

Management of Intracranial Pressure

Stroke Conference

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Disclosures

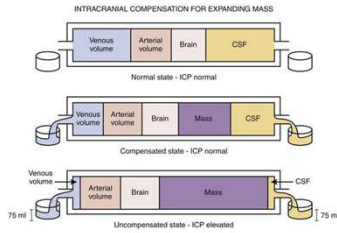
- No conflicts of interest.

Outline

- Intracranial physiology and autoregulation
- Signs and symptoms of elevated ICP
- Initial evaluation and management
- ICP monitoring
- Medical management
- Decompressive craniectomy

Monro-Kellie Doctrine

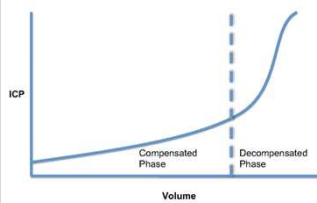
- The cranial vault is a fixed space of ~1400-1700 ml in average sized adults.
 - Blood 10% (~150 ml)
 - CSF 10% (~150 ml)
 - Brain 80% (~1400 ml)



Normal ICP

Age Group	Normal range (mmHg)
Adults and older children	10-20
Young children	3-7
Term infants	1.5-6

The Compliance Curve



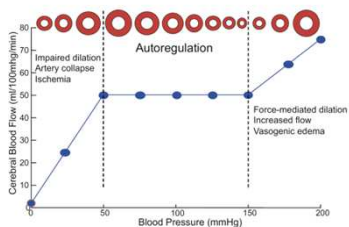
- Nonlinear
- As mechanisms are exhausted, compliance falls and even small increases in volume can dramatically increase ICP.

Cerebral Perfusion Pressure (CPP)

- The critical parameter for brain function and survival is not actually ICP.
 - Is there adequate cerebral blood flow to meet oxygen demands?
 - Cerebral blood flow depends on CPP, which depends on ICP (which is easily measured)
 - CPP = MAP-ICP
 - Normal >50 mmHg

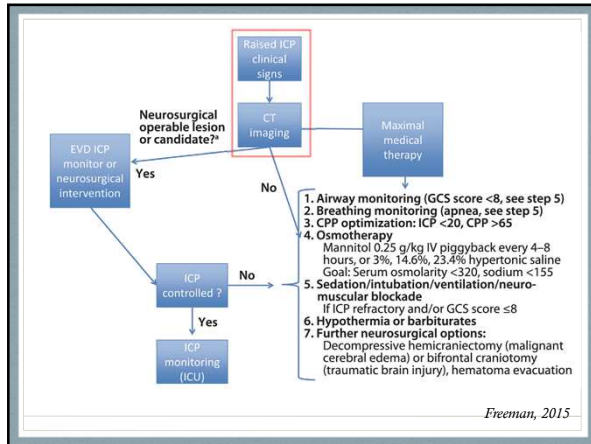
Autoregulation

- Cerebral vasculature can vasoconstrict and vasodilate in response to various stimuli
- Changes in systemic blood pressure produce only small changes in CBF.



Causes of Elevated ICP

Intracranial (primary)	Extracranial (primary)
Traumatic brain injury (cerebral contusions, epidural and subdural hematomas)	Hypoxia
Brain tumor	Hypercarbia
Intracranial hemorrhage (nontraumatic)	Hypertension
Ischemic stroke	Hyponatremia
Hydrocephalus	Hyperpyrexia
Infection	Seizures
Status epilepticus	Hepatic failure
Idiopathic	Drugs and toxins
Postoperative (hemorrhage, edema, CSF disturbances)	Jugular venous obstruction
	High-altitude cerebral edema



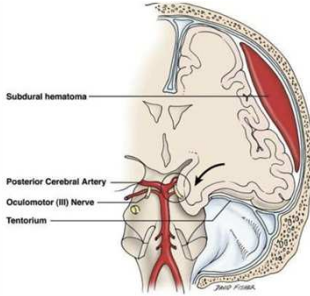
Signs and Symptoms of Elevated ICP

- Headache
- Nausea/vomiting
- Blurred vision
- Uneven or dilated pupils
- Diplopia
- Papilledema
- Altered level of consciousness
- Cushing triad: Hypertension, bradycardia, respiratory irregularity

Herniation

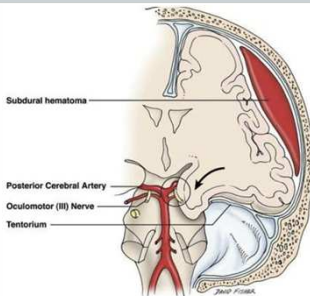
1. Subfalcine Herniation
2. Uncal Herniation
3. Downward Herniation

Uncal Herniation



- Generally from pathology in the frontotemporal region.
- Uncus is pushed over the tentorial edge compressing the third nerve and posterior cerebral artery.
 - Unilateral dilated pupil
 - Occipital lobe infarct

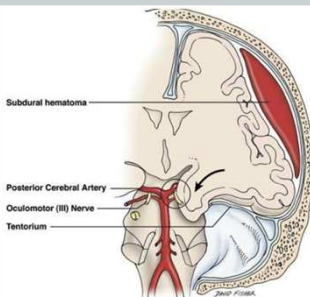
Uncal Herniation



EARLY SIGNS:

- Earliest consistent sign is unilaterally dilated pupil
 - Not to be confused with anisocoria.
- Often accompanied by confusion, aggritation or somnolence.

Uncal Herniation

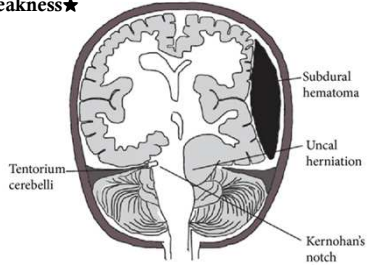


LATE SIGNS

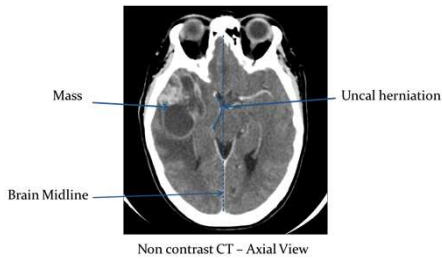
- Brainstem involvement
- Contralateral weakness
 - Kernohan's phenomenon
- Followed by decerebrate posturing
- Sustained hypernea
 - Cheyne-Stokes respirations are rare.

Kernohan's Notch

★ Ipsilateral weakness ★



Uncal Herniation

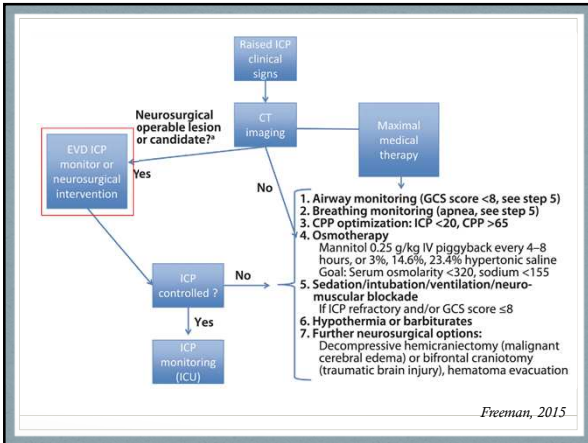


Initial Measures

- Elevate head of bed to 30-45°
 - ↓ ICP by enhancing venous outflow
- Keep neck straight and avoid neck constrictions (tight trach tape, tight cervical collar)
 - Constriction of jugular venous outflow causes ↑ ICP
- Avoid arterial hypotension (SBP <90 mmHg)
 - Hypotension reduces CBF
 - Normalize intravascular volume (isotonic fluids)
 - Pressors if needed

Initial Measures

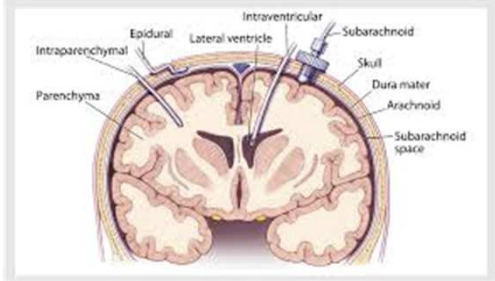
- **Avoid hypoxia**
 - May cause further ischemic brain injury
 - Intubate if GCS <8.
- **Ventilate to normocarbia (avoid prophylactic hyperventilation)**
- **CT head without contrast to rule out surgical pathology**



Indications for ICP Monitoring

- **No level I evidence.**
- **Level II evidence:**
 - GCS <8 and abnormal CT head
- **Level III evidence:**
 - Also indicated in severe TBI patients with normal CT if two of the following criteria are met...
 - Age >40
 - SBP <90 mmHg
 - Decerebrate or decorticate posturing on motor exam
- **Contraindications: awake patients, coagulopathy**

Potential Monitoring Sites



External Ventricular Drain (EVD)

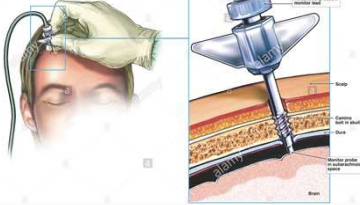


- Gold standard
- Can monitor ICP and drain CSF to lower pressure as needed.
- 10% risk of infection
- 1-2% risk of hemorrhage
- Frequently become clogged and require flushing or replacement.

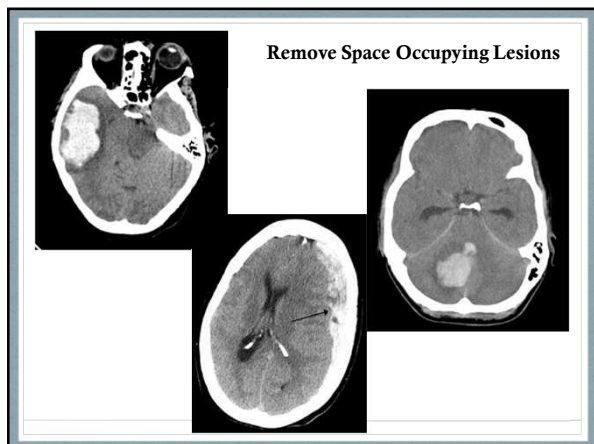


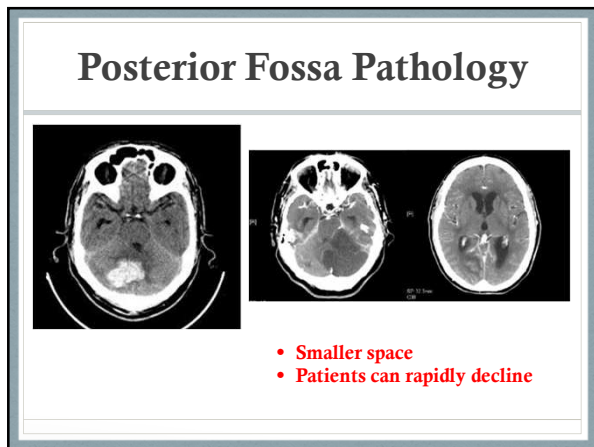
Subarachnoid Bolt

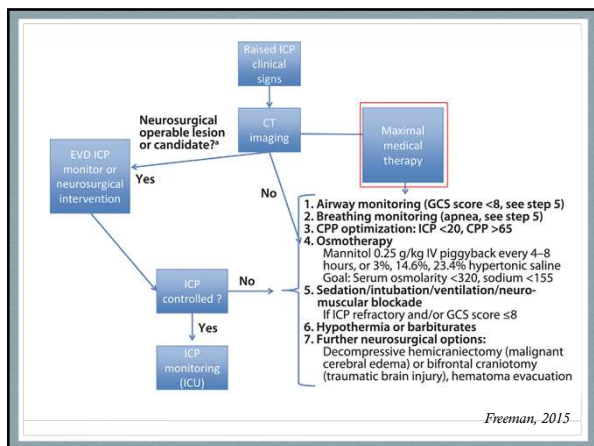
Area of Intracranial Pressure Monitor



- Quick and easy to put in.
- Low infection risk.
- May still need to place EVD if CSF drainage is necessary.







**Medical Management
Mannitol**

- Mannitol has been used for ICP reduction for nearly 100 years.
- Large molecule (similar to starch)
- Causes increase in serum osmolality leading to an osmotic gradient between the serum and intracranial compartment
 - Net effect is the removal of brain water to ↓ ICP
- Rheologic properties
 - Decreases blood viscosity potentially improving cerebral perfusion

**Medical Management
Mannitol**

- Dosage
 - Acute setting: 1.5g/kg IV bolus
 - Less acute settings: 0.25g/kg IV bolus
 - Interval dosing: 25g q6h
- Simplify especially in the emergency setting with absolute doses 25g, 50g, 75g, or 100g.

**Medical Management
Mannitol**

- Cautions
 - Osmotic diuretic; must monitor for volume loss and prevent hypotension.
 - May require electrolyte replacement
 - E.g. Hypokalemia, hypophosphatemia
 - Renal injury (serum osmolality <320 mOsm/k)
 - Especially for q6h dosing.
 - Precipitates when cold, may need IV filter.
 - Mannitol opens the blood brain barrier, and mannitol that's crosses the BBB may draw fluid into the CNS (minimized with bolus dosing)
 - Must taper scheduled mannitol to prevent ICP rebound.

Medical Management Hypertonic Saline

- 1.5 %, 3%, or 23.4% solutions
- Provides hyperosmolar state and increased circulating blood volume compared to mannitol.
- May be preferable in patient populations where volume depletion may compromise cerebral perfusion.
 - Subarachnoid hemorrhage
- Goal Na 145-155.

Medical Management Hypertonic Saline

- Cautions
 - Risk of thrombophlebitis if ran through a peripheral IV.
 - Need for central access if administration required for >24h.
 - Overshoot causes hypernatremia and hyperchloremic acidosis
 - Q6h Na monitoring.

Medical Management Sedation

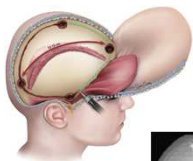
- Propofol, midazolam, fentanyl infusions
- Requires intubation if not already done.
- Reduces ICP by reducing Valsalva maneuver and jugular venous pressure elevation

Medical Management Neuromuscular Paralysis

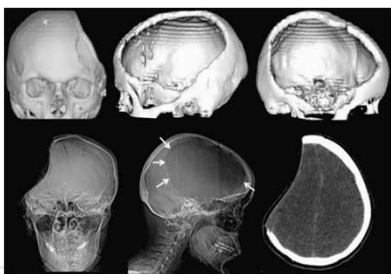
- Prevents coughing, which may cause ICP spikes.
- Requires intubation if not already done.
- Disadvantage:
 - Loss of neurologic exam aside from pupillary reflexes.

Medical Management Barbituates

- Reduces brain metabolism and therefore oxygen demands leading to ↓ CBF.
- Anti-epileptic benefit.
- Cautions
 - Requires intubation and EEG monitoring to titrating to burst-suppression pattern.
 - Reduces cardiac output and may require vasopressor support
 - Contraindicated in patients with heart history.



Decompressive Craniectomy



Decompressive Craniectomy

- Most commonly used in large MCA or ICA infarcts.
- Mortality rate in large MCA infarcts approaches 80%
 - Decompressive craniectomy may reduce mortality to as low as 32% in nondominant hemisphere strokes (37% in all comers)

Decompressive Craniectomy

- Meta-analysis of 3 randomized controlled trials found that hemicraniectomy within 48 hrs after stroke onset:
 - Decreased mortality
 - Increased the number of patients with favorable functional outcomes.

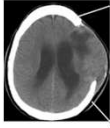
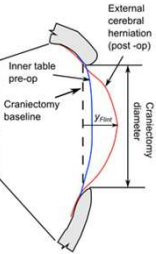
Vahedi et al. 2007

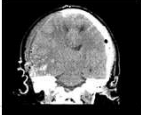
Decompressive Craniectomy

- Indications
 - Age <70
 - Usually more strongly considered in nondominant hemisphere infarcts
 - Clinical and CT evidence of acute, complete ICA or MCA infarcts and direct signs of impending swelling or herniation.

Decompressive Craniectomy

- Technical Notes
 - GO BIG! Bone flap should be >12cm
 - Dura should also be opened, ± duraplasty
 - Bone flap can be stored in the abdomen or bone freezer.

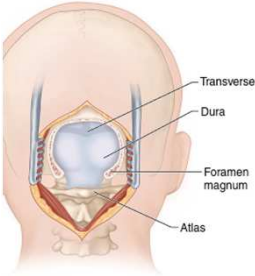





Decompressive Craniectomy

- Potential Complications
 - Bleeding
 - Herniation of the brain through the bone opening (can cause local ischemia, minimized by making a big craniectomy)
 - Post-op fluid collections (subdural hygromas)
 - Hydrocephalus

Suboccipital Craniectomy

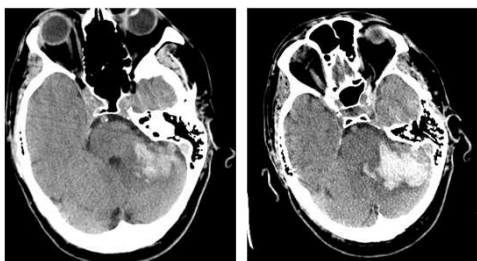


- Patients can decline quickly from posterior fossa infarcts.
 - Swelling
 - Obstructive hydrocephalus
 - Brainstem compression
- Duraplasty
- Removal of infarcted tissue
- Caution with aggressive EVD drainage prior to decompression.
 - Risk of upward herniation

68 year old male

- Presented to the ER with severe headache, nausea and dizziness
- PMH: afib, hypertension, CAD, on Xarelto, ASA, and Plavix
- ICH score 1, NIH stroke score 4

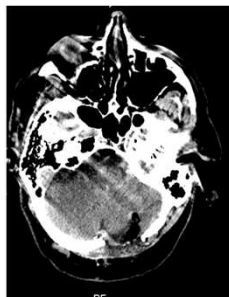
68 year old male



Admission

6 hrs later

68 year old male



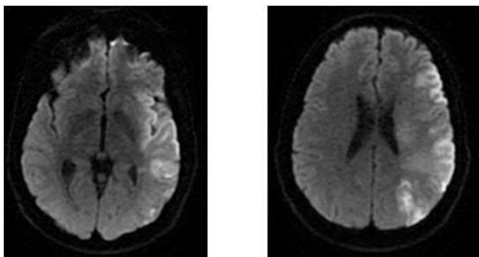
68 year old male

- 9 months post-op
 - Ambulating with a cane
 - No headaches

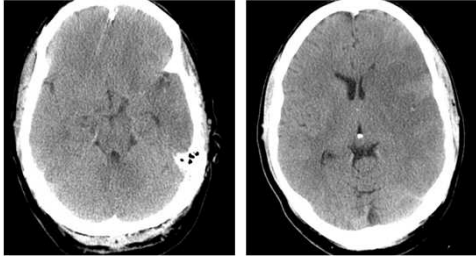
38 year old male

- Presented to outside ER with slurred speech and right sided weakness. CTA showed left common carotid thrombosis as well as left MCA occlusion
 - Given tPA at outside hospital
- PMH: smoker
- Exam: lethargic, right hemiparesis, withdraws left side to pain.

38 year old male

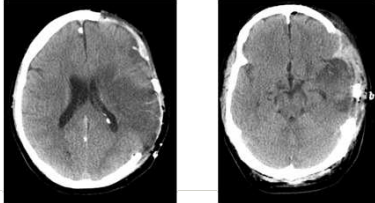


38 year old male



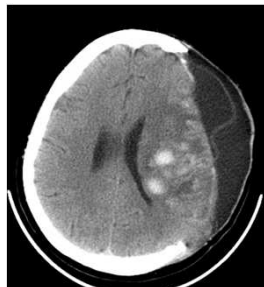
38 year old male

- Taken to OR for decompressive craniectomy and ICP monitor placement on stroke day 2.



38 year old male

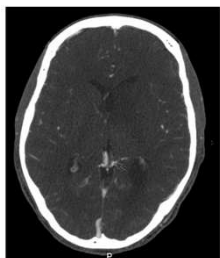
- Outcome (6 weeks out)
 - Bone flap replaced
 - Required shunt placement for extra-axial hygroma
 - Able to speak but still has considerable word finding difficulties, able to follow commands on the right.



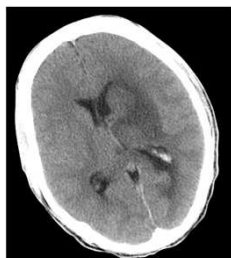
22 yo male

- Presented to the ER with new right sided weakness and a couple week history of worsening headache.
- Exam: Answering some questions appropriately and intermittently following commands, right hemiparesis.

22 year old male



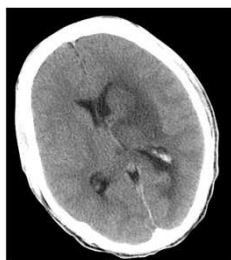
CTA on admission



CT head on day 2

22 year old male


- Heparin gtt
- Mental status improved significantly on 3% and mannitol.
- Held off on mechanical thrombectomy



CT head on day 2

22 year old male

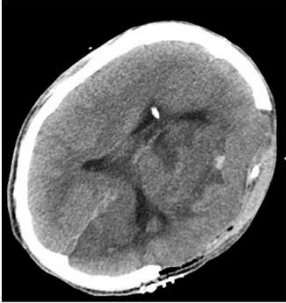
- Patient no longer responding
- Left pupil nonreactive
- Patient intubated.



Day 4

22 year old male

- Emergent EVD placement
- Decompressive craniectomy



22 yo male

- **Outcome (almost 6 months out)**
 - Trapped left ventricle, underwent shunt placement
 - LUE DVT
 - Shunt malfunction with post-op seizures
 - Bone flap replaced last month
 - Exam: can carry on a conversation, able to stand, RUE plegic.

References

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