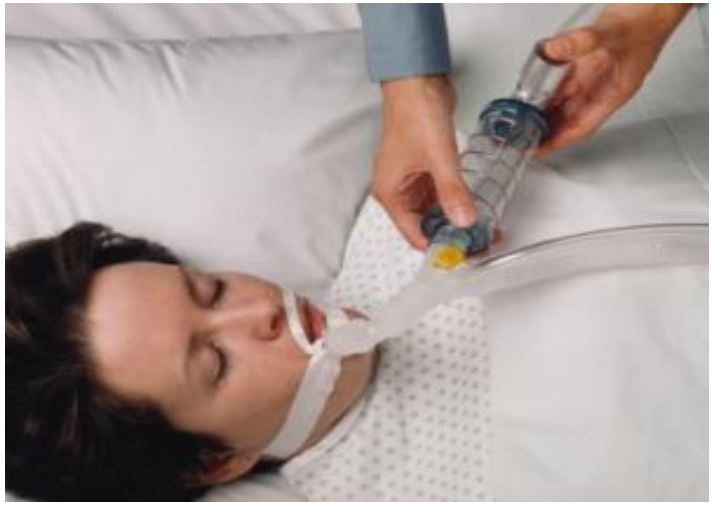
- Wernicke encephalopathy → thiamin 100 mg IV or IM
- If plasma glucose ↓-→ 50 mL of 50% dextrose IV
- If trauma → neck immobilization
- If opioid overdose is suspected → naloxone 2 mg IV
- If a recent drug overdose → gastric lavage

Endotracheal intubation

- Infrequent, shallow respirations
- Low oxygen saturation
- Impaired airway reflexes
- Severe unresponsiveness

Management of Intracranial Pressure

- Mechanical ventilation to ensure efficient oxygenation



ICP control

Goal:

ICP ≤ 22 mm Hg

cerebral perfusion pressure - 50 to 70 mm Hg.

elevate the head of the bed to 30°

keep the patient’s head in a midline position.

Sedation

- control agitation, excessive muscular activity (eg, due to delirium), or pain.

Propofol is often used in adults.

Benzodiazepines (midazolam, lorazepam) .

Hyperventilation

Hypocania → vasoconstriction →decrease cerebral blood

Reduction in Pco_2 from 40 to 30 mm Hg can reduce ICP about 30%.

ICP decreases for only about 30 min and is used as a temporary measure until other treatments take effect.

Osmotic diuretics

- **Goal:** Serum osmolality - 295 to 320 mOsm/kg.

Osmotic diuretics

-mannitol

-3% saline solution

Mannitol:

- should not be used if the serum osmolality exceeds 320 mosm/l
- it should be given rapidly as in IV bolus
- in adult patients the dose is 0.5-1 g/kg body weigh

Loop diuretics:

Furosemide 1 mg/kg IV

- Diuretics exert their effect through:
  - an osmotic gradient caused by a mild diuresis
  - reduction in CSF formation
  - reduction in brain water
  - loop diuretics increase the effect of osmothic drugs

Corticosteroids

- helpful for patients with a brain tumor or brain abscess

- ineffective for patients with head trauma, cerebral hemorrhage, ischemic stroke, or hypoxic brain damage after cardiac arrest.

Side effects:

- immunosupression
- upper gastrointestinal bleeding
- hyperglicemia

BP control

- hypertension (> 180/95 mm Hg)
- Nicardipine, labetalol

Management: CSF Drainage

The goal of placing the catheter tip in the frontal horn of the lateral ventricle or in the third ventricle.

In cases of uncontrolled intracranial hypertension, an intracranial drain can be placed to remove CSF and monitor ICP

Pentobarbital coma

Sodium thiopental:

- reduces cerebral blood flow and cerebral metabolic rate
- has immunosuppressive effect
- when used in high doses it increases the duration of mechanical ventilation and length of stay in intensive care unit
- its efficiency can be evaluated by continuous EEG monitoring
- adverse effects – hypotension, arrhythmias, myocardial depression

Management: Hypothermia

- Decreases cerebral metabolic rate

Controlled hypothermia has been shown to help reduce ICP in some patients with refractory intracranial hypertension and may improve outcome

Decompressive craniotomy

- Craniotomy with duraplasty can be done to provide room for brain swelling.
- prevents deaths, but overall functional outcome may not improve much.

Brain death

is irreversible end of brain activities due to total necrosis of neurons due to loss of O_2.

Brain death

- Complete unresponsiveness to all modes of stimulation, respiratory arrest, and absence of all EEG activity for 24 h.
- The central considerations in the diagnosis of brain death are

  (1) absence of cerebral functions;

  (2) absence of brainstem functions, including spontaneous respiration

  (3) irreversibility of the state such as drug overdose.

Brain Death

- **I. The clinical evaluation**
- **A. Establish irreversible cause of coma.**
- The cause of coma can usually be established by history, examination, neuroimaging, and laboratory tests.
- Exclude the presence of a CNS-depressant drug, no recent administration of neuromuscular blocking agents
- There should be no severe electrolyte, acid-base, or endocrine disturbance.
- Achieve $PaCO_2$= 35-45 mm Hg
- Achieve normal core temperature

B. Achieve normal systolic blood pressure.

C. Perform 2 neurologic examinations

The clinical evaluation (neurologic assessment).

A. Coma.

B. Absence of brainstem reflexes.

- Absence of pupillary response to a bright light in both eyes.
- Absence of ocular movements using oculocephalic testing and oculovestibular reflex testing.
- Absence of corneal reflex.
- Absence of facial muscle movement to a noxious stimulus.
- Absence of the pharyngeal and tracheal reflexes.

Apnea Test

- Absence of a Respiratory Drive.
  --- is tested with a CO_2 challenge:
- Disconnect the patient from the ventilator
- Preserve oxygenation
- If respiratory movements are absent and arterial PO_2 is 60 mm Hg the apnea test result is positive

apnea test should be aborted in patents with brain death:

- SpO_2<80%
- cardiac rhythm disturbancess
- systolic BP <90 mmHg
- patient resume spontaneous breathing

Common confirmatory tests

- **Cerebral angiography**

No intracerebral filling at the level of the carotid or vertebral artery entry to the skull.

- **Electroencephalography**

no electroencephalographic reactivity to intense somatosensory or audiovisual stimuli.

- **Transcranial Doppler ultrasonography**

lack of diastolic or reverberating flow, small systolic peaks in early systole, and a lack of flow