Hemodynamic Monitoring in Traumatic Intracranial Hemorrhage

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Disclosures

- Academic Associate Professor at Florida State University Emergency Medicine Residency Program
- Director for Research in Emergency Medicine at Florida State University Emergency Medicine Residency Program
- Chief Academic Director of the World Academic Council of Emergency Medicine
- President of The Academic College of Emergency Experts of India
- No Industry Disclosures or Conflicts

Objectives

- Hemodynamics in Trauma
- Monitoring in Head Injury
- Case Scenarios
- Discussion

Trauma Presentations

- Trauma and Shock = Unstable Trauma
- Trauma without Shock = Stable Trauma
- Stable Trauma Becomes Unstable Trauma
- Hidden Trauma (Dementia , Seizure, Anticoagulants, Abuse)

Intracranial Bleeds

- With Skull Fracture
- Without Skull Fracture
- On Anticoagulation
- Not on Anticoagulation
- Other Fracture: HFN
- +/- TAP Extremity Trauma

SHOCK

- Hemorrhagic
- Cardiogenic
- Neurogenic
- Post Traumatic Sepsis
- Fluids + Blood
- < 8 Intubate
- Protect airway

Cardiac and Respiratory Failure

- Shah SP, Pitroda P, Patel K, Chandak R, Ford T. Polymorphic Ventricular Tachycardia Secondary to Subarachnoid Haemorrhage: A Rare Occurrence in the Setting of Normal QTc. *Cardiol Res*. 2017;8(5):232-235. doi:10.14740/cr574w
- Elmer, Jonathan et al. "Acute respiratory distress syndrome after spontaneous intracerebral hemorrhage*." *Critical care medicine* vol. 41,8 (2013): 1992-2001. doi:10.1097/CCM.0b013e31828a3f4d

Key Pointers

- Stabilization of the patient
- Prevent intracranial hypertension
- Maintain a stable cerebral perfusion pressure (CPP)
- Avoid secondary brain insults (SBI)
- Optimize cerebral hemodynamics and oxygenation

Factors of Neuro-Pressure Dynamics

- Formula for cerebral blood flow (CBF) :
- CBF = (MAP – ICP) / CVR
- MAP- Mean arterial pressure, CVR= Cerebral vascular resistance
- CPP = MAP – ICP or CVP (whichever is higher) (ICP – Intracranial pressure, CVP- Central venous pressure).
- Play of Ventilator Management
- Coagulation Reversal v/s Blood Products
- Pressor and Need for Surgery

Trauma Monitoring

- IV (2)
- Oxygen
- Pulse Ox
- Monitor : Oxygenation , Pulse, BP, Rhythm
- Invasive and Non Invasive

General Monitoring

- Electrocardiography (ECG monitoring), EEG
- Arterial oxygen saturation (pulse oxymetry, SpO_2)
- Capnography (end-tidal CO_2, $PetCO_2$)
- Arterial blood pressure (arterial catheter)
- Central venous pressure (CVP)
- Systemic temperature
- Urine output
- Arterial blood gases
- Serum electrolytes and osmolality.

Neuro-Monitoring

- **Jugular Venous Oxygen Saturation ($SjvO_2$)** marks cerebral oxygenation and cerebral metabolism, reflecting the ratio between cerebral blood flow (CBF) and cerebral metabolic rate of oxygen ($CMRO_2$). Retrograde catheterization of (IJV) used for $SjvO_2$ monitoring, $SjvO_2$ measures global cerebral oxygenation
- **Brain Tissue Oxygen Tension ($PbtO_2$)** measures cerebral oxygenation, $PbtO_2$ measures focal cerebral oxygenation via invasive probe (Licox).
- $PbtO_2$ 35 mm Hg- 50 mm Hg: Normal. < 15 mm Hg = focal cerebral ischemia

ICP Monitoring Indications always Debatable

- Comatose patient ; Age > 40
- Diffuse axonal injury (DAI); Posturing
- Bi-frontal contusions in the non-comatose patient
- Following surgery such as a decompressive craniotomy
- Le Roux P. Intracranial Pressure Monitoring and Management. In: Laskowitz D, Grant G, editors. Translational Research in Traumatic Brain Injury. Boca Raton (FL): CRC Press/Taylor and Francis Group; 2016. Chapter 15. Available from: https://www.ncbi.nlm.nih.gov/books/NBK326713/

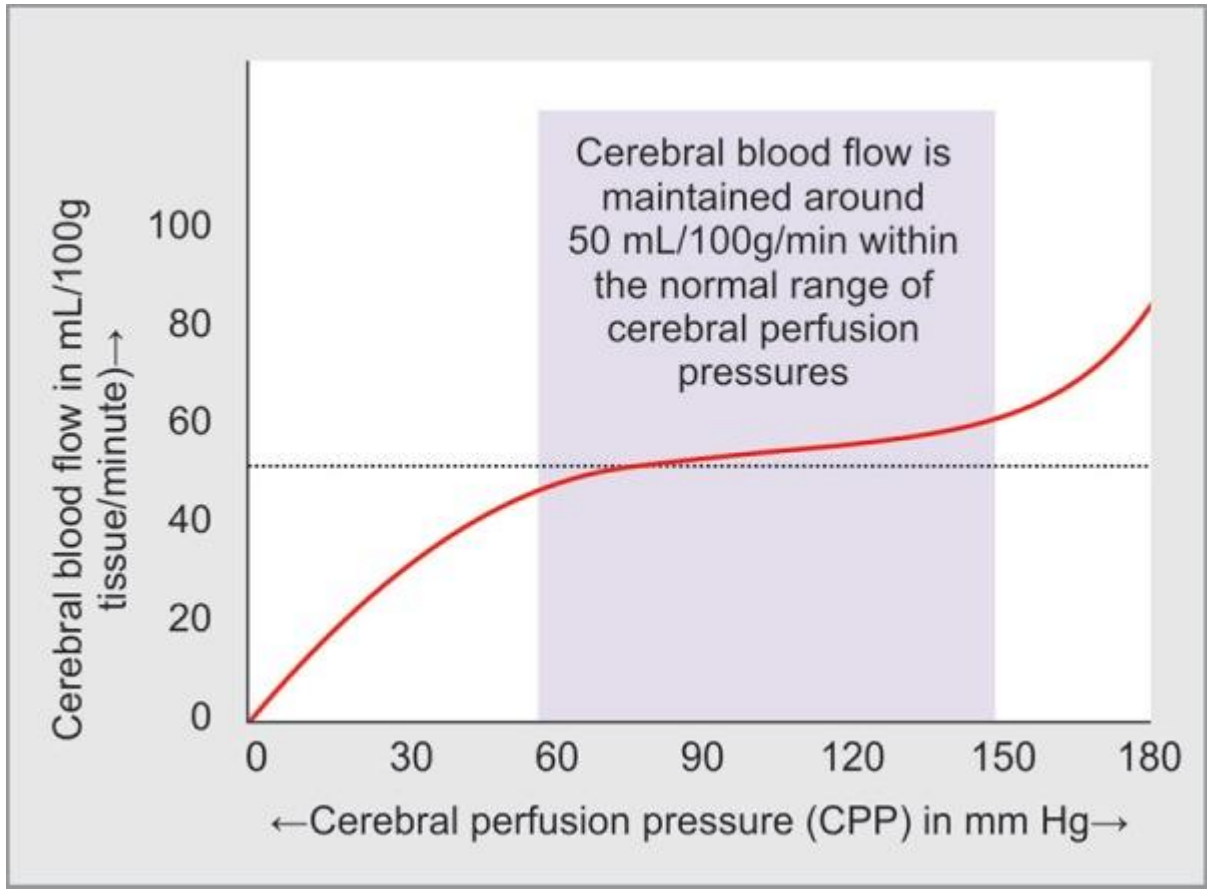
Blood Pressure

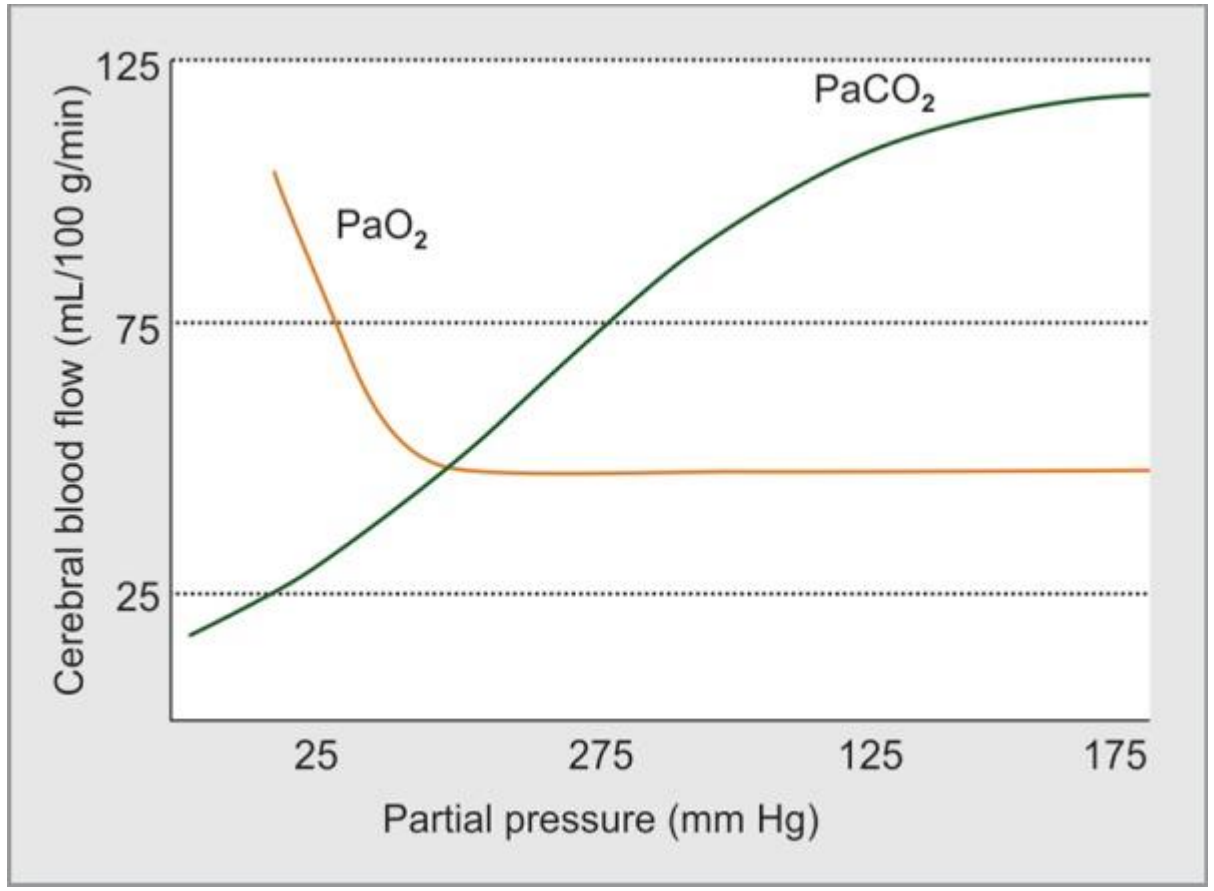
- Krishnamoorthy V, Rowhani-Rahbar A, Chaikittisilpa N, et al. Association of Early Hemodynamic Profile and the Development of Systolic Dysfunction Following Traumatic Brain Injury. *Neurocrit Care*. 2017;26(3):379-387. doi:10.1007/s12028-016-0335-x

- ***Systolic dysfunction post TBI = HTN & Tachycardia Secondary to catecholamine-excess state***

CPP Driven Protocols

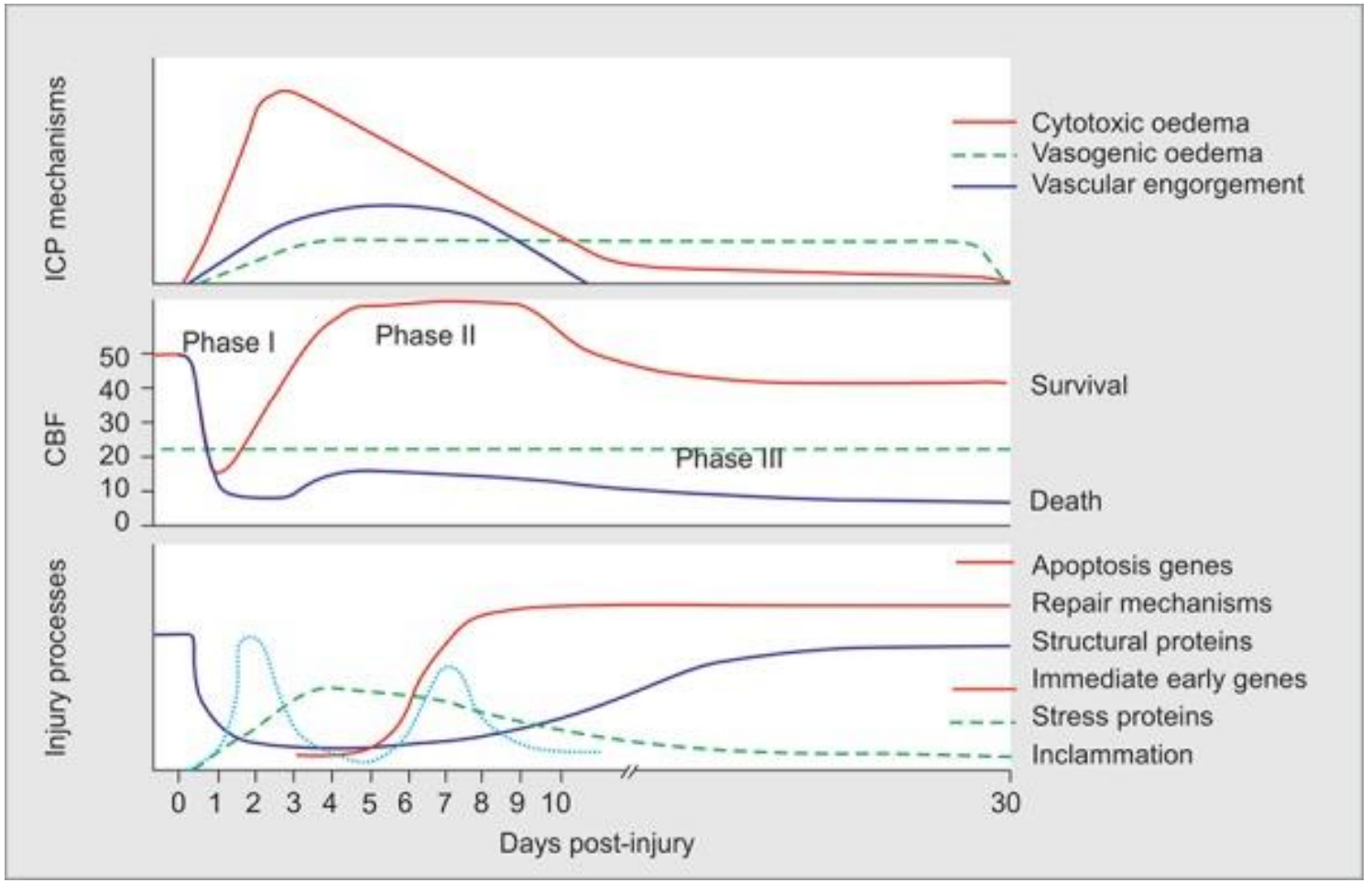
- Robertson CS, Valadka AB, Hannay JH, et al. Prevention of secondary ischemic insults after severe head injury. Crit Care Med. 1999;27:2086–95.
- 189 patients comparing ICP- versus CPP-driven treatment protocols
- CPP >70 had less ischemia





Jain V, Choudhary J, Pandit R. Blood Pressure Target in Acute Brain Injury. Indian J Crit Care Med. 2019 Jun;23(Suppl 2):S136-S139. doi: 10.5005/jp-journals-10071-23191. PMID: 31485122; PMCID: PMC6707499.

- **Normal cerebral cortical blood flow = 50 mL/100g tissue per minute.**
- **< 20 mL/100g/minute = Impairment of the neuronal tissue**
- **<10 mL/100g/minute= Irreparable damage to the neuronal tissues within a few minutes.**



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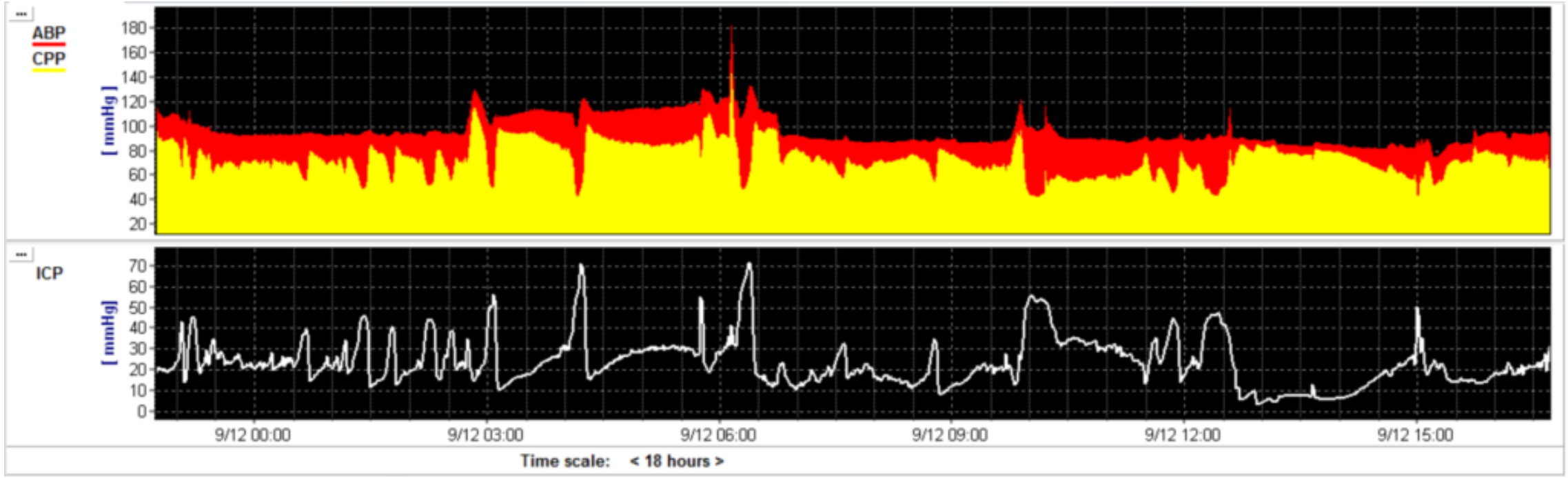
ICP /CPP/ ABP



https://cppopt.org/

Monitoring Advances

- Carandang, R.A. The Role of Invasive Monitoring in Traumatic Brain Injury. *Curr Trauma Rep* 1, 125–132 (2015). https://doi.org/10.1007/s40719-015-0022-y
- ICP > 20 = Harm
- ICP Rx Volatility: hypertonic saline, mannitol, hyperventilation , Steroids and pentobarbital.

Indexes

- PRx Pearson correlation looking at the slow waves in ICP and ABP. In The **pressure reactivity index (PRx)** decreases in CPP. It is this an index of cerebrovascular reactivity
- **Optimal cerebral perfusion pressure (CPPopt):** 24 Hour monitoring comparing with PrX.
- 'Optimal' CPP, = CPP in which the PRx is the lowest and so cerebral autoregulation works 'optimally"

Cerebral Microdialysis (CMD)

- Invasive bedside monitor to measure brain tissue biochemistry.
- CMD catheter inserted in affected brain tissue to measure biochemical changes in the area of brain. Glucose, lactate, pyruvate, glycerol, and glutamate.
- Cerebral hypoxia or ischemia = Raised lactate-pyruvate ratio (LPR) [4
- LPR > 20-25 = cerebral ischemia

Transcranial Doppler Ultrasonography (TCD)

- TCD Non Invasive measure of CBF velocity.
- Diagnoses vasospasm, critical elevations of ICP and decreases in CPP, carotid dissection, and cerebral circulatory arrest (brain death).
- Predicts post-traumatic vasospasm very early prior to its clinical manifestations.

Near infrared spectroscopy (NIRS)

- Continuous, direct, and non-invasive monitor of cerebral oxygenation and cerebral blood volume (CBV).
- In Brain two main chromophores (light-absorbing compounds) hemoglobin (Hb) and cytochrome oxidase (CytOx)
- NIRS is based on differential absorption properties of these Hb & CytOx
- NIR 700- 1,000 nm.
- At 760 nm Hb is deoxygenated state (deoxyHb)
- At 850 nm, it occurs in the oxygenated state (oxyHb).
- Minitor difference in absorbency between these two wavelengths, the degree of tissue deoxygenation can be measured.
- NIRS is less accurate in determining cerebral oxygenation compared to In $SjvO_2$,

Brain Temperature

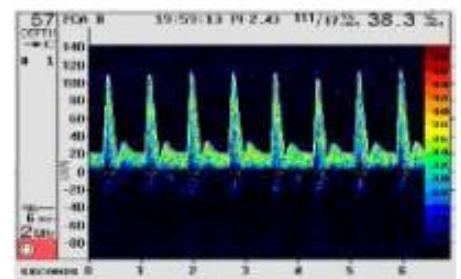
- Brain Temp 3°C higher than body temp in trauma
- Invasive and non-invasive continuous cerebral temperature monitors available.

Laser Doppler Flowmetry

Thermal conduction (Hemedex)

Optical-ultrasound modulation (Ornim)

Bulk flow – Transcranial Doppler (TCD)



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Herniation syndromes

A) Uncal (lat transtentorial)**:** Ipsi CN III palsy ("blown" pupil) + contra hemiplegia/posturing (Kernohan notch phenomenon)

temporal lobe mass → medial temporal lobe under tent. cerebelli

B) Central transtentorial: Coma + b/l small pupils → decorticate → decerebrate posturing + rostral → caudal loss brainstem reflexes

diffuse cerebral edema → ↓ displacement diencephalon

C) Subfalcine: Coma + contra. weakness → posturing esp leg ± ACA stroke

frontal/parietal mass → cingulate gyrus under falx

D) Cerebellar (↑ or ↓)**:** Cerebellar Si/Sx + medullary dysfxn → coma + b/l posturing

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