L8-Raised intracranial Pressure

Surgery Team
MED 433

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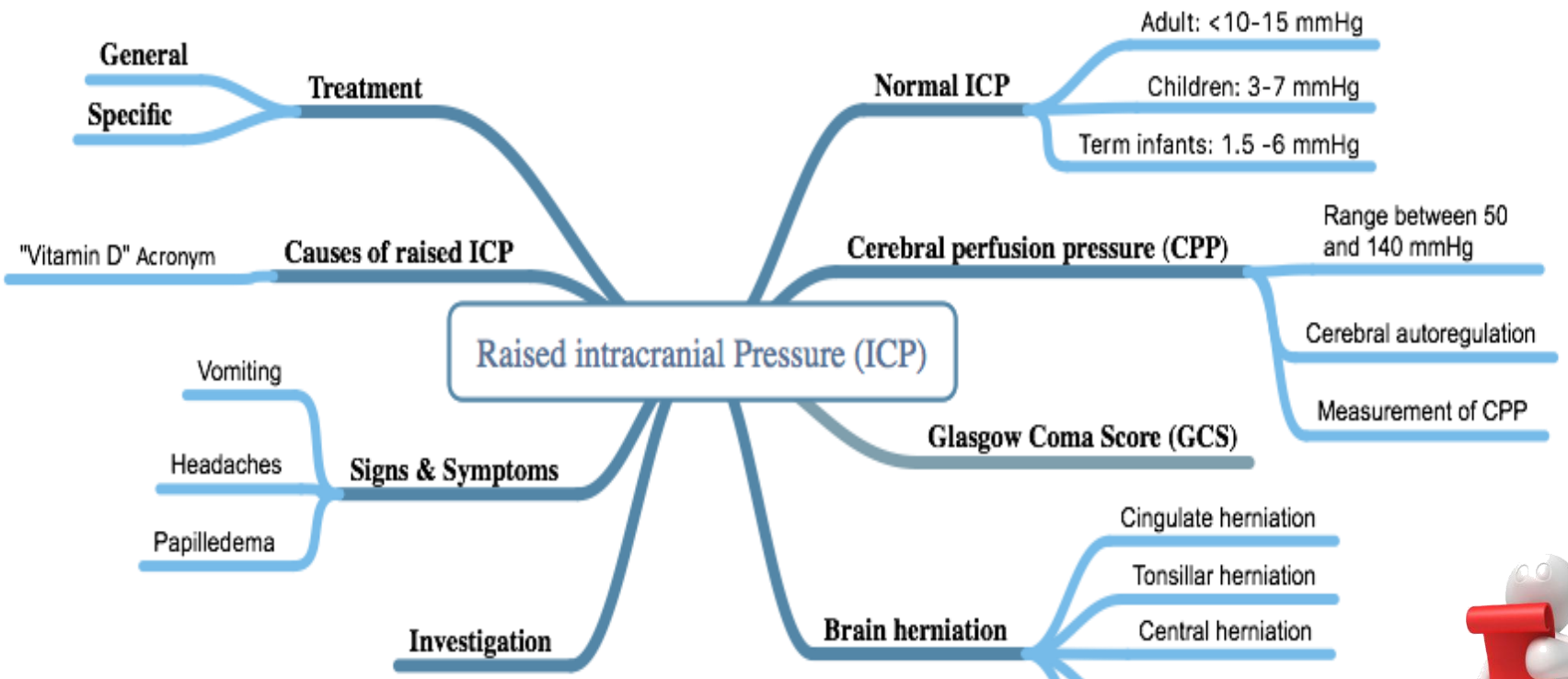
Objectives :

Color Index: Slides & Raslan's () | Doctor's Notes | Extra Explanation | Additional

This work is based on doctor's Slides + Notes + Raslan booklet + Davidson's Surgery (Pg. 458-459 + 464-466)

➲ Mind map


Raised intracranial Pressure (ICP)
Treatment
General
Specific
Causes of raised ICP
"Vitamin D" Acronym
Signs & Symptoms
Vomiting
Headaches
Papilledema
Investigation
Normal ICP
Adult: <10-15 mmHg
Children: 3-7 mmHg
Term infants: 1.5 -6 mmHg
Cerebral perfusion pressure (CPP)
Range between 50 and 140 mmHg
Cerebral autoregulation
Measurement of CPP
Glasgow Coma Score (GCS)
Brain herniation
Cingulate herniation
Tonsillar herniation
Central herniation
Uncal herniation
Outside herniation

➲ introduction

Note: ICP normally fluctuates in response to intrathoracic pressure (increasing with coughing or defecation) and to cardiac pulsation.

➥ Components of cranium:

✓ Brain	1400 ml
✓ CSF	75-100 ml
✓ Meninges, vessels & blood	75 ml

➲ Basic principles of Intracranial pressure (ICP)

➥ Monro-Kellie Doctrine

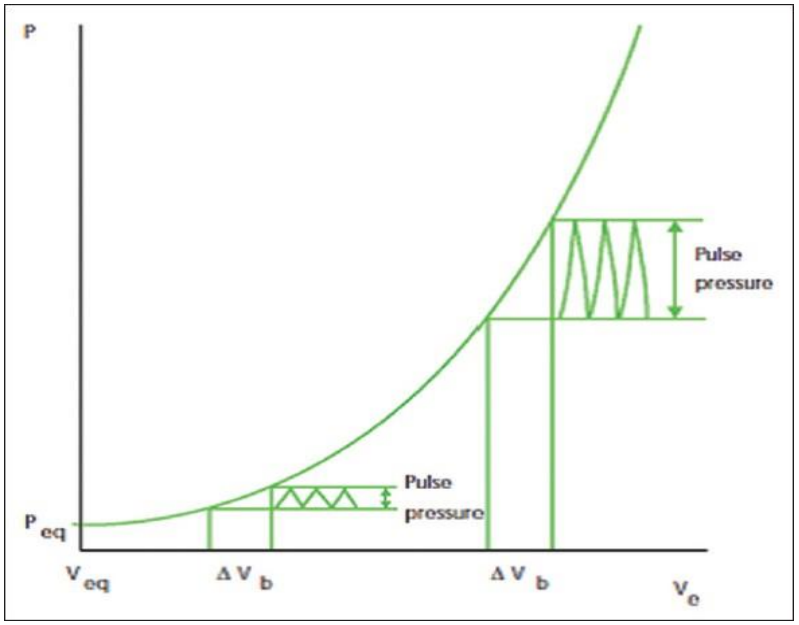
- ✓ Any change in the brain's volume is associated with a change in CSF or blood volume .These contents are incompressible.
- ✓ When the volume of the brain increases, the other components will have to compensate. CSF will decrease and vasoconstriction will occur in order to decrease the blood volume.

➥ Volume – pressure curve (intracranial pressure curve)

- ✓ Increase in volume in one compartment leads to change in volume in 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.

➥ Volume – pressure curve

- ✓ Assume that brain develops a tumor. Depending on how fast the tumor grows, the pressure will either increase slowly and be tolerated, or massively (sudden hemorrhage) and lead to comatose.



➥ 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.

➥ Normal ICP values

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

Note: ICP is the same as CSF pressure obtained at a lumbar puncture → 5-15cm H2O, 4-10mmHg

* Because children have softer bones, their ICP value is lower.
** Infants have lesser ICP = 1.5 – 6 because their bones haven't united yet.

➲ Cerebral perfusion pressure (CPP)

- ✓ Cerebral perfusion pressure is the pressure coming from the blood rushing into the brain.
- ✓ It has a very wide range between 50 and 140 mmHg
- ✓ In trauma cases, it is preferred to keep cerebral perfusion pressure around 70-80 (to still allow for cerebral blood flow).
- ✓ The brain only dysfunctions at a very high extreme pressure or very low extreme pressure.

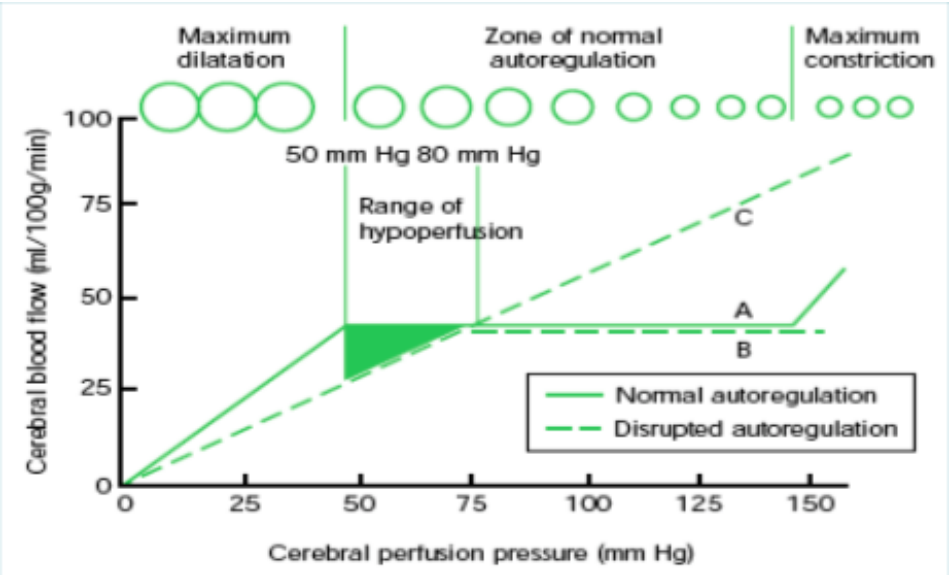
➥ Cerebral autoregulation

- ✓ 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.

➥ Cerebral autoregulation

- ✓ 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.



➥ Measurement of cerebral perfusion pressure (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.

Cerebral perfusion pressure = mean arterial pressure - Intracranial pressure

CPP = MAP - ICP

✓ **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.

✓ **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 Measure CPP?
  - 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.
- If ICP goes up, how does the brain get perfusion? Process of auto-regulation.

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

➲ Raised Intracranial pressure (ICP)

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

➥ Causes of raised ICP

- ✓ 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.
- ✓ **Vitamin D:** An Acronym to remember the causes of raised ICP:
  - ✓ Vascular, Infection, Trauma, Autoimmune, Metabolic, Endocrine, Neoplastic, Drugs

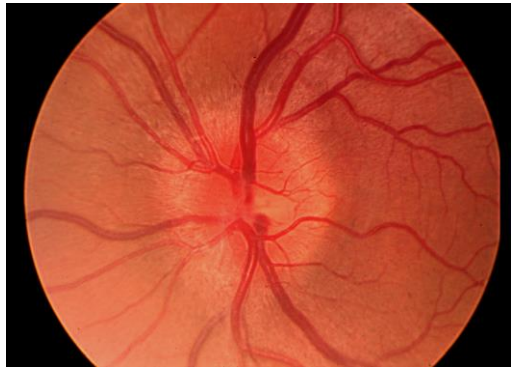
➥ Signs & Symptoms

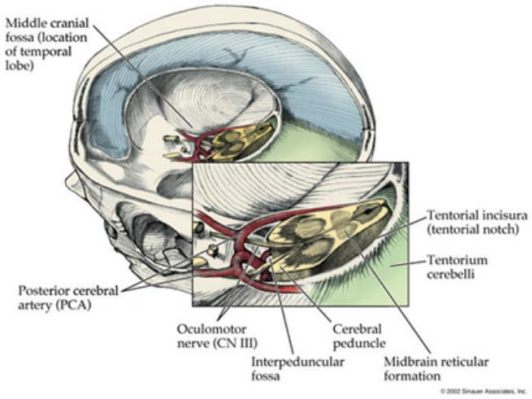
** This is known as **Cushing's Triad**: (for increased ICP) → Headache, vomiting, and papilledema.

- ✓ 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 papilledema 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.

➥ Signs & Symptoms

- ✓ Papilledema
  - ✓ 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 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 (because CN3 is the 1st to be affected) and contralateral hemiplegia "weakness" will occur. → with further compression, bilateral pupillary dilation will ensue

↪ Systemic reaction to increased ICP: (Cushing's reflex/vasopressor response)

- ✓ Raised BP 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 change: 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).

↪ 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)

↪ False localization sign (KERNOHAN'S NOTCH)

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.

➲ Glasgow Coma Score (GCS)

****This slide is important for the OSCE as well!**

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

- ✓ 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 – 14 or 15
- ✓ Moderate GCS= 9 – 12
- ✓ Severe GCS= 3 – 8

The lowest number in GCS is 3 and the highest number is 15

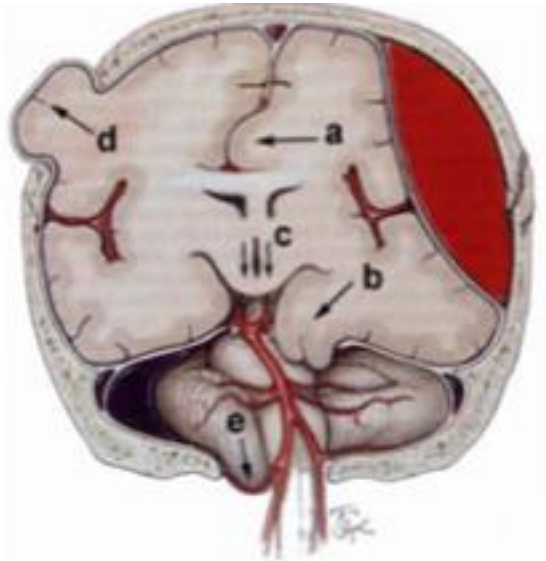
-**Note**: The best postresuscitation GCS is used to classify severity of head injury

➲ 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 herniation.
- ✓ 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.

➥ Types of brain herniations

a. Cingulate herniation
b. Uncal herniation
c. Central herniation
d. Outside herniation
e. Tonsillar herniation



↪ Types of brain herniation

a. 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 → the anterior cerebral artery may be compromised leading to medial hemispheric infarction.

b. Uncal herniation = transtentorial herniation (very close to the brain stem!)

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 (tentorial notch) and compresses the brainstem, causing dilated pupil "3rd cranial nerve affected", coma state and hemiaplagia *.

c. 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.

d. 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.

e. Tonsillar herniation (part of the cerebellum)

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. → mostly due to performing a LP on a patient with increased ICP. It is known as coning. → rapid deterioration in consciousness with decerebration.

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

↪ Uncal (Transtentorial) Herniation → from book!

Transtentorial (uncal) herniation

With large ipsilateral brain lesions, the medial part of the temporal lobe is pushed down through the tentorial notch to become wedged between the tentorial edge and the mid-brain (Fig. 24.3B). The opposite cerebral peduncle is pushed against the sharp tentorial edge, and the midbrain and uncus become wedged at the tentorium. The aqueduct is compressed, obstructing CSF flow, and venous obstruction leads to midbrain haemorrhage. The clinical features of an uncal herniation, most often due to a traumatic intracranial haematoma, are:

- The Glasgow Coma Score (GCS) falls (Table 24.1)
- The motor component of the GCS becomes asymmetrical
- The ipsilateral pupil dilates and becomes non-reactive to light
- The blood pressure rises
- The pulse slows
- The respiratory rate falls and the patient become apnoeic.

➲ Investigations

- ✓ 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 VR
- ✓ 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). It can't be given for edema happened after head injury because it can't control it → give in case of vasogenic edema of the brain.
- ✓ Sedation, muscle relaxants decrease metabolic rate.

➲ Treatment

"Dexamethasone after head injury is harmful" (CRASH trial → Lancet journal)

➥ General measures:

- ✓ 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 (to still maintain perfusion of the brain).
- ✓ Hypothermia decrease metabolic rate
- ✓ Barbiturates "rarely used": terminal option, when everything fails because it has many complications → it put the brain in complete relaxation.

➥ Specific treatment: **Depends on the cause of raised ICP**:

- ✓ **Vascular** – SAH (Subarachnoid hemorrhage due to aneurysm) →bleeding into the CSF from a ruptured intracranial aneurysm is the commonest cause of spontaneous subarachnoid hemorrhage- ICH (Intracerebral hemorrhage)
- ✓ **Infection/Abscess:**
  - There are 3 common causes (penetrating wound of the skull, direct spread "75% of cases" and blood-borne spread)
  - Rounded space
  - In IV drug abusers or immune suppressed patients, with sinusitis. Sustained infection, that when you give contrast →enhanced picture "ring-enhancing lesion" (big collection of pus)

➲ Treatment

↪ Specific treatment:

- ✓ **Trauma**:
  - **Localized:** Epidural Hematoma, results from skull fracture ormiddle meningeal artery injury. Subdural Hematoma, results from bleeding into the subdural space from lacerated brain or torn vessels. They compress brain, subfalcine herniation + temporal herniation. → both cause midline shift!

  →Epidural or extradural hematomas typically have a lucid interval followed by rapid deterioration, but brain injury is often minimal.

  - **Diffuse:** Severe shaking of head→ diffuse axonal injury due to tearing and shearing of the axons → Salt and pepper appearance of blood scattered around in brain. → We see this with RTAs when sudden deceleration has occurred (so the car was originally driven in very fast speed)

  → ironically, the head CT may appear normal or with minimal punctuate lesions and the ICP my even be normal, but the severe neurological deficits seen clinically prove otherwise.
- ✓ **Tumor**: midline shift to other side, edema around it (Meningioma, Glioblastoma Multiforme). (you dissect the tumor)
- ✓ **Hydrocephalus**: Treated with shunt, ventricles enlarged, diffusion of CSF into brain substance.

➲ ICP monitoring

ICP can be monitored by inserting a catheter in the right ventricle of the brain substance to give pressure and suck fluid. → to monitor, so this should not be your 1st step to control ICP! (OSCE question)

➲ Subdural hematomas → from book!

Subdural haematoma

This is more common than extradural haematoma and is due to laceration of vessels (especially small cerebral veins) on the brain surface, or 'bursting' of the brain. CT shows a haematoma that is concave on its inner surface (Fig. 24.9B). Craniotomy is performed to remove the haematoma and arrest the bleeding. Morbidity and mortality are often high because of the severity of the primary brain injury. An increasingly common problem with the ageing population is chronic subdural haematoma (CSDH). This is a collection that varies in viscosity from breaking-down clot to bloodstained CSF-like fluid, and which can collect after relatively minor head trauma. Patients with cerebral atrophy who are on aspirin or anticoagulants are predisposed to CSDH. Because the collection can occur slowly, there may be significant midline shift and sometimes very few signs and symptoms. CSDH can mimic most neurological syndromes in their presentation. Treatment involves drainage of the collection through burr holes or mini-craniotomy, with or without drainage of the subdural space.

➲ Head Trauma Examination: → from book!

1. Pupil size and reaction
2. CSF leaks from nose, mouth, or ears
3. Survey of the scalp for penetrating injuries
4. Basal skull fracture? (look for signs: Battle's sign and raccoon eyes)
5. Assess maxillofacial skeleton
6. Peripheral neurological exam

- Note: Head Injury Alone Never Causes Hypovolemic Shock!!!

➲ Head Trauma Management: → from book!

1. ABC
2. Immobilize cervical spine
3. GCS
4. GCS <= 8 → intubate and ventilate!
5. Assess other injuries
6. Head CT
7. Surgical evacuation if needed
8. ICP monitor if needed
9. Compound cranial injuries should be surgically explored

Note:
- Sedatives must be avoided!
- Indications for clot evacuation: >5mm midline shift, significant GCS impairment, and protracted headache/vomiting
- Goal is to limit secondary damage due to ischemia and brain herniation due to increased ICP, hypoxia, and hypotension.
- Sustained ICP of >25mmHg is associated with poorer outcome

➲ Summary

- ✓ The pressure in the skull is called the Intra-cranial pressure (ICP). The ICP must stay balanced in order for the brain to survive.
- ✓ Cerebral autoregulation is the ability of cerebral vessels to maintain cerebral perfusion within strictly determined limits.
- ✓ Headache, vomiting and papilloedema are the clinical signs of raised ICP.
- ✓ Types of brain herniations:
    - Cingulate herniation
    - Uncal herniation
    - Central herniation
    - Outside herniation
    - Tonsillar herniation
- ✓ ICP can be monitored by inserting a catheter in the right ventricle of the brain substance to give pressure and suck fluid.

Case

A 20 year old man presented to the ER unconscious with BP of 75/30, HR of 125 bpm, and with a right hemiplegia caused by a motor vehicle crash as unrestrained driver.

What are the differential diagnoses?

Intracranial bleeding (he's unconscious, with right hemiplegia)
Hematoma in the brain (that's why he is with hemiplegia and he is bleeding somewhere in the body and because of that he is hypotensive and unconscious and he has high HR)

How to deal with him in the emergency?

1. ABC:
   - Check airway → endotracheal intubation (the first thing done for unconscious patient, because if his airway was blocked he will die within seconds)
   - Breathing → chest tube (if tube was inserted and the patient's lungs were not inflated, he might have pneumothorax, and this will kill him in a minute)
   - Circulation → stop the external bleeding but after giving I.V fluids. (Brain needs fluids so fluids must be replaced)
2. insert 2 large I.V lines to start fluid, blood.
3. C.T: to find out why he is unconscious.

MCQs

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 postinjury 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%.

ANS: **1- C** **2-b** **3-e**

Thank You..

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