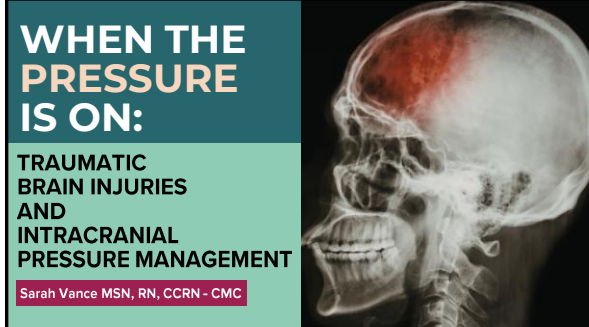


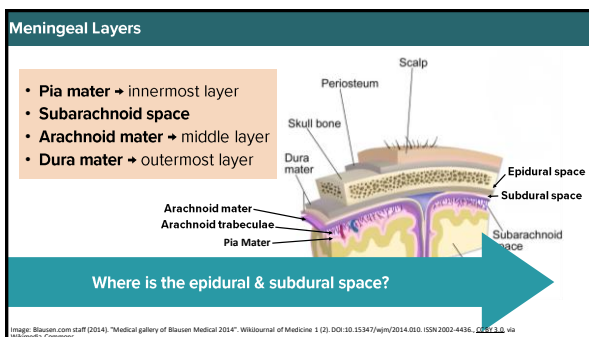


1

Objectives

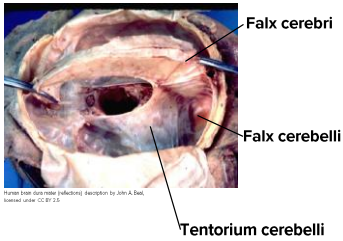
- Explain how traumatic brain injuries alter cerebral perfusion and pressure regulation.
- Recognize early warning signs and monitoring data that indicate rising ICP.
- Discuss appropriate nursing interventions and critical care protocols for managing elevated ICP and improving patient outcomes.

2



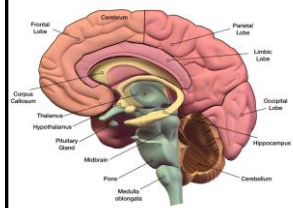
6

Dural Folds



7

Brain Facts



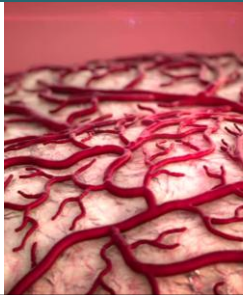
- The weight of the brain is **~ 2%** of the human body
- Consumes **15 - 20%** of total cardiac output

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Cerebral Oxygen Metabolism

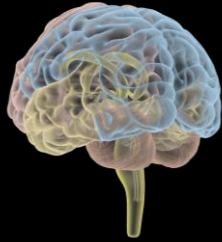
- Uses **25%** of glucose and **~ 20%** of available O_2 to function normally
- Functions almost entirely by **aerobic metabolism**; ineffective anaerobic metabolism
- Cerebral Metabolic Rate of Oxygen (CMRO₂) → **~3–3.5 mL O_2 /100 g/min**



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Cerebral Spinal Fluid (CSF)

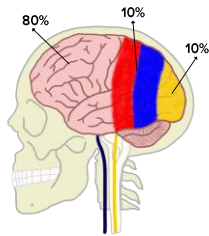
- **Ventricles produce CSF**
 - 20mL/hour (500 mL/day) of CSF
 - ~ 150 ml in the brain
- CSF reabsorbed in the venous sinuses within the brain



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The Cranial Vault

- **Rigid cranial vault** →
 - Brain tissue (80%)
 - Venous & arterial blood (10%)
 - CSF (10%)
- Intracranial **pressure** is influenced by **volume and compliance**
- **Normal ICP ≤ 15 mmHg**

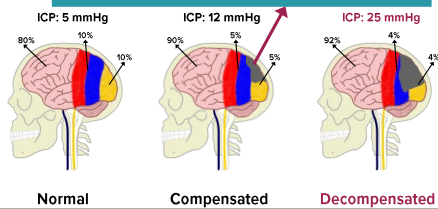


11

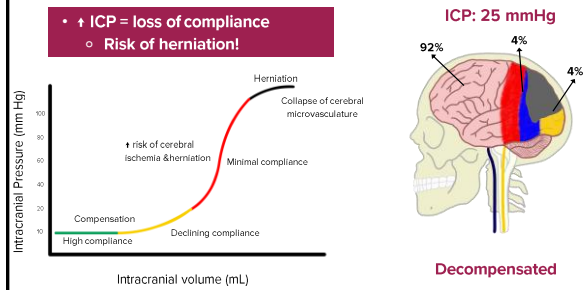
Monroe-Kellie Doctrine

- An ↑ in one will cause ↓ in the others...when **compensation** is intact
- An ↑ in **total volume** leads to ↑ ICP

New volume (i.e. cerebral edema, tumor, SDH, ect...)



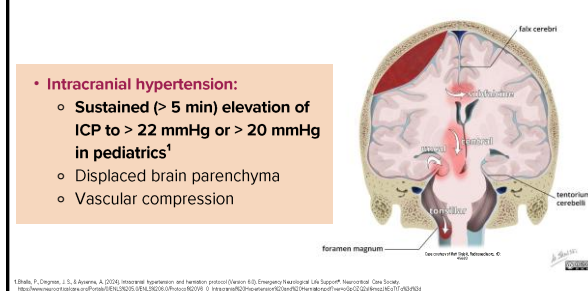
12



13

[illegible]

Intracranial Hypertension



14

[illegible]

Cerebral Blood Flow

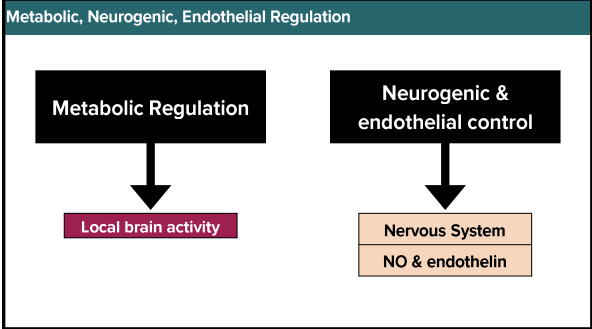
CBF = Cerebral Perfusion Pressure (CPP) / Cerebral Vascular Resistance (CVR)
Normal ~ 55 mL/100g/min

```
graph TD; A[Myogenic regulation] --- B[Chemical regulation]; A --- C[Metabolic regulation]; A --- D[Neurogenic & endothelial control]; B --- C; B --- D; C --- D;
```

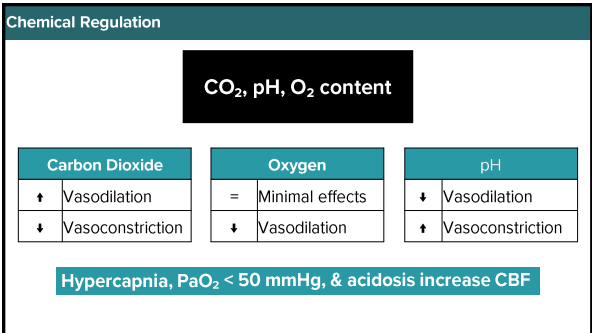
The diagram consists of four colored boxes arranged in a 2x2 grid, connected by lines. The top-left box is light green and contains the text 'Myogenic regulation'. The top-right box is teal and contains the text 'Chemical regulation'. The bottom-left box is maroon and contains the text 'Metabolic regulation'. The bottom-right box is light orange and contains the text 'Neurogenic & endothelial control'. All four boxes are interconnected by a network of lines, indicating that these four mechanisms collectively regulate cerebral blood flow.

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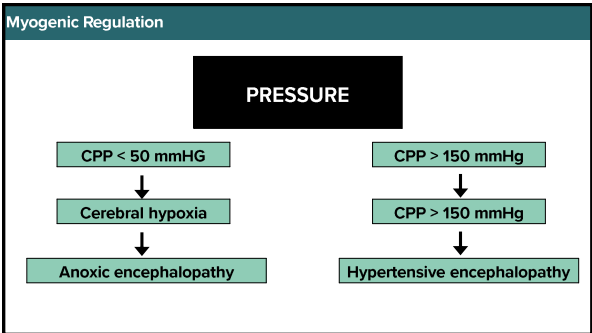
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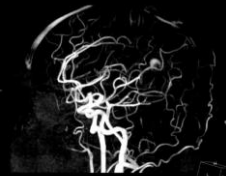
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Cerebral Perfusion Pressure (CPP)

- The MAP of the brain
- Pressure required to perfuse the brain
- **CPP = MAP - ICP**
 - Goal CPP: 60 - 70 mmHg
 - < 30 mmHg irreversible ischemia



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Cerebral Perfusion Pressure (CPP)

- MAP 65 - ICP 15 = CPP 50!
- MAP 90 - ICP 25 = CPP 65
- MAP 55 - ICP 25 = **CPP 30!!!!**
- MAP 60 - ICP 40 = **CPP 20!!!**

Hypotension + ICP =
LIFE THREATENING!



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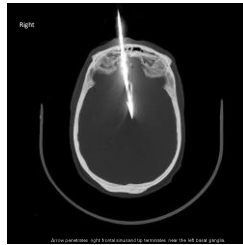
What about this?



YIKES!

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Penetrating Head Trauma



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Epidural Hematoma

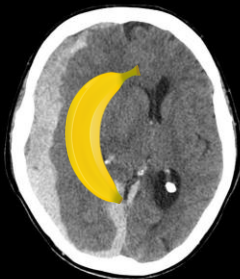


- No natural epidural space
- Can occur anywhere in the skull
- Usually in the temporal or parietal region
 - Location of meningeal artery/vein
- High association with skull fx
- **Arterial bleed!!**

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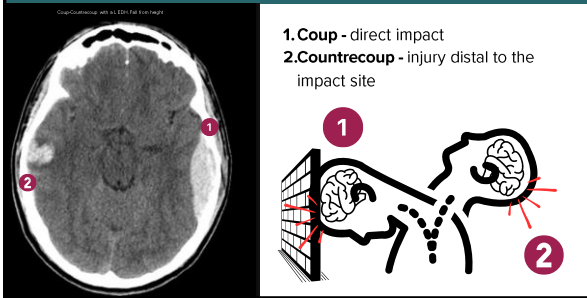
Subdural Hematoma

- Between dura and arachnoid membrane
- Tearing of the bridging **veins**
- Elderly
 - Anticoagulants!
 - Cerebral atrophy
- Acute, subacute, chronic



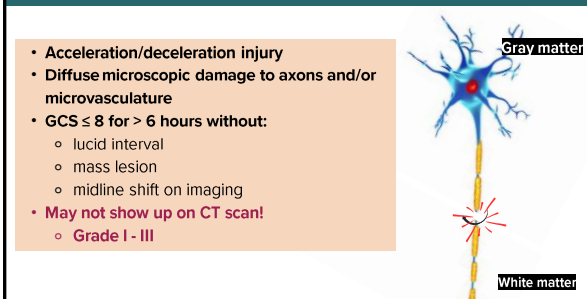
24

Coup-Countercoup



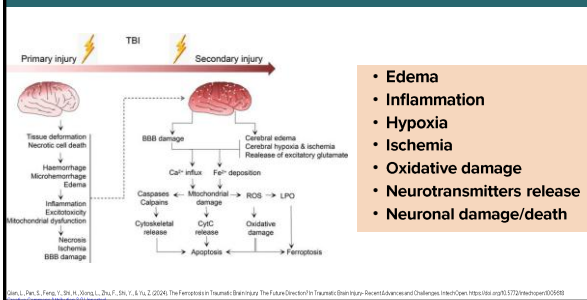
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Traumatic axonal and/or microvascular injury (TAMVI)



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Primary vs Secondary Injury



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Cerebral Edema

Vasogenic Edema

Mechanism:

- Blood-brain barrier (BBB) disruption → plasma proteins & fluid leak into extracellular space

Location:

- White matter predominantly

Clinical Impact:

- Increased ICP, midline shift, herniation risk

Cytotoxic Edema

Mechanism:

- Cell energy failure → Na⁺/K⁺ pump dysfunction → intracellular water accumulation (cell swelling)

Location:

- Gray & white matter leading to neuronal death

Clinical Impact:

- More refractory to treatment; BBB remains intact

Both types + intracranial volume → ↑ ICP → ↓ CPP, TBI often involves BOTH

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Impaired Autoregulation in TBI

Normal Autoregulation

Cerebral vessels constrict/dilate to maintain constant CBF across a wide CPP range (50–150 mmHg)

After TBI — Autoregulation Fails

CBF becomes **pressure-passive** → it rises and falls directly with MAP, losing protective buffering

BBB Disruption

- Impairment of myogenic (pressure) and chemical regulation
- Unable to adjust vascular tone

Neuronal & Vascular Injury

- Direct injury to the vasculature
- Disruption of coupling between CBF and metabolic demand

Inflammatory Cascade

- Cytokines, free radicals & excitotoxic neurotransmitters released
- Blunts CO₂ and pressure responses.

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Tools are great, but...

DO YOUR NEURO ASSESSMENTS

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Clinical S/S of ↑ ICP

Symptoms of Increased Intracranial Pressure	
Early	Late
• Altered LOC ◦ Confusion, agitated, restless, irritable • ↑ GCS • ↓ Motor function • Weak reflexes • Pupillary changes ◦ Sluggish • Nausea, vomiting • Visual disturbances • Seizure • Headache	• ↓ LOC ◦ Obtunded, comatose • ↓ GCS • ↓ Motor function ◦ Decordicate, decerebrate ◦ Hemiparesis (ipsilateral, contralateral) • Pupillary changes ◦ Ipsilateral dilation → bilateral • Respiratory pattern changes • Rising systolic blood pressure • Hypertension with no obvious cause • Temperature changes

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Vital Sign Changes



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ICP Monitoring Devices

Does not replace serial neurological and radiographic examinations

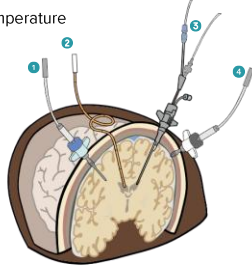
When to consider ICP monitoring:

- Comatose patients ($GCS \leq 8$) + structural brain damage on CT
- $GCS > 8$ + structural brain damage + high risk for progression
- $GCS > 8$ when knowing the ICP might facilitate management of other issues
- Progression on CT imaging or clinical deterioration
- Neurosurgical procedure

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ICP Monitoring Devices

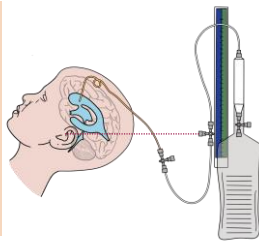
- 1 Intraparenchymal/bolt: ICP, PbtO₂, temperature
- 2 Intraventricular/E.V.D: Pressure, drain
- 3 Combination / multimodality
- 4 Subarachnoid: ICP, temperature
- 5 Subdural, epidural



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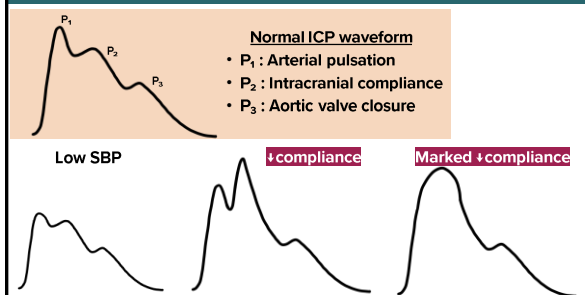
External Ventricular Device (EVD) / Ventriculostomy

- Level to tragus
 - EAM, foramen of Monro
- Provider will set the height of burette
- Accurate leveling to avoid:
 - Erroneous ICP readings
 - Under/over drainage of CSF
- Understand stopcock positioning
- Know drainage orders!
- Dressing changes per unit policy
- Monitor/record output

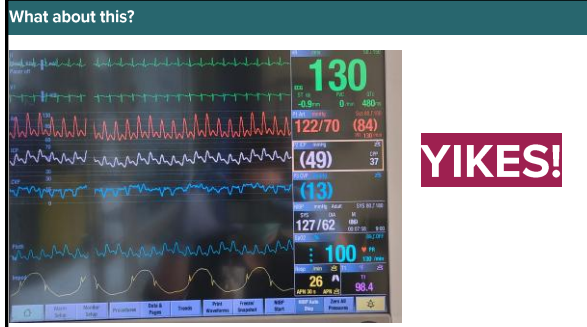


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Intracranial Pressure Waveforms



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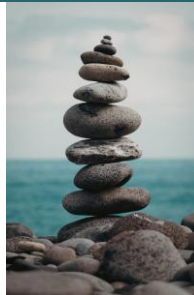
PbtO₂ monitoring

Is this a delivery issue?

Is this a consumption issue?

- Balance between O₂ delivery & consumption
- Typical goal: > 20 mmHg
- Used with other multimodal monitoring devices
- Probe location can influence reading
 - Local brain oxygenation

Lookout → BOOST-III Trial



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Non-Invasive Monitoring

Near-Infrared Spectroscopy (NIRS)

- Non-invasive technique to measure O₂ levels in the brain
- Real-time regional brain oxygen saturation (rSO₂)
- Critical ischemia threshold: rSO₂ < 50%
- Less precise compared to invasive methods
- **Not fully standardized or validated...yet!**

Transcranial Doppler Ultrasound (TCD)

- Measures realtime cerebral blood flow velocity in major brain arteries
 - Hypoperfusion
 - Hyperemia
- Assist in *estimating* ICP and autoregulation
- Detects vasospasms - risks of ischemia

Both used in conjunction with other monitoring modalities

Reuter 2021
Petrova et al., 2022

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Standard TBI Care

Cluster, cool, calm, controlled, centered, CO₂

- **Positioning**
 - HOB > 30-45° → Improved venous outflow
 - Centered / straight
- **Pain & agitation management**
- **Normothermia**
 - Fever control 38.0°C (100.4°F)
- **Oxygenation & ventilation management**
 - EtCO₂ / PaCO₂ normal 35 - 45 mmHg
- **Decreased stimulation**
- **Avoid & correct hypothermia**
 - Serum Na 135-145 mEq/L

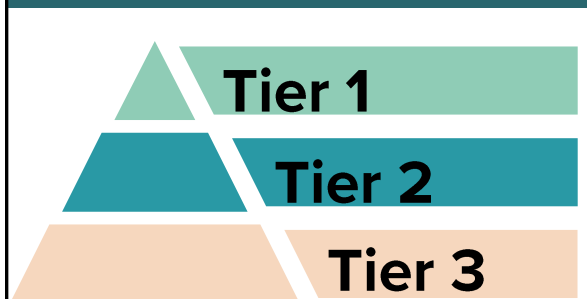
Parameter	Goal Range
Pulse oximetry	≥ 94%
PaO ₂	80-100 mm Hg
PaCO ₂	35-45 mm Hg
Systemic blood pressure	≥ 110 mm Hg
ICP	< 22 mm Hg
PaH ₂ O	≤ 15 mm Hg
CPP	60-70 mm Hg
Serum sodium	135-145 mEq/L
INR	≤ 1.4
Temperature	36.0-37.5°C
Platelets	≥ 75 × 10 ⁹ /mm ³
pH	7.35-7.45
Glucose	100-180 mg/dL
Hemoglobin	≥ 7 g/dL

*Depending on status of cerebral autoregulation
 Key: PaO₂, partial pressure of oxygen; PaCO₂, partial pressure of carbon dioxide; ICP, intracranial pressure; PaH₂O, partial brain tissue oxygenation; CPP, cerebral perfusion pressure; INR, international normalized ratio.

Source: College of Surgeons (2016). Best practice guidelines: The management of traumatic brain injury. Accessed 10/10/2016. <http://www.collegesurgeons.org/trauma/braininjury/management/standard-of-care/>

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Tiered Approach to ICP Hypertension



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Tier One

Tier One

- ICP monitoring and CSF drainage
- CPP 60 - 70 mmHg
- PaCO₂ 35 - 38 mmHg
- Hyperosmolar therapy
- ICP guided analgesia & sedation
- EEG monitoring
- Anti-seizure medications

- **Opioid agonist:**
 - Fentanyl
 - Morphine
 - Hydromorphone
- **Sedatives/Anxiolytics:**
 - Propofol
 - Dexmedetomidine
 - Midazolam
 - Ketamine

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Tier One



- **Mannitol:**
 - 0.5-1 g/kg IV bolus q 4-6h
 - Onset 15 - 20 minutes, duration 90 - 6 hours
 - Crystallizes → Filter!
 - Monitor for **hypotension**
- **Hypertonic NaCl**
 - 2-23.4% continuous vs. bolus
 - Monitor serum Na⁺ q4-6h
 - Monitor for hypokalemia, hyperchloremic *acidosis*
- Limits for sodium (155 mEq/L) & osmolality (320 mEq/L)
- **Monitor for: rebound ICP, AKI, lytes, I/Os**

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Tier Two and Three

Tier Two

- MAP challenge & ICP guided CPP/MAP
- PaCO₂ 32 - 35 mmHg
- NMBA

Tier Three

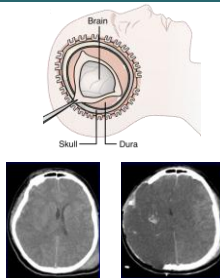
- Pentobarbital or sodium thiopentone
- Burst suppression
- Decompressive craniectomy
- Mild hypothermia (35 - 36°C)

- **MAP challenge:**
 - Record MAP, ICP, CPP, PbtO₂ baseline
 - † MAP 10 - 15 mmHg for < 20 minutes
 - Record MAP, ICP, CPP, PbtO₂ during/post

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Surgical Interventions

- **Decompressive craniectomy**
 - Removal of a section of the skull to allow for swelling/expansion
- **Nursing Care:**
 - Caution with repositioning/mobility
 - Helment when OOB
 - Family education



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