Raised Intracranial pressure(ICP)

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First, the human skull is a rigid closed cavity that does not pair any expansion in volume or increase in pressure.

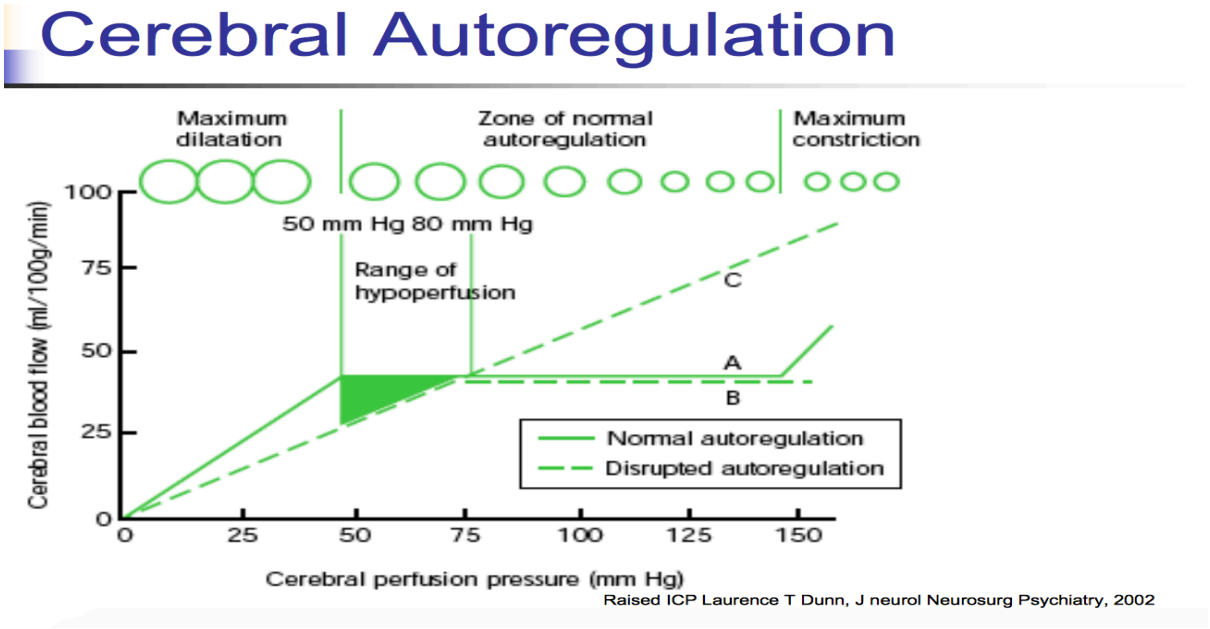
Components of the cranium:

- Brain 1400 ml
- CSF 75-100 ml
- Blood 75ml

Because most components of the brain are water the brain is incompressible.

Most liquids have very small compressibility since there's not much space between the molecules to move closer.

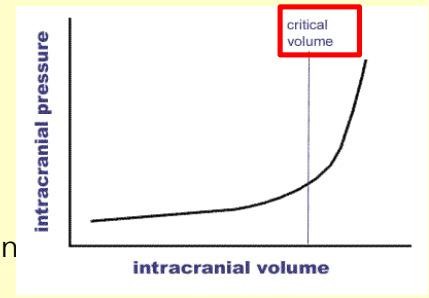
Intracranial pressure: is the pressure inside the cranium (skull), **normal** values are:
ADULTS: <10-15
CHILDREN: 3-7
INFANTS: 1.5-6
These values fluctuate in response to intrathoracic pressure (ex: coughing) and cardiac pulsations.



Monroe-Kellie Doctrine[1]: this hypothesis stasis that The cranial Pressure is in equilibrium due to the interaction of 3 components: *CSF, blood & brain tissue*, and those components are incompressible so a change in one will lead to change of the others.

To understand this: The adult skull is a closed cavity & because of that it has a constant intracranial volume (intra cranial volume=the volume of the brain components[2]) if there were any changes in the volume of the brain due to any reason (ex: brain lesion) the intracranial pressure wouldn't change due to compensatory mechanisms which will try to keep the brain in as much equilibrium as possible.

What are the compensatory mechanisms?



1- Changes in CSF volume
2- Changes in Blood volume
3- Displacement of brain tissue to other regions which are of a less pressure leading to herniation of the brain

Types of herniation:

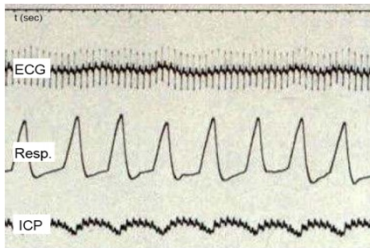
A. Cingulate herniation (Subflacine)
B. Uncial herniation (Transtentorial)
C. Central herniation
D. Outside herniation
E. Tonsillar herniation

(Will be discussed in details later)

Until a certain point those mechanisms can compensate till they reach a critical point where compensation wouldn't help to exceed the intracranial pressure that's occurring, so at that point any small changes in the volume will increase the intracranial pressure dramatically and at this point the symptoms will start to occur, those mechanisms will occur depending on the progression of the increase of volume:

ICP waveform:

corresponds to changes in hemodynamics & intra respiratory system, its controlled by the blood pressure and therefore the ICP is a dynamic process.



[1] A principle or body of principles presented for acceptance or belief
[2] Brain tissue / blood / CSF
[3] The failure of an organ to compensate for the functional overload resulting from disease

Cerebral Perfusion Pressure:

because brain is a valuable organ it can't be affected with changes in systemic blood pressure or else it will suffer from aneurysms & hemorrhages , for this reason the cranial blood vessels maintain the cerebral perfusion rate within a strictly detriment limits :

- A rise in the systolic blood pressure ➔ will cause constriction of cerebral arteries ➔less blood coming ➔ less pressure.
- A drop in the systolic blood pressure ➔ will cause cerebral vessels to dilate for accommodation ➔more blood ➔ increase blood pressure.
  Hence, the cerebral blood perfusion will not affect the *Cerebral Perfusion Pressure*.

CPP = MAP – ICP

CPP 50-140 mmHg, Recommended to keep it above 70 in head injuries

But a constant increase in blood pressure will increase cerebral perfusion rate which ultimately will increase to the point where the autoregulation mechanisms fail, and the cerebral blood perfusion will be affected by the systemic blood pressure, this disruption in the auto regulatory mechanisms will affect the blood supply (with increase pressure➔ blood supply will increase) and this could cause bleeding inside the brain.

INCREASED INTRACRANIAL PRESSURE:

an increase in volume[1] of brain due to any reason which will increase the pressure inside the cranium causing symptoms.

[1] brain volume = blood volume+ CSF volume + brain tissue, a change in these components leads to increased ICP

Causes:

VITAMEN D

- **V**ascular
- **I**nfection
- **T**rauma
- **A**utoimmun
- **M**etabolic
- **E**ndocrine
- **N**eoplastic
- **D**rugs

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:

Headche

Early morning

very characteristic

Throbbing / Bursting

increases with intrathroacic pressure

Papilledema

take several days to develop

It can be associated with fundal hemorrhage and this indicates acute and severe rise in ICP.

This symptom is reliable but may take several days to develop. Therefore when a patient comes to the ER with raised ICP, he is not examined for papilleodema first.

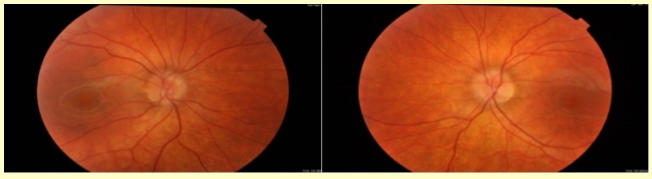
Vomiting

To understand this: HEADCHE: patients with raised ICP have an early morning headache due to the fact that while laying down asleep the venous return to the brain increase which will increase the ICP, that's why they have an EARLY MORNING HEADCHE, the ICP is affected by the ITP, because increase in the intrathoracic pressure will keep the blood from coming down and this will increase the ICP.

VOMITTING: the area postrema[4] is located on the dorsal surface of the medulla oblongata at the caudal end of the forth ventricle, an increase in the ICP will be transmitted throughout the ventricles, resulting in increased pressure within the forth ventricle this in turn stimulates the vagal nucleus resulting in emesis.

Papilledema: raised ICP will be transmitted to the optic nerve through the subarachnoid space because the optic nerve is continuous with the subarachnoid space.

When you look into the eye you'll find a blurred optic disk because the venous return from the eye that's supposed to go to the head, wants to go but it finds it very high pressure so it becomes congested. Thick congested veins cause edema.



Signs upon neurological examination:

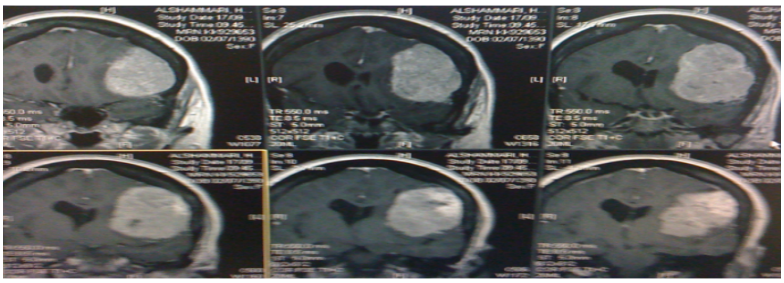
- Hemiplegia (any weakness)
- decreased mental abilities
- confusion about time, and then location and people as the pressure worsens
- Pupillary dilation[5]

Systemic reaction to increased ICP:

Blood pressure will rise, if ICP is high and MAP is low your CPP will go down (CPP=MAO-ICP) so MAP has to go up to overcome the rise in ICP, & if there is a compression on the respiratory centers will have *a Cheyne-Stokes breathing:* which is a Oscillating periods of apnea-tachypnea and these are all signs of compression.

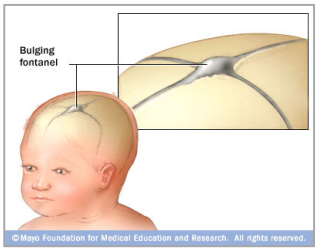
Can somebody walk around with a raised ICP?

Yes, because as we mentioned earlier brain is able to accommodate up to a certain point.



Coronal section MRI showing a tumor compromising the intracranial space causing a midline shift and growing very slow so brain was able to accommodate.

Raised ICP in infants:

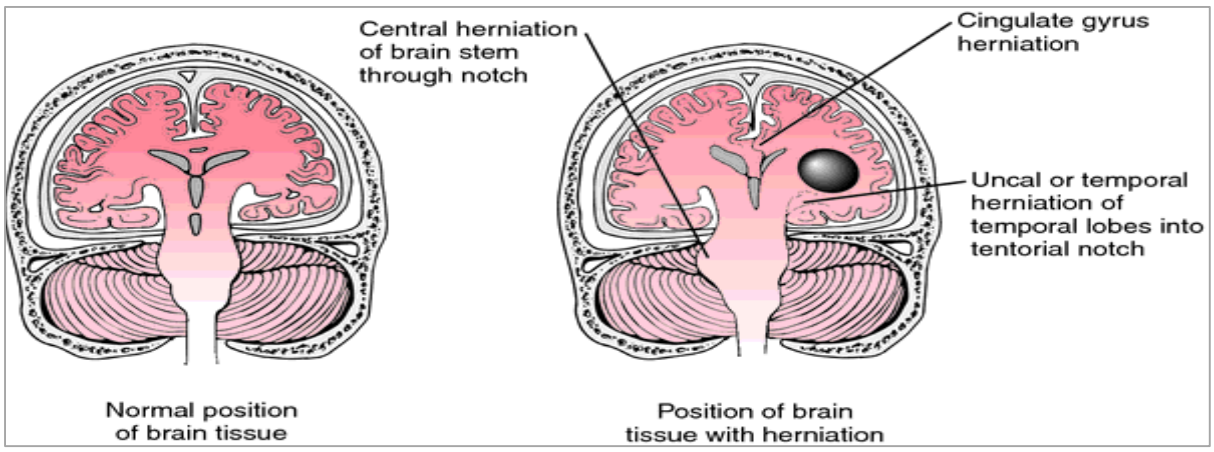


Skull here isn't fully developed yet so it can accommodate:

- Widened sutures
- Increased Head circumference
- Dilated head veins
- "Sun set" eyes "his eyes always looking down" pushed down
- Tense and bulging fontanels (normally flat and sunken except if he cries it bulge and come flat again)
- Head is to large (Macrocephaly)
- A lots of dilated veins.

Kernohan's notch:

- phenomenon with a false-localizing sign
- brain lesion is on one side, pupillary dilatation is on the contralateral side, and hemiparesis is on the ipsilateral side (both are reversed)
- etiology is mass effect from either a brain tumor or intracranial bleed, pushing the hemisphere (and the brainstem) contralaterally which leads to the contralateral brainstem being pushed against the tentorium cerebelli
- Compression of contralateral brainstem (where the corticospinal tract fibers are), leads to weakness on the side ipsilateral to the brain lesion (the fibers decussate further down in the medulla)
- Revise the anatomy ☺



Brain Herniation:

Because as mentioned previously our brain is mainly consisting of water any changes trying to compress it will make it shift (herniate) to areas with less pressure, Types of brain herniation are mentioned below:

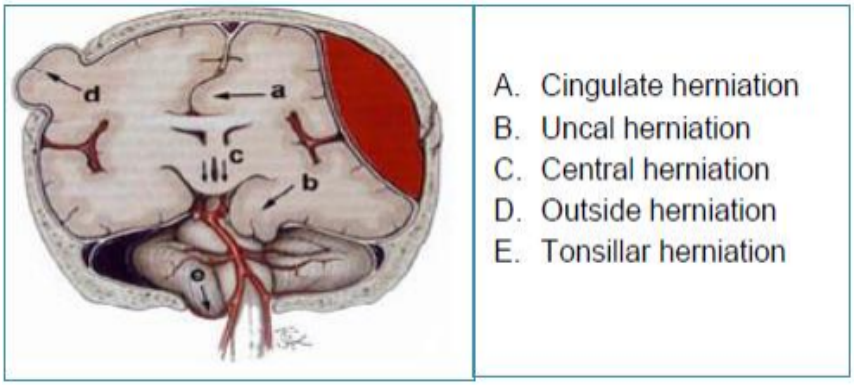
- **Uncal herniation:** It is the most common clinically seen type of brain hernias. Uncus is the most medial part of the temporal lobe. It's the part that is going to be herniated. If there's an increased ICP, the uncus goes above the tentorium and compresses the brainstem, causing dilated pupil "3rd cranial nerve affected", coma state and hemiplegia.(ipsilateral dilated pupil, contralateral weakness)[6]

- **Central herniation:** If there was a hematoma or mass that compresses the upper part, it will push the whole brain down through the tentorial opening.

- **Tonsillar herniation:** This type is fatal. If there was massive increase in the ICP especially that around the cerebellum, the tonsil will come down through the foramen magnum and will compress the lower medulla where the center of respiration lays and the patient will stop breathing

- **Cingulate herniation:** subfalcine herniation, it's when the left side of the brain is compressed and pushes the right side then goes under the falx cerebri to other side.

- **Outside herniation:** If there was a skull fracture and the pressure inside was so huge so the brain will look for the easiest way to be out.



Glasgow Coma Score:

Neurological scale which aims to give a reliable and objective way of recording the conscious state of a person for initial as well as subsequent assessment.

Relies on 3 things:

1- The ability to open the eyes
2- Verbal responses
3- Motor responses.

Glasgow Coma Score		
Eye Opening (E)	**Verbal Response (V)**	**Motor Response (M)**
4=Spontaneous 3=To voice 2=To pain 1=None	5=Normal conversation 4=Disoriented conversation 3=Words, but not coherent 2=No words.....only sounds 1=None	6=Normal 5=Localizes to pain 4=Withdraws to pain 3=Decorticate posture 2=Decerebrate 1=None
		Total = E+V+M

Mild GCS= 13 – 15

Moderate GCS= 9 – 12 Severe GCS= 3 – 8*

*Lowest, he might die within days.

Investigations:

Physical Examination: check for Papilledema

Imaging: urgent CT to the head

Lumbar Puncture: is contraindicated until you do at least the CT (because if you take the CSF from the back and there was high pressure in the brain, it will cause tonsil herniation which will kill the patient because he won't be able to breathe.)

Treatment:

General Measures:

- To increase the venous return, elevate the Head (30 degrees) to help with venous return.
- No neck compression to relief veins
- Give Mannitol[1] for patients who have decreased LOC (or Furosemide) it will increase osmotic pressure in vessel & suck fluid from intracellular.
- Steroids (Dexamethazone) only for tumors (a lot of edema around the tumor, it can be controlled by giving dexamethazone).
- Hyperventilation: controlled to PCO2 35-40 mmHg a lot of hyperventilation.

To understand this: when you hyperventilate you wash out Co_2 , Co_2 is very potent vasodilator if the patient has a lot of Co_2 , cerebral vessels would dilate and blood flow increases and ICP increases as will ,

so when you hyperventilate to washout Co_2 > cerebral vessels constrict and you decrease ICP , but don't drop it too much to the extent where no blood comes to brain .

- Sedation, muscle relaxants decrease metabolic rate
- Hypothermia decrease metabolic rate
- Barbiturates: terminal option if it cannot be controlled , you put the brain in complete relaxation.

[1] Mannitol is an Osmotic diuretic, goes into the blood, makes the blood very light and will suck fluids 12

Specific treatment: Depends on the cause of raised ICP (VITAMIN D)

- Vascular: Subarachnoid hemorrhage, intracranial hemorrhage
- Infection/Abscess: Rounded space In IV drug abusers or immune suppressed patients, with sinusitis. Sustained infection, that when you give contrast
- Trauma:

- *Localized:* Direct insult to one area (epidural hematoma, subdural hematoma)

* Epidural hematoma: mostly affecting middle meningeal artery and it results in an overlying skull fracture

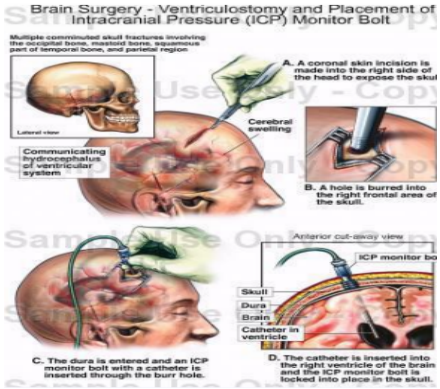
*Subdural hematoma: it results from a less severe trauma caused by rupture of a bridging Veins, seen in older individuals

- Diffuse: Severe shaking of head

- Tumor: midline shift to other side, edema around it (Meningioma, Glioblastoma Multiformi). (you dissect the tumor)
- Hydrocephalus: Treated with shunt, ventricles enlarged, diffusion of CSF into brain substance.

Can we monitor ICP?

ICP can be monitored by inserting a catheter in the right ventricle of the brain substance to give pressure and suck fluid and by this the cerebral perfusion pressure can be maintained.



CASE :

20 year old man. Had car accident (MVC) as unrestrained driver. He presented with BP 75/30, HR 125 bpm. Unconscious, with right hemiplegia. What to do next?

Airway: intubation
Breathing: look at chest and measure O2 saturation
Circulation: 2 large IVs and you will run fluid
Disability: do CT to discover the reason of the hemiplegia
Neurological Exam:

- Pupillary dilation
- Hemiplegia
- Cranial nerve deficit