432 Surgery Team

7 RAISED INTRACRANIAL PRESSURE

Done By:
Nourah Al-ajmi
Sarah Bin Abdulqader

Reviewed By:
Omar alzuman

جامعة الملك سعود
King Saud University

COLOR GUIDE:• Females' Notes• Males' Notes• Important• Additional

Objectives

Not given

Introduction

- The skull is like a rigid box that doesn't allow any expansions:

It contains: the brain (volume measured is 1400 ml), meninges, vessels,

Blood (volume measured is 75 ml), and CSF (volume measured 75- 100ml). Water, blood, and CSF are incompressible.(brain is incompressible because it contain high amount of water)

Note(s):

Doctrine means a particulate system of principles taught of advocated.

- The pressure in the skull is called the Intra-cranial pressure (ICP). The ICP must stay balanced in order for the survival of the brain.

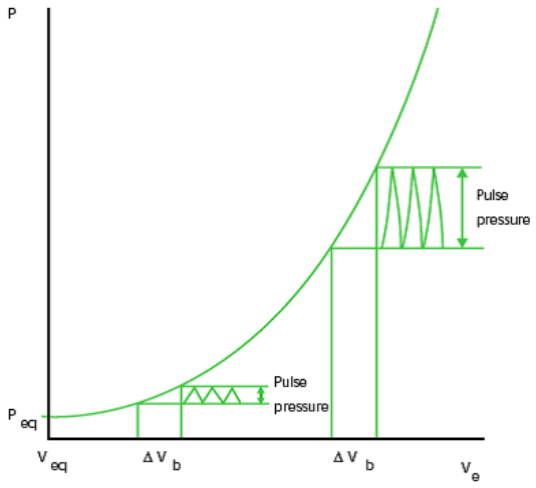
1- BASIC PRINCIPLES OF ICP

a. MONRO-KELLIE DOCTRINE:

- This principle states that any change in the brain's volume is associated with a change in CSF or blood volume.
- When the volume of the brain increases, the other components will have to Compensate. CSF will decrease and vasoconstriction will occur in order to Decrease the blood volume.

b. VOLUME – PRESSURE CURVE:

- Increase in the volume of one compartment will lead to change in the volume of the other ones.
- When the blood volume increases, the ICP will increase but the cranium's components' accommodation will keep it balanced until a certain level where even, a small increase in the volume can take the curve over and will no longer be able to accommodate leaving the ICP with a sudden increase. At this point, symptoms such as headache, nausea, vomiting, numbness and weakness will start to occur.
- Assume that brain develops a tumor. Depending on how fast the tumor grows, the pressure will either increase slowly and be tolerated, or massively (Ex, sudden hemorrhage) and lead to comatose.
  (Slowly growing tumor or abscess > there is time for compensation so there is no increase in ICP, while acute hemorrhage cause increase ICP)
- Example 1: A patient came to the ER complaining from headaches. He was conscious when the doctor talked to him and examined him. Few minutes later he collapsed and went into a coma. In this case, the patient was at the at edge of the pressure - volume curve
- Example 2: A patient with a brain tumor that grows 1 mm yearly, his brain will have enough time to accommodate, CSF will get a lot of time to change its absorption and production pattern, and the blood flow will change and has time to accommodate. Unlike a sudden change which isn't tolerated well.



At the beginning of increase in volume there is little change in pressured due to accommodation of other component (brain volume increase > CSF and blood volume will decrease) , until certain level where even small change in volume result in increase in ICP

c. ICP WAVEFORM:

- Any pressure has a waveform.
- The ICP waveform corresponds to the cardiac waveform. So when systole occurs, there will be a rise in the ICP waveform. It gives the brain pulsation and this pulsation is what forms the ICP. Pulsation of heart is transmitted into the great vessel then into the internal carotid artery and into the brain.

d. NORMAL ICP VALUES:

Table 1 Normal intracranial pressure values

Age group	Normal range (mm Hg)
Adults	<10–15
Children	3–7
Term infants	1.5–6

Note(s):

Because children have softer bones, their ICP value is lower. Infants have lesser ICP =1.5 – 6**because their bones haven't united yet.up)**
fontanelle: soft membranous gaps between the cranial bones>to allow stretching because brain expands faster than the surrounding bone can grow

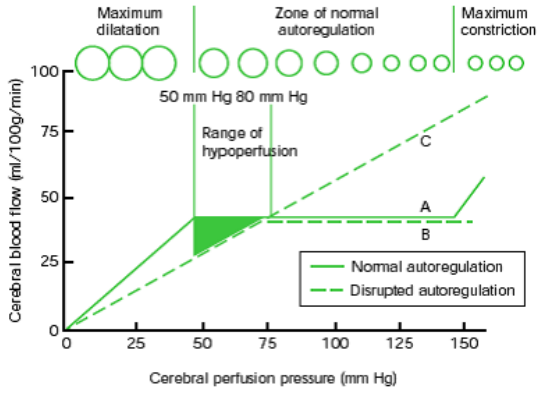
2- CEREBRAL PERFUSION PRESSURE :

- Cerebral perfusion pressure is the pressure coming from the blood rushing into the brain (impaired with increase ICP)
- It has a very wide range between 50 and 140 mmHg
- In trauma cases, it is preferred to keep cerebral perfusion pressure around 70.
- The brain only dysfunctions at a very high extreme pressure or very low extreme pressure.

a. CEREBRAL AUTOREGULATION:

- It is the ability of cerebral vessels to maintain cerebral perfusion within strictly determined limits.
- Mechanisms of cerebral auto-regulation:
    - A rise in the systolic blood pressure will cause constriction of cerebral arteries.
    - A drop in the systolic blood pressure will cause cerebral vessels to dilate for accommodation.
    - This will help keep the person conscious and able to judge.
    - Example: someone got dehydrated; s/he will still be able to go drink water. But if the brain collapsed, one won't be able to protect him/her self.

- If there is a repetitive increase in the pressure such as hypertension, the brain vessels will start to develop small aneurisms. They're very tiny aneurisms that develop on the small arterioles and at some point they rupture and cause hypertensive hemorrhage to the brain.
- Loss of auto regulation will cause changes in cerebral blood flow with changes in the BP levels.
- Increase of pressure will constantly increase the blood flow pressure. When it reaches to an extreme abnormal state, the auto regulation will then fail.
    - Example:. 25:25 , 50:50. 75: blood flow pressure remains constant.
- Disrupted auto-regulation: BBB or vessels badly affected like bad hematoma or bad contusion of brain. In that area, increased pressure will increase flow and this area can bleed inside.



Increase of pressure will constantly increase the blood flow but.When it reaches to an extreme (very high or very low) , the auto regulation will then fail.

Note(s):

. . . . . .

. . . . . .

MAP = mean arterial pressure and it's the blood coming from the body to the brain.

b. MEASUREMENT OF CPP

• The heart pumps the blood with pressure into the brain. The brain has its own pressure. The pressure that goes into the brain has to be the average pressure in the head subtracted from the average of the blood's pressure.
CPP = MAP – ICP

1) MEASUREMENT OF MEAN ARTERIAL PRESSURE

• The systolic heart beats over the diastolic heart beats divided by 3.
• You can find out by using the blood pressure cuff and connecting it to a monitor in the ICU where it will show the results there.

2) MEASUREMENT OF ICP

• It is measured by inserting a catheter into the head.
• ICP can be adjusted by giving fluids or medications that can increase the pressure and by this the cerebral perfusion pressure can be maintained.
• Example: if a MAP of someone was = 85. And the ICP was = 15
Raised Intracranial Pressure
Measure the CPP = 85 -15 = 70.
(Recommended to keep it above 70 in head injuries)
• In a case of trauma with bad head injury:
ICP and MAP must be measured, CPP must be around 70. If it was around 40 then BP must be increased or ICP must be decreased.(in case of trauma patient will have high MAP but we must not try to decrease it because it is a compensatory mechanism for increase ICP to maintain CPP)
• If ICP goes up, how does the brain get perfusion? Process of auto-regulation.

3- RAISED ICP

Any abnormal contents such as masses, tumors or hematoma will cause an increase in the pressure which will affect the brain.

a. CAUSES OF RAISED ICP

• Vitamin D → is an Acronym to remember the causes of raised ICP:
Vascular, **I**nfection, **T**rauma, **A**utoimmune, **M**etabolic, **E**ndocrine, **N**eoplastic, **D**rugs
• ICP causes can be classified in several ways. It can be classified according to the structures over there. If the problem was in the brain causes can be tumor, traumatic contusion, CSF obstruction, obstructive hydrocephalus, thrombosis, etc.
• Or classified according to major pathological criteria: infection, trauma, and tumor.

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

Idiopathic intracranial hypertension= benign intracranial hypertension = pseudotumor cerebri increased intracranial pressure in the absence of a tumor or other diseases. The main symptoms are headache, nausea, and vomiting, as well as pulsatile tinnitus double vision and other visual symptoms. If untreated, it may lead to swelling of the optic disc in the eye, which can progress to vision loss.

IIH is diagnosed with a brain scan (to rule out other causes) and a lumbar puncture; lumbar puncture may also provide temporary and sometimes permanent relief from the symptoms. Some respond acetazolamide), but others require surgery to relieve the pressure. The condition may occur in all age groups, but is most common in women aged 20–40, especially those with obesity

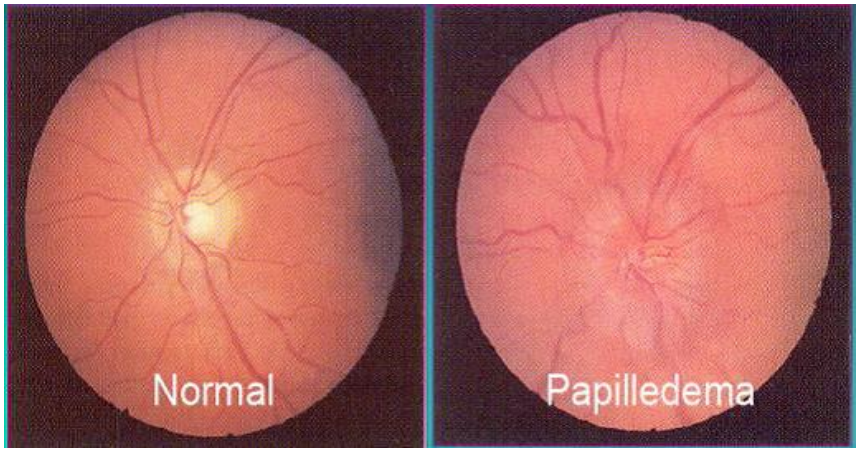
b. SIGNS AND SYMPTOMS

Triad (1- headache 2- vomiting 3- papilledema)

- Vomiting
- Headaches:
    - Characteristics of the headache:
        - Early morning headaches. It is very characteristic. Once the patient wakes up with a really bad headache, when he's in his best situation. What happens? Patient was laying flat during sleeping which will increase venous return and the amount of blood reaching the brain will increase. But when the patient is sitting upright, gravity will take blood down and ICP will decrease.
        - Throbbing / Bursting
        - It increases with sneezing and coughing. Coughing and sneezing will increase intrathroacic pressure which will keep the blood from coming down and this will increase the ICP
- Papilledema:
    - It's important to examine the fundus in patients with raised 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.
    - It can be associated with fundal hemorrhage and this indicates acute and severe rise in ICP.
    - It happens only with chronic problems like with growing brain tumor.

- 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's finding very high pressure so it becomes congested.

- Thick congested veins cause edema.



  - Increase pressure in brain → veins within optic nerve become congested → whole optic nerve head becomes congested.
  - Very large tortures veins , elevated and floored optic disk margin can be seen.

- In Neurological exam the most common signs:
  - Hemiplegia (any weakness)
  - Cranial nerve deficit
  - Pupillary dilation:
    - It is one of the earliest signs that occur and it is very characteristic.
    - The pupil dilates or constricts based on the Occulomotor nerve that comes from the midbrain in the brainstem (figure -1-), just next to the temporal lobe.
    - So if the temporal lobe is pushed, it compresses the nerve. In the beginning of herniation, this nerve will be affected.
    - If there is a mass compressing the 3rd nerve → ipsilateral pupil dilation (and not reactive to light) and contralateral hemiplasia "weakness" will occur.

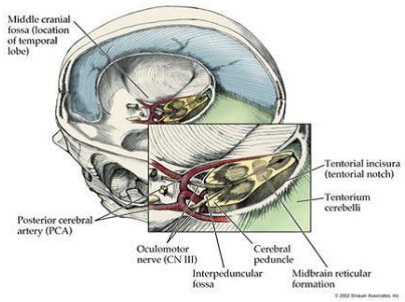
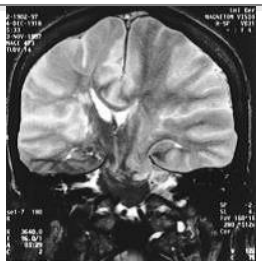


Figure 1: Coronal cut MRI shows u the same thing



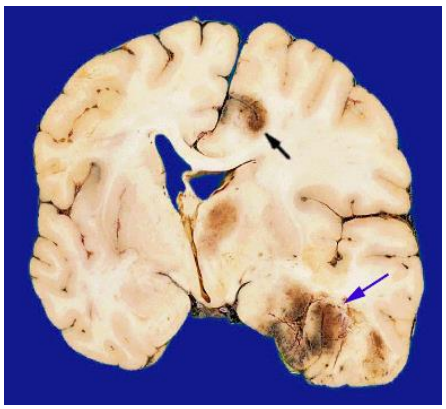


Figure 2: This pathological picture shows Cingulate herniation (subfalcine herniation), central herniation, and some Uncal herniation. Blood in temporal area, basal ganglia, frontal area.

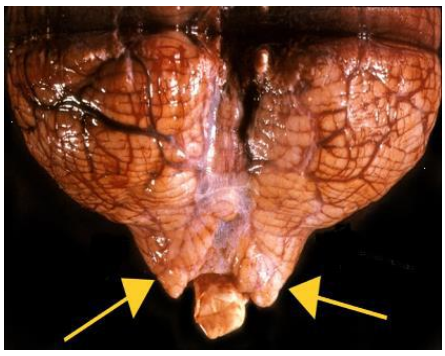


Figure 3: Tonsillar herniation, tonsil comes down from foramen magnumand bone compress it make it flat

Systemic reaction to increased ICP:

- Raised BP (recall: CPP=MAP-ICP) blood is pumping so high to compensate (you rise MAP by rising systolic BP) if you drop his Bp you Kill him
- When you have a raised ICP, if you increase the ICP how to maintain a good CPP? By increasing MAP.
- Respiratory changes:
  - Cheyne-Stokes breathing: not seen in every case
  - Oscillating periods of apnea-tachypnea.
  - A lot of pressure on the brainstem (stop breathing →suddenly breathing fast → again suddenly stop breathing...Etc).
- Cushing triad: high BP, irregular breathing (Cheyne-Stokes breathing), bradycardia

Raised ICP in infants results in: 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: false localizing sign

- Simply, when there is a huge growing right side hematoma it will push the whole brain stem to the opposite side (it will push the whole brainstem against the contralateral tentorium) and that may cause ipsilateral weakness and contra-lateral dilated pupil.
- Don't take any patient to the OR room unless we do a CT to make sure.
- This sign is used to clinically estimate the side of bleeding.
- CT scan is done to know the exact location of the bleeding.

Glasco Coma Scale

- It is very important for the assessment of the severity of coma.(so will be easier to estimate prognosis)
- It relies on 3 things: the ability to open the eyes, verbal responses and motor
- responses.
- If a patient's GCS was 3 (which is the lowest), he might die within days.
- If a patient's was GCS 14, he should be admitted to the hospital for 2 days then leave.

- When it comes to head injury there is a classification of GCS:
  - Mild GCS= 13 – 15
  - Moderate GCS= 9 – 12
  - Severe GCS= 3 – 8
  - The lowest number in GCS is 3 and the highest number is 15

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

Raised ICP and brain herniation

• Most of our body organs contain water. If you try to compress an organ that is full of water, this organ is going to shift. And this is what happens in case of raised ICP.
• When ICP increases, the brain goes under so much pressure that it will go to least resistance part in the brain and go out through it
→ brain herniations.
• If there was a severe brain compression, the brain is going to shift and go through an opening such as foramen magnum which will compress the respiratory center in the brain stem and cause a fatal problem.

Note(s):

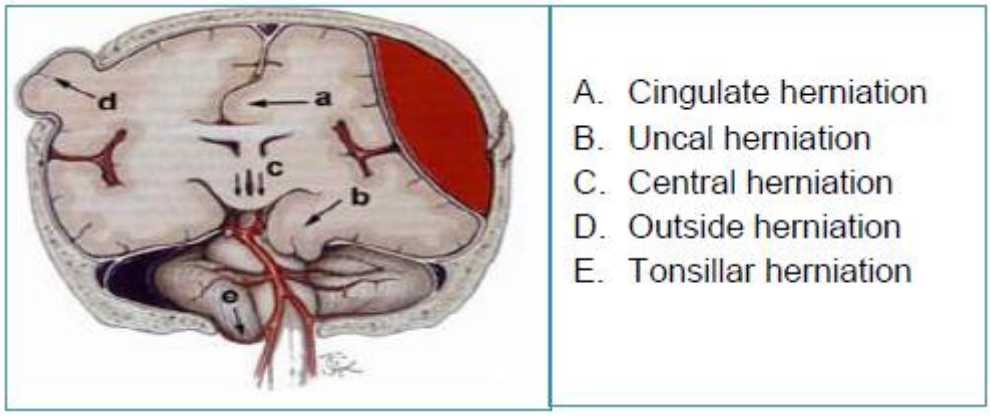
-Hemiplegia means total paralysis of the arm,
leg, trunk of the same side of the body.

-Tentorium is a membranous cover of cerebellum the process of the dura mater supporting the occipital lobes and covering the cerebellum

Types of brain herniation:

- **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 hemiaplagia.(ipsilateral dilated pupil, contralateral weakness)
- **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 centre 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.



Investigation

- If a patient came with headache and vomiting, check for Papilledema and do an 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.)**
- If also has fever, you start by checking for Papilledema and do a CT before doing Lumbar puncture to rule out meningitis.

Treatment

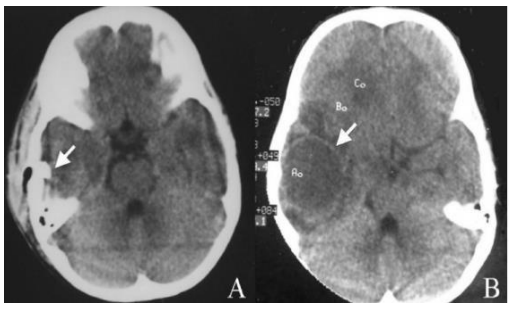
General Measures:

- To increase the venous return, elevate the Head (30 degrees) to help with Venous return
- No neck compression to relief veins
- Give **Mannitol** 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 →wash out CO2 →shrink blood vessels (decrease the amount of blood reaching brain) a CO2 is a very potent vasodilator so you want to decrease the amount CO2 so the blood vessels will go down and ICP will go down, a controlled hyperventilation. Lower CO2 but keep it within normal
- 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.

> ***Note(s):***
>
> Mannitol is an Osmotic diuretic, goes into the blood, makes the blood very light and will suck fluids

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 → enhanced. See picture (big collection of pus)



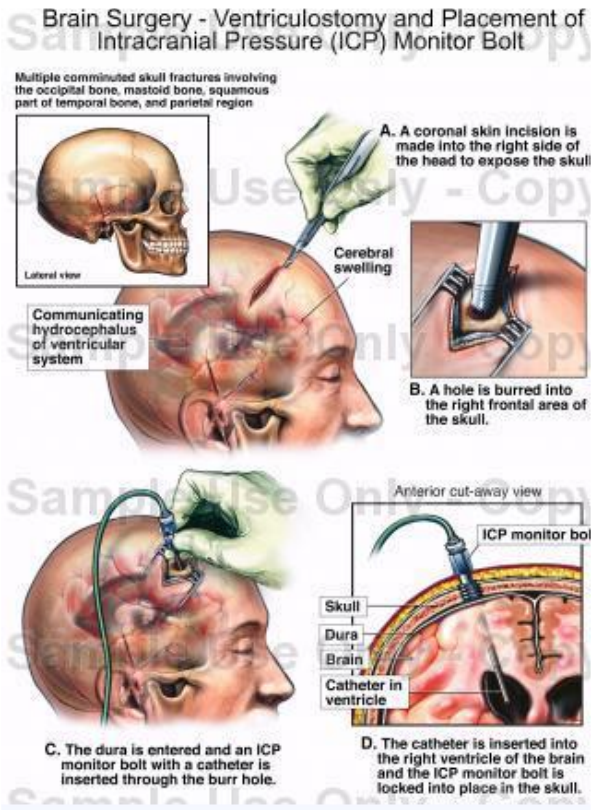
- Trauma:
  - Localized: Direct insult to one area (epidural hematoma, subdural hematoma)
    * Epidural hematoma: mostly affecting middle meningeal artery and it results in an overlying skull fracture
    *Subdural hematoma: it results from a less severe trauma caused by rupture of a bridging Veins, seen in older individuals

- Diffuse: Severe shaking of head → cut of Fx → Salt and pepper appearance of blood scattered around in brain

- 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.



Note(s):

A patient came comatose to ED and was diagnosed by CT with epidural hematoma, would you measure his/her ICP? No! the management of this patient is surgical intervention by removing the hematoma

SUMMARY

From Principles &practice of surgery

1. The rigid bony framework enclosing the central nervous system means that any increase in mass content increases intracranial pressure (ICP)
2. Acute increases in ICP lower perfusion pressure and, if unrelieved, lead progressively to decreased Coma Score, herniation syndromes, bradycardia, hypertension, respiratory abnormalities (e.g. apnoea), vasoparalysis and death
3. The principal symptoms of chronic raised ICP are headache, vomiting and visual disturbance (blurring of vision). Papilloedema may be apparent
4. If ICP is due to a unilateral mass lesion, intracranial structures may be displaced. There are three major forms of herniation: subfalcine, transtentorial and foraminal.

IMPORTANT NOTES FROM EXTERNAL RESOURCES

	Notes
Essential Neurosurgery By Andrew H. Kaye	Papilloedema is the definitive sign of raised intracranial pressure
	As intracranial pressure rises, in order to maintain a constant CPP, there has to be a compensatory rise in the systemic blood pressure. A hypertensive response is therefore elicited which is classically associated with a bradycardia. This is termed the Cushing reflex
	Sixth nerve palsy, causing diplopia, may occur in raised ICP

Questions

1) The Glasgow coma scale (GCS) is dependent upon the following except:
   A. Response to speech
   B. Response to pain
   C. Response of the pupils
   D. Best response
   E. Response of the patient

2) Severe head injury is defined as Glasgow coma score of:
   a. 3
   b. 3-9
   c. 10
   d. 11-12

3) Which of the following statements regarding the Glasgow coma scale is true?

A. It serves as a scale to assess the long-term sequelae of head trauma
B. A high score correlates with a high mortality
C. It includes measurement of intracranial pressure
D. It includes measurement of papillary reflexes
E. It includes measurement of verbal response

Explanation: The Glasgow coma scale was developed to enable an initial
assessment of the severity of head trauma. It is now also used to standardize serial neurologic examinations in the early post injury period. It measures the level of consciousness using three parameters: verbal response (5 points), motor response (6 points),
and eye opening (4 points). The score is the sum of the highest number
achieved in each category. The fully oriented and alert patient will receive a maximum score of 15. A score of less than 5 is associated with a mortality of over 50%.

4) An acute increase in intracranial pressure is characterized by which of the following clinical findings?

A. Respiratory irregularities
B. Decreased blood pressure
C. Tachycardia
D. Papilledema
E. Compression of the fifth cranial nerve.

Explanation: The onset of irregular respirations, bradycardia, and finally increased blood pressure with increasing intracranial pressure (ICP) is termed the Cushing response. These physiologic alterations are caused by brainstem compression. Slow rises in ICP are, by contrast auto regulated by the brain's compensatory mechanisms and lead to a late onset of neurologic sequelae. A mass lesion is more apt to compromise local cerebral blood flow and increase cerebral edema and ICP. The vector of the mass effect may lead to herniation of brain parenchyma through the tentorial incisura or foramen magnum with resultant brainstem compression. Herniation usually causes compression of the third cranial nerve and thus leads to a fixed and dilated pupil on that side. Papilledema is a finding with chronic increases in ICP.

Answers:

1st Questions: C

2nd Questions: B

3rd Questions: E

4th Questions: A