Raised intracranial pressure

Objectives:

- Not Given.

Resources:

- Slides
- Davidson

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[Color index | Important | Notes | Extra]
[Editing file]

Once you stop learning
you start dying.

Raised IntraCranial Pressure (ICP)

❖ Basics

The brain is enclosed within a rigid bony container. Intracranial pressure (ICP), therefore, depends on the relative volumes of **components of cranium:**

- ★ Brain parenchyma **1400** ml
- ★ CSF **75-100** ml
- ★ Blood **75** ml

Also, depends on the fluctuates in response to changes in intrathoracic pressure (e.g. increased by coughing, defecation) and cardiac pulsation.These transient increases do no harm.

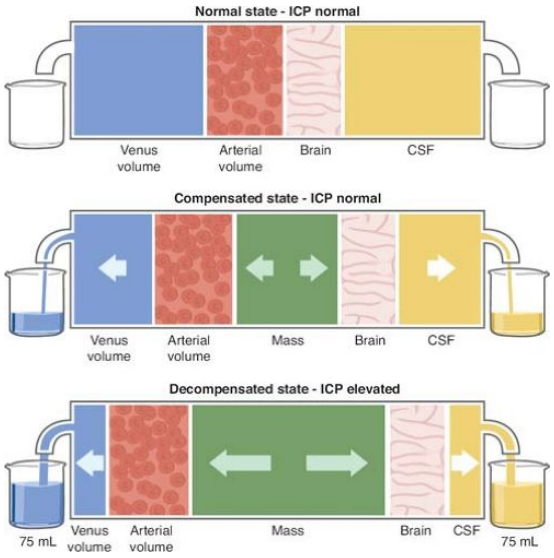
❖ Monro-Kellie Doctrine:

This equation states that the volume of blood, brain, and cerebrospinal fluid within the nonexpansile cranium must remain constant for ICP to remain constant. If an additional substance, such as an expanding hematoma, is added, the ICP will increase unless a compensatory amount of blood, brain, or cerebrospinal fluid is removed.

A pressure-volume relationship that aims to keep a dynamic equilibrium among the essential non-compressible components inside the **rigid compartment of the skull**.

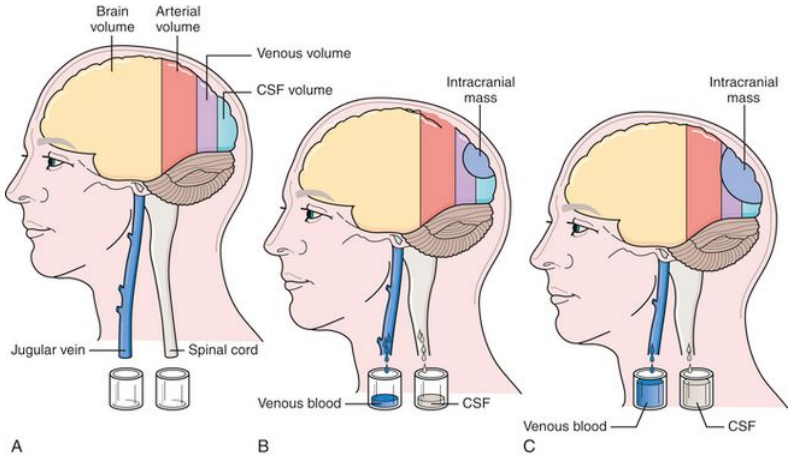
- These contents are incompressible.

Blood is water, CSF is water, brain is tissue, and human tissue is mostly water! Water can move from one area to another but is incompressible. This means if for example CSF is increased, the blood will be less and brain tissue will shift to accommodate.



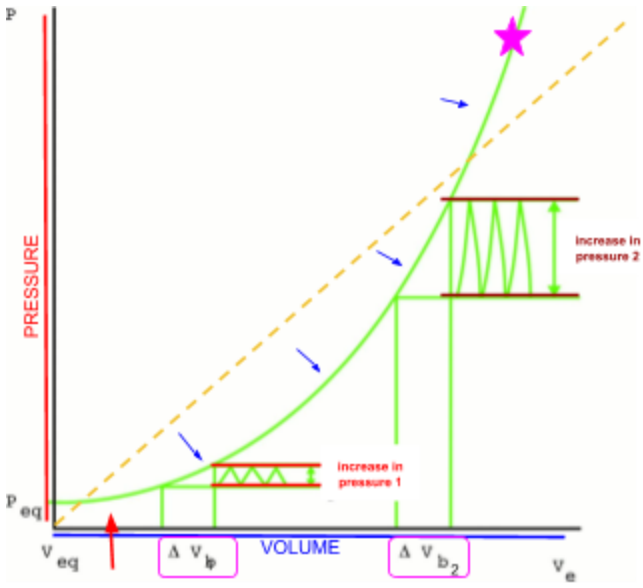
Pressure-Volume

- **Increase in volume** in one compartment leads to **change in volume** in the other ones, for example brain tumor (which increase in tissue volume) leads to **decrease** in CSF volume → **decrease** in blood volume.
- For how long could this go on? until the system compensate.



Pressure-Volume Curve

In a normal supine adult, intracranial pressure (ICP) is the same as the CSF pressure obtained in a lumbar puncture (5-15 cm H2O, 4-10 mmHg). In patients with intracranial **mass lesions** (Tumour, haemorrhage), **oedema** or **CSF obstruction**, the extra volume is at first compensated by a reduction in cerebral blood volume and CSF volume. However, a critical point is reached where no further compensation is possible, and any additional volume insult will lead to exponential rises in intracranial pressure ICP.



What you need to know about the pressure-volume curve:
In general, if you have one point increase in volume you will have one point increase in pressure, and if you have two points increase in volume you will have two points increase in pressure.
It is a linear relationship.
so you would expect the curve to be like the yellow line.

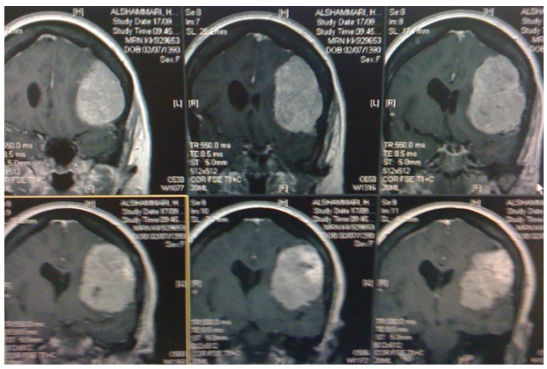
But this is not the case here! why?
Red arrow despite the increase in volume (Vb1) the pressure is almost the same, because the brain is compensating! but after that *Blue arrows* the same amount of increase in volume (Vb2) is associated with huge increase in pressure!
Why?
Because at Vb2 the system has reached a point where it can't compensate anymore!
and this is characteristic for the pressure-volume curve of ICP.

Which means what?
It means, that patient can come to your clinic complaining of headache for the last 3-4 days, and when you examine him you will find signs of an increased ICP (headache, vomiting, papilledema..), you do a CT scan and you find for example an abscess formation.
You don't know where this person stand on the curve, he could be anywhere, but if he is at the end point *pink star* that means any tiny increase in the abscess would result in huge increase in the pressure!
which means that he can suddenly collapse!

So this curve explains why some people collapse quickly, and why you have to act quickly in case of raised ICP..!

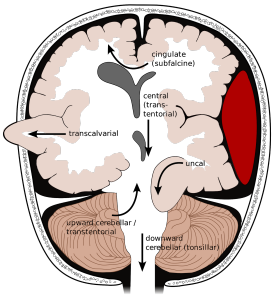
How can you identify where a person is on the curve?
it depends on the clinical picture and CT scan findings, like +ve brain midline shifting in the CT scan or severe headache or loss of consciousness.

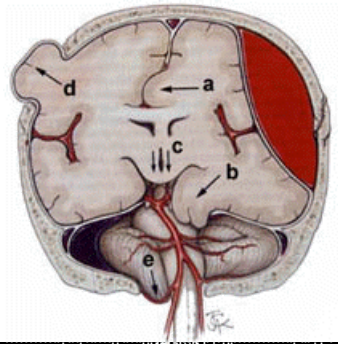
Can somebody walk around with a raised Intracranial Pressure (ICP)?

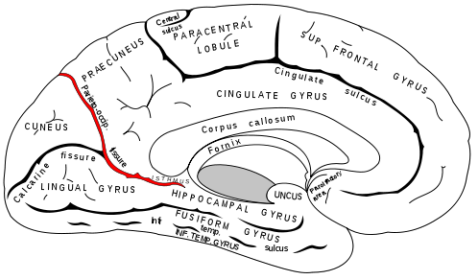


IMAGE; Here you can see a tennis-like large mass!
this 36 y/o female came to ER/clinic with only numbness in the right body, why?
because it was a slowly growing mass and you can see how much the brain can compensate and accommodate: (significant midline shift small ventricles on the same side).
The diagnosis was a slowly growing meningioma, and it was compensated that she could walk around (if it was growing faster, she would develop severe symptoms suddenly).
The rate of increase in the volume of intracranial mass is crucial to the shape of the ICP pressure-volume curve. With more chronic slow-growing lesions such as brain tumours, abscesses or congenital abnormalities, extraordinary degrees of compensation can occur. In some situations, even massive lesions can lead to minimal symptoms and signs, despite brain herniation.

❖ Raised Intracranial Pressure (ICP) and brain shift:







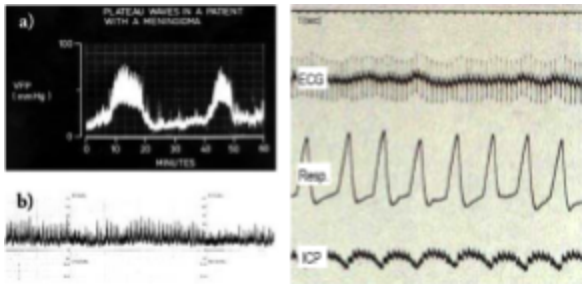
a	**Cingulate herniation** aka **(Subfalcine)**	The cingulate gyrus is the curved fold that covers the corpus callosum. With parasagittal frontal lobe mass, the ipsilateral cingulate gyrus may herniate beneath the free edge of the falx. ★ The anterior cerebral artery <u>may be</u> compressed sufficiently to cause medial hemispheric infarction.
b	**Uncal herniation** aka **(Transtentorial)**	With large ipsilateral brain lesions, the medial part of the temporal lobe (the uncus, it's the innermost part of the anterior parahippocampal gyrus, part of mesial[1] temporal lobe) is pushed down through tentorial notch to become wedged between tentorial edge and midbrain. The opposite cerebral peduncle is pushed against the sharp tentorial edge, and the midbrain and uncus became wedged at the tentorium. The aqueduct is compressed, obstructing CSF flow, and venous flow is obstructed which leads to midbrain haemorrhage. the clinical features most often due to traumatic intracranial haematoma: - Compression of **<u>third nerve (oculomotor)</u>**→The **<u>ipsilateral</u>** pupil dilates and becomes non-reactive to light. - **<u>Compression of corticospinal tract</u>**→**<u>Contralateral</u>** Hemiplegia. - Affect respiratory center→The respiratory rate falls and the patient become apnoeic. - The Glasgow Coma Score (GCS) falls. - The motor component of GCS becomes asymmetrical. - The blood pressure rises. - The pulse slows.
c	**Central herniation**	The whole brain structure will go down through the tentorium.
d	**Outside herniation** aka	Following trauma to the skull, eg. skull fracture.

[1] mesial means directed toward the sagittal plane or midline.

	(Transcalvarial)	
e	**Tonsillar herniation** aka **(Foraminal)**	With mass **lesions of the posterior cranial fossa**, the cerebellar tonsils and medulla are displaced downwards through the foramen magnum. compressing the brainstem, stopping it from sending signals to the heart & lungs. Cerebellar impaction leads to medullary compression. following traumatic or spontaneous haematoma, this can lead to: - Dramatic decrease in the GCS. - Acute hypertension. - Bilateral extensor responses. - Bilateral fixed dilated pupils. - Sudden respiratory arrest.

❖ Intracranial Pressure (ICP) waveform:

ICP is dynamic, not static.
It changes with the change in circulation which is affected by respiration, if you have raised intrathoracic pressure you will have decreased venous return and the blood will be accumulated inside your head, so your ICP will be HIGHER.
ICP can be measured by inserting a catheter.



❖ Normal Intracranial Pressure (ICP)

- Adults <10 -15 mm Hg
- Children 3-7 mm Hg
- Term infants 1.5-6 mm Hg

★ Why ICP is lower in infants? their bones (skull sutures) aren't united yet.

❖ Cerebral autoregulation

★ If Intracranial pressure (ICP) goes up, how does the brain get perfusion?

Process of autoregulation:

Cerebral perfusion pressure CPP = Mean Arterial Pressure (MAP) **-** Intracranial pressure (ICP)

If MAP=**85** mmHg **and** ICP=**15** mmHg **then** CPP **will be around 60-70, approximately = 50-140** mmHg

Cerebral perfusion pressure (CPP) is simply how much of the arterial blood can overcome the resistance of ICP and reaches the brain.

Blood Pressure (BP) and Cerebral Blood Flow (CBF):

- Ability of cerebral vessels to maintain cerebral perfusion within strictly determined limits:
  - **Rise** in Systolic Blood Pressure (SBP) will lead to: **Constriction** of cerebral arteries. (increase in SBP > increase in MAP > increase in CPP > vasoconstriction)
  - **Low** Systolic Blood Pressure (SBP) will lead to: **Dilatation** of cerebral vessels to accommodate.

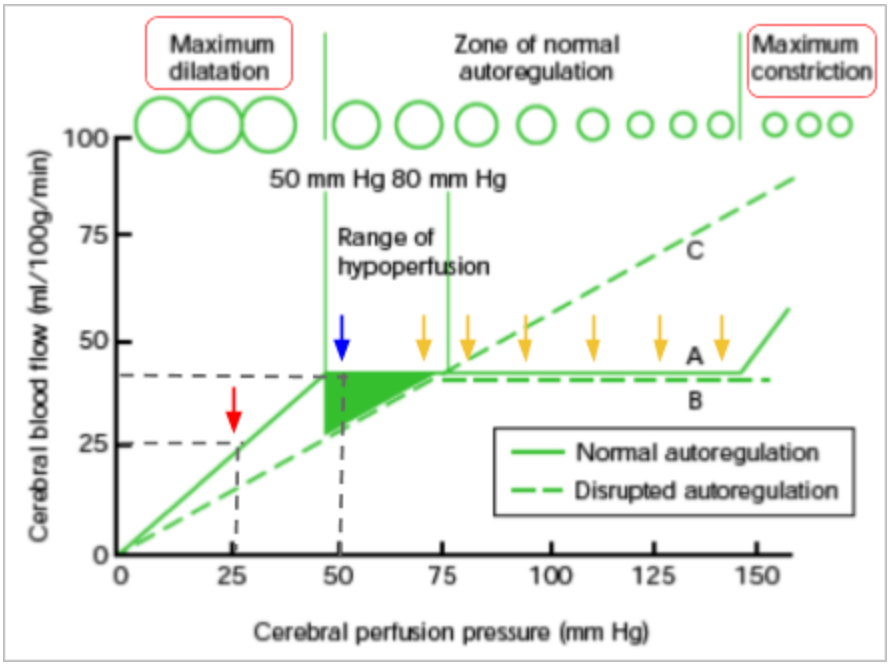
So, the volume of blood going to the brain is constant no matter what happen outside the skull.

- Loss of autoregulation: Change in cerebral blood flow with the change in blood pressure (BP).

What is the relationship between Cerebral blood flow and Cerebral perfusion pressure?

- When the perfusion pressure is 25 the blood flow is 25 *red arrow*.
- When the perfusion pressure is 50 the blood flow has also increased *blue arrow*.
- After that the perfusion pressure is **increasing** but the blood flow **stays the same** *yellow arrows*. **why?**
  because this is the brain! a controlled environment that it system has the ability to autoregulate itself.

if the perfusion pressure is too high you get a maximum constriction.
if the perfusion pressure is too low you get a maximum dilatation.



Example:

20 year old man, had car accident (MVC) as unrestrained driver.
He presented with Blood Pressure (BP) of 75/30 and Heart Rate (HR) of 125 bpm. Unconscious, with right hemiplegia.

What Should you do?

First ABCD:

A: Airway → intubate and maintain cervical spine applying a collar.
B: Breathing → examine chest movement.
C: Circulation → two large IVs, ringer lactate or normal saline.
Then you stabilize the patient and if his blood pressure goes down and heart rate goes up this is a sign of bleeding.
D: Disability →the patient is unconscious, right hemiplegic, so you examine his pupil to see if it is dilated or not and you do a CT scan to find the cause of both right hemiplegia and the low blood pressure.

❖ Possible Causes of Raised Intracranial Pressure (ICP)

★ **VITAMEN D** (a mnemonic, no actual relation with vit D :)).

V: Vascular
I: Infection
T: Trauma
A: Autoimmune
M: Metabolic
E: Endocrine
N: Neoplastic
D: Drugs
Other Causes:

Table 2 Examples of causes of raised intracranial pressure

Pathological process	Examples
Localised mass lesions	Traumatic haematomas (extradural, subdural, intracerebral) Neoplasms (glioma, meningioma, metastasis) Abscess Focal oedema secondary to trauma, infarction, tumour
Disturbance of CSF circulation	Obstructive hydrocephalus Communicating hydrocephalus
Obstruction to major venous sinuses	Depressed fractures overlying major venous sinuses Cerebral venous thrombosis
Diffuse brain oedema or swelling	Encephalitis, meningitis, diffuse head injury, subarachnoid haemorrhage, Reye's syndrome, lead encephalopathy, water intoxication, near drowning
Idiopathic	Benign intracranial hypertension

Clinical Presentation of raised Intracranial pressure (ICP)

Symptoms

Headache, vomiting, papilloedema[2]

Headache

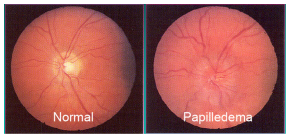
<u>Early morning</u>. Throbbing / Bursting in nature. increases with sneezing or coughing[3].

Because while sleeping in supine position venous return from the head decreases and ICP increases causing early morning headache.

Signs

Papilledema

Congestion of optic disk caused by decrease venous return.
Reliable but may **take several days**.
Associated fundal haemorrhage indicates acute and severe rise in ICP.



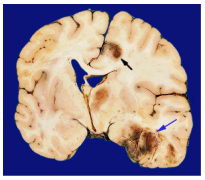
in the abnormal pic. you can see congested tutious vessels with loss of margins and may be hemorrhage.

Neurological

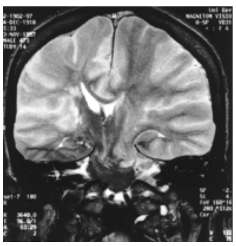
When we examine neurologically we look for Glasgow Coma Scale (GCS)
next page

1) Pupillary dilation
2) Hemiplegia
3) Cranial nerve deficit

because of herniation e.g:



this autopsy shows hemorrhages, cingulate herniation under the falx and midline shift.



in the MRI midline shift, temporal herniation, central herniation

Systemic

Raised BP

CPP = MAP-ICP

if ICP goes up, perfusion will go down.
so
MAP
has to go up.

Respiratory changes

<u>Cheyne-Stokes breathing:</u>
- Oscillating periods of apnea-tachypnea

- Respiratory centers comprom.

Glasgow Coma Scale (GCS)

Severe head injury score = 3-8 Moderate head injury score = 9-12
Mild head injury score= 13-15
if traumatic patient has score of 3 i know that he is close to dying more than living.

[2] Raised ICP triad
[3] Coughing/sneezing → increase intrathoracic pressure → decrease venous return from the jugulars.

Table 24.1 Glasgow Coma Scale	
Eyes open	
• Spontaneously	4
• To verbal command	3
• To pain	2
• No response	1
Best motor response **To verbal command**	
• Obeys verbal command	6
To painful stimulus	
• Localizes pain	5
• Flexion withdrawal	4
• Abnormal flexion (decorticate rigidity)	3
• Extension (decerebrate rigidity)	2
• No responses	1
Best verbal response	
• Orientated and converses	5
• Disorientated and converses	4
• Inappropriate words	3
• Incomprehensible sounds	2
• No response	1
Total number of points (minimum 3, maximum 15)	

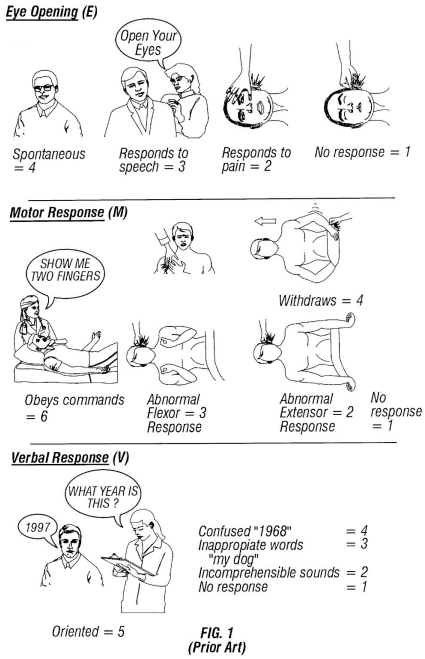
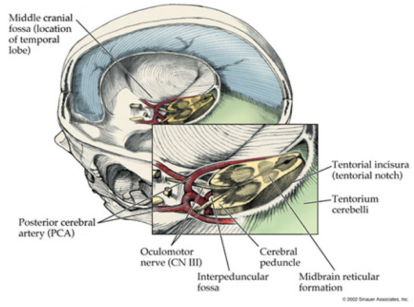
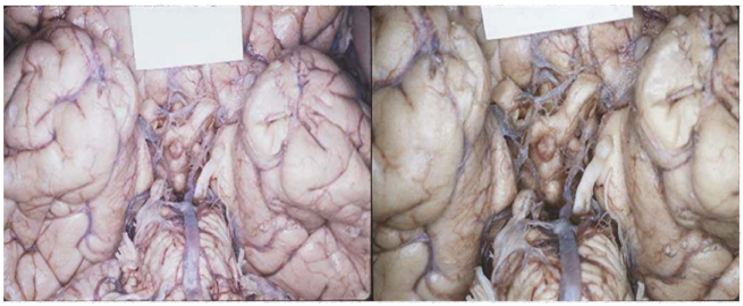


FIG. 1
(Prior Art)

More Explanation

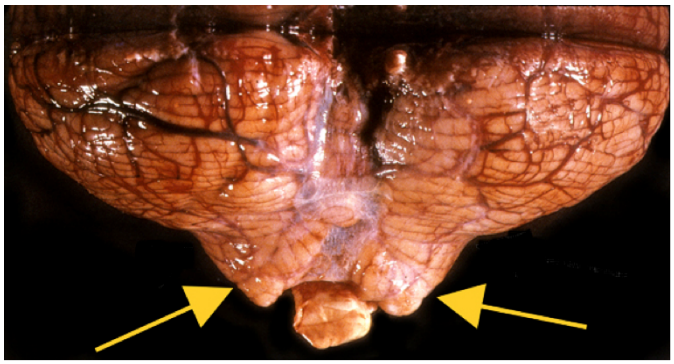


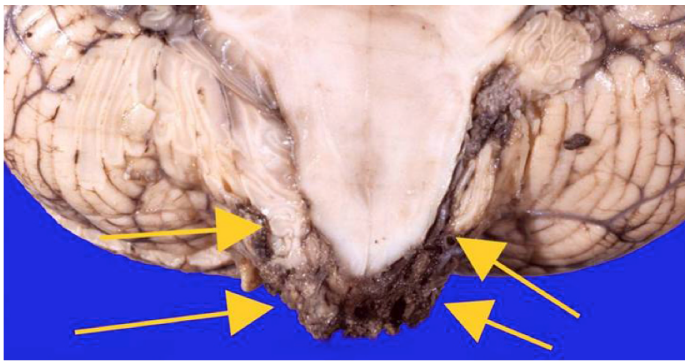


A right temporal hematoma would compresses the ipsilateral midbrain and compresses the 3rd cranial nerve that come from the midbrain causing **ipsilateral pupil dilation**, also compresses the corticospinal tract resulting in **contralateral weakness.**

Transtentorial herniation:
- Ipsilateral dilated pupil
- Contralateral weakness

This autopsy of the base of the brain, and you can see the temporal lobe, the third nerve is right close to the temporal lobe.
so any pressure here compresses the third nerve





This is autopsy shows tonsillar herniation, the tonsil is flattened peaked down from foramen magnum.

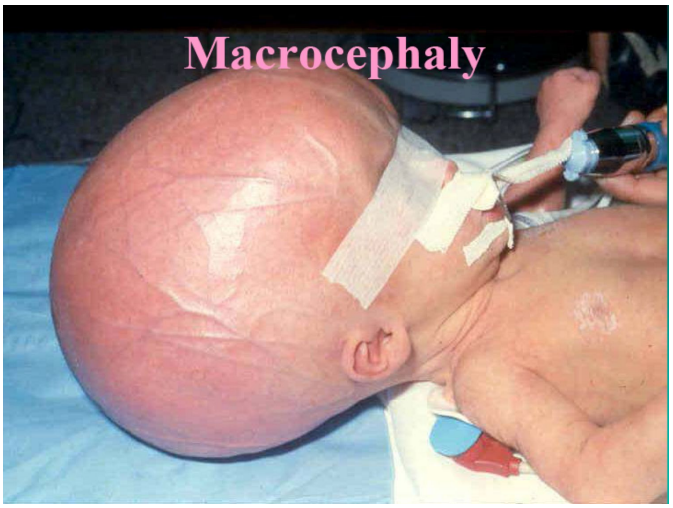
False localization

Although a patient with right frontoparietal extradural haematoma is **likely to have <u>left hemiparesis</u>**, in the presence of a transtentorial herniation, the uncus displaces the midbrain against the tentorium resulting in compression of the left crus cerebri which produces a **<u>right hemiparesis</u> → paresis ipsilateral to the lesion referred to as the Kernohan's notch.**

More explanation: we expect pressure from the right side to cause ipsilateral dilated pupil and contralateral muscle weakness, sometime the opposite happens → pressure from the right side causes contralateral dilated pupil and ipsilateral weakness, **<u>How?</u>** it depends which third nerve is compressed, sometimes the temporal lobe will not compress the ipsilateral third nerve, instead it will push the whole structures in the midline to the opposite side so the opposite third nerve is compressed, and this is called **Kernohan's notch.**

❖ Raised Intracranial Pressure (ICP) in infants

- Widened sutures.
- Increased Head circumference.
- Dilated head veins.
- "Sunset" eyes → Eyes are down.



Extreme photo of hydrocephalus → large head, shiny skin, dilated veins, wide sutures and if you can feel fontanel it is tense and purging as a reflection of the high pressure.

❖ Investigations

- URGENT **<u>CT</u>** for the head.
- **NO** Lumbar Puncture.

Even when you suspect meningitis don't ever do a lumbar puncture if the CT scan shows signs of raised ICP because this will create an exit for the system and everything (CSF can escape, as the CSF pressure drops in the spinal column, CSF and brain mass may then shift towards the low-pressure outlet (the LP site). This may lead to either trans-tentorial or uncal herniation and acute neurological deterioration) will come out and **herniate**.

❖What is the treatment of high Intracranial Pressure ?

General measures: (1st step→ consult a neurosurgeon)

- Head elevation (30 degrees). To improve venous return
- **No** neck compression.
- Mannitol for patients who have decreased level of consciousness LOC (or Furosemide).

Mannitol is an osmotic diuretic, that helps shrinking the brain a little bit, sucks out the fluids. It should not be used unless the patient is adequately resuscitated because it can aggravate hypovolemia and cause uncompensated shock.

- Steroids (Dexamethasone) for tumors

Because tumors are surrounded by edema, so the edema should be reduced; **not given in trauma.**

- Hyperventilation: controlled to PCO2 35-40 mmHg.

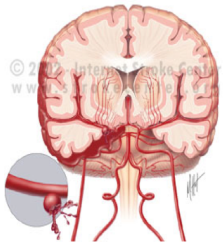
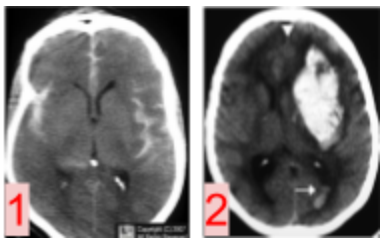
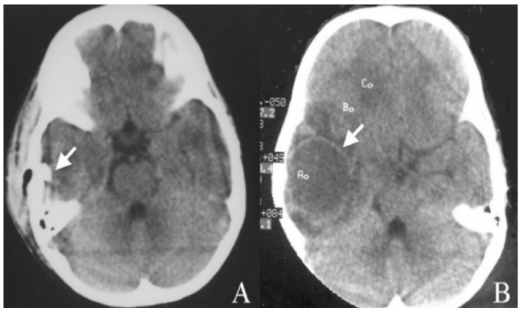
hyperventilation constricts blood vessels → decreased cerebral blood flow (the amount of blood in the brain will be decreased) → decreased ICP . Why? because CO2 is a very potent vasodilator. Low PCO2 reduces the volume of blood in the cranium which will allow more room for the intracranial mass lesion.

- Sedation, muscle relaxants. To slow down the system metabolism.
- Hypothermia[4]. also lowers the system metabolism. so the demand of the brain will be less
- Barbiturates: terminal option if everything fails.

You put the brain to coma like general anesthesia to lower the metabolic significantly to control the pressure.

Specific treatment:

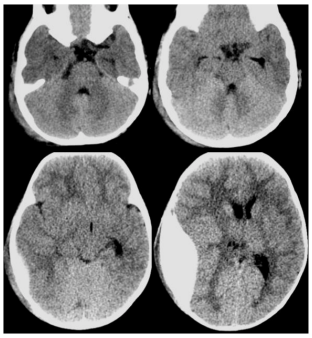
★ Depends on the cause; **VITAMEN D.**

Common causes of high Intracranial Pressure (ICP)	
1-Vascular - SAH / ICH	**2- Infection - Abscess**
  1-Subarachnoid hemorrhage SAH : ventricles and subarachnoid space should be black, but here the subarachnoid space appears white indicating hemorrhage. (commonly due to an aneurysm) Most common cause of non traumatic SAH is ruptured aneurysm. Treatment: the current standard of care for ruptured aneurysms requires early aneurysmal occlusion. There are two options for occlusion. The patient may undergo craniotomy with microsurgical dissection and placement of a titanium clip across the aneurysm neck to exclude the aneurysm from the circulation and reconstitute the lumen of the parent vessel. The second option is to "coil" the aneurysm via an endovascular approach. 2-Intracranial hemorrhage, large clot.	 Suspected infection from the ear, with contrast shows ring enhancement. Treatment is a medico-surgical emergency, as well as loculations of pus. CT permits the rapid diagnosis and localization of pus and greatly facilitates surgical drainage.
3- Trauma	

[4] The findings from the recently published multicenter randomized controlled trial demonstrated that hypothermia was of no benefits in patients with severe brain injuries

a- Localized

Epidural Hematoma



Biconvex appearance, why? Because normally there is no existing space between the skull and dura so the bleeding will create the space, but will be limited by the sutures.
Treatment: Open craniectomy for evacuation of the congealed clot and hemostasis generally is indicated.

Subdural Hematoma

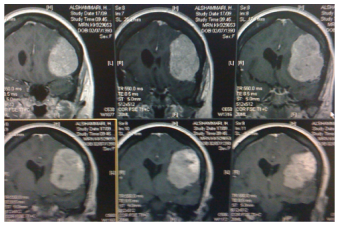
Semilunar appearance, why? Because there is normal existing space.
Treatment: Craniotomy is performed to remove the haematoma and arrest the bleeding

b- Diffuse

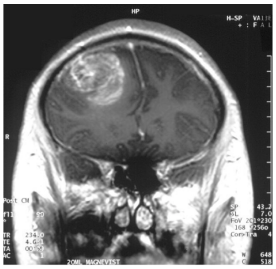
Diffuse axonal injury (salt & pepper appearance):
Caused by rotational head movement. It is common after high-speed motor vehicle accident.
The GCS is usually low (High mortality).

4- Tumor

Meningioma (Extra-axial)



Glioblastoma Multiforme (intra-axial)

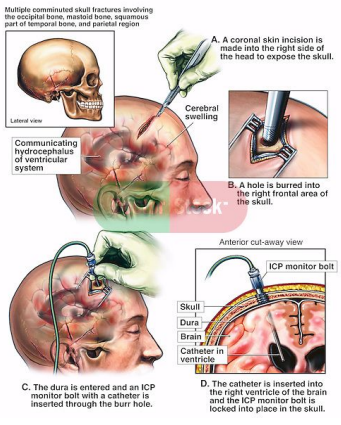


Management principles of surgical neuro-oncology generally rely on:
- obtaining tissue diagnosis.
- undertaking appropriate surgeries (craniotomy and tumour resection) to relieve patients' signs and symptoms.
- using appropriate radiotherapy and chemotherapy.
- providing support services for the patient and family.

5- Hydrocephalus

Large ventricles with accumulated CSF, treated usually with VP shunt.
Treatment consists of relieving the pressure by bypassing the block to CSF drainage. In some cases of aqueduct stenosis, this can be done in a minimally invasive way by endoscopic third ventriculostomy. In this procedure, using an endoscope a small hole is formed in the floor of the third ventricle, allowing CSF to flow into the basal cisterns. In most cases, however, a ventriculo-peritoneal (VP) shunt will have to be inserted.

Monitoring Intracranial Pressure:



Recall:

What is the Glasgow Coma Scale (GCS)?
GCS is an objective assessment of the level of consciousness after trauma.
What indicates coma by GCS score?
□<8 (Think: "less than eight—it may be too late").
What does unilateral, dilated, nonreactive pupil suggest 'blown pupil'?
Focal mass lesion with ipsilateral herniation and compression of CN III
What do bilateral fixed and dilated pupils suggest?
Diffusely increased ICP.
What is the initial radiographic neuroimaging in trauma?
1. Head CT scan (if LOC or GCS □15)
2. C-spine CT
3. T/L spine AP and lateral
Should the trauma head CT scan be with or without IV contrast?
Without!
What is normal ICP?
5 to 15 mm H_2O
What is the worrisome ICP?
□>20 mm H_2O
What determines ICP (Monroe-Kelly hypothesis)?
1. Volume of brain 2. Volume of blood 3. Volume of CSF
What is the CPP?
Cerebral **P**erfusion **P**ressure = □mean arterial pressure—ICP (normal CPP is >□70)
What is Cushing's reflex?
Physiologic response to increased ICP:
1. Hypertension
2. Bradycardia
3. Decreased RR
What are the three general indications to monitor ICP after trauma?
1. GCS <□9
2. Altered level of consciousness or unconsciousness with multiple system trauma.
3. Decreased consciousness with focal neurologic examination abnormality.
What non operative techniques are used to decrease ICP?
1. **Elevate** head of bed (HOB) 30□ (if spine cleared).
2. Diuresis-mannitol (osmotic diuretic), Lasix®, limit fluids.
3. Intubation (PCO_2 control).
4. Sedation.
5. Pharmacologic paralysis.
6. Ventriculostomy (CSF drainage).
What is the acronym for the treatment of elevated ICP?
"**ICP HEAD**":
INTUBATE
CALM (sedate)
PLACE DRAIN (ventriculostomy)/
PARALYSIS
HYPERVENTILATE TO PCO_2 approximately □35
ELEVATE head
ADEQUATE BLOOD PRESSURE (CPP> □70)
DIURETIC (e.g., mannitol)
Can a tight c-collar increase the ICP? Yes (it blocks venous drainage from brain!)
Why is prolonged hyperventilation dangerous?
It may result in severe vasoconstriction and ischemic brain necrosis!. Use only for very brief periods.

MCQS

1- A 33-year-old male patient who presented with a headache. An MRI showed a mass in the fourth ventricle. What do you expect to see in this patient?

A. High ICP with papilledema.
B. Dilated lateral ventricles with normal 3rd and 4th ventricles.
C. Obstruction of the foramen Magnum.
D. Diffuse brain edema.

2- A 55-year-old women presented with hemiplegia. She has a history of cancer. Brain MRI was done and showed multiple enhanced lesion in the brain with high intracranial pressure. What is the best step in initiating the management?

A. Cortisol.
B. Elevate the head.
C. Mannitol.
D. Consult a Neurosurgeon.

3- Male admitted to the ICU with head injury. He was sedated and on ventilation. His ICP was 20 and continue as 20. After while it suddenly rise to 40. What is the next best step?

A. Give phenytoin.
B. Give steroids.
C. Arrange urgent CT.
D. Take him to the operative room.

4- 34-year-old male sustained a head injury. His ICP was 20mm/hg. What is the optimal mean arterial pressure required to maintain adequate cerebral perfusion?

A. 60mm/hg
B. 70mm/hg
C. 80mm/hg
D. 90mm/hg

5- 4 weeks preterm baby with rapid head enlargement ,the anterior fontanel was large and bulging and the skull sutures were widely separated.
ultrasound shows increased brain ventricles size.
What is the most likely cause of hydrocephalus in this case?

A. Brain tumor.
B. Meningitis.
C. Intraventricular hemorrhage.
D. Aqueductal stenosis.

Answers
1-A
2-D
3-C
4-D
5-D