CASE STUDIES IN ICP MANAGEMENT IN TRAUMATIC BRAIN INJURY

OR – JOE THE PLUMBER CAN HELP!

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DISCLOSURES

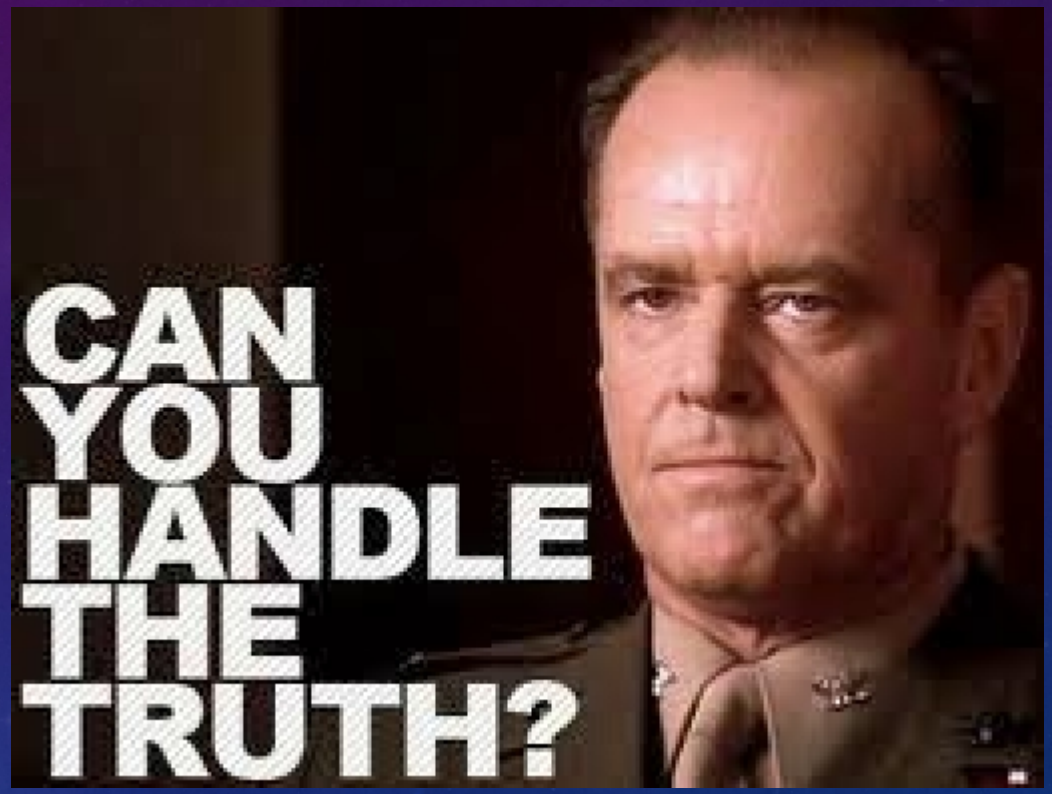
- None

OBJECTIVES

- Discuss bedside tools for the assessment and management of ICP
- Talk about bedside autoregulation challenge and discuss how to use it
- Talk about the process for assessing and interpreting the pressure equalization ratio
- Look at the effects of $PaCO_2$ on ICP
- Talk about how common venous outflow obstructions influence ICP management

DISCLAIMER

These studies contain elements of the truth

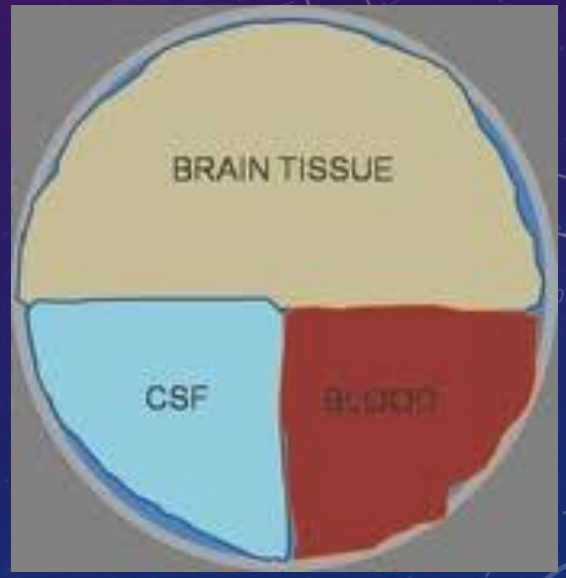


THE GOAL

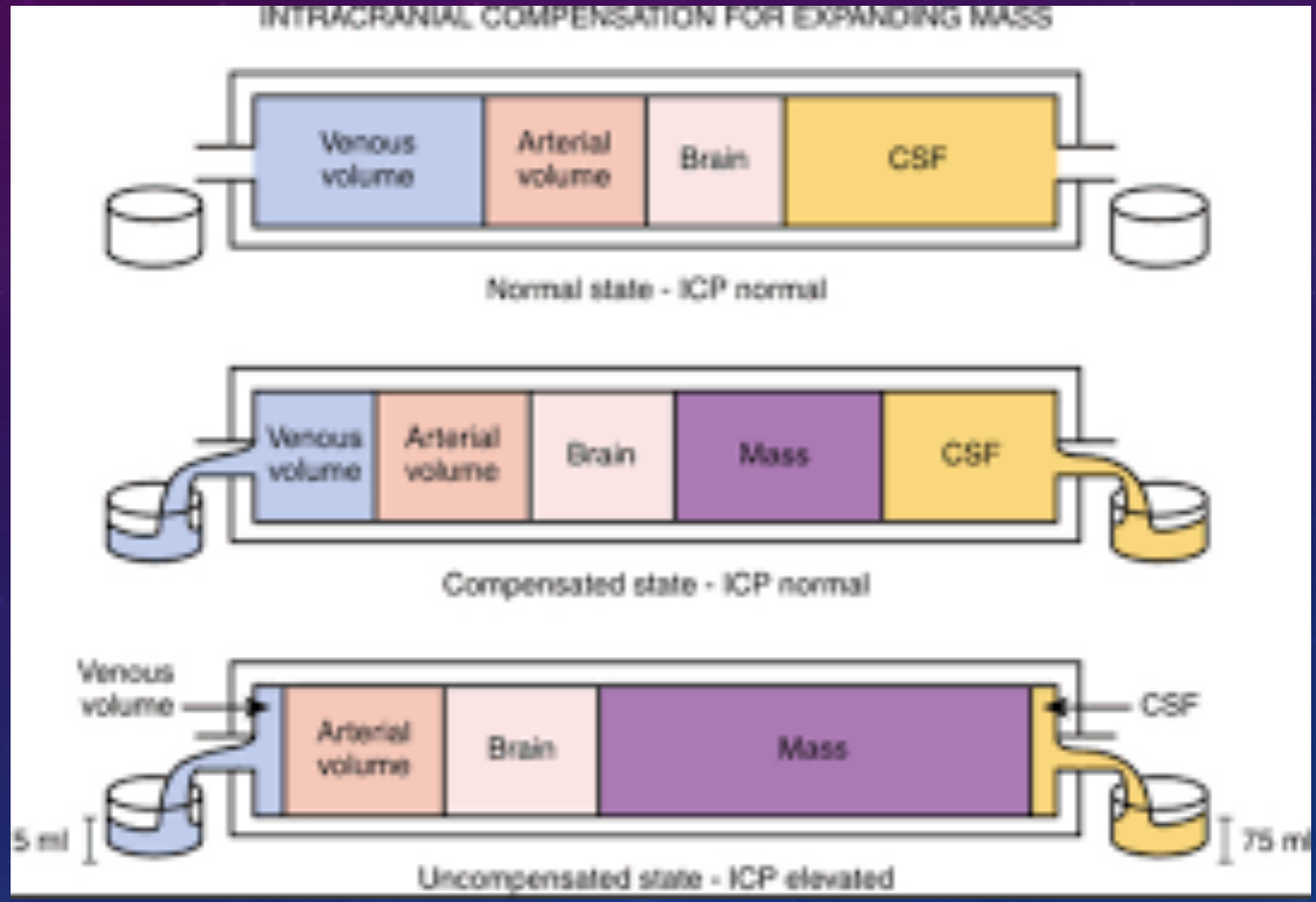
- Prevent further harm
- Perfuse the tissue
- Give best chance of recovery

MONRO-KELLIE HYPOTHESIS. THIS AGAIN??

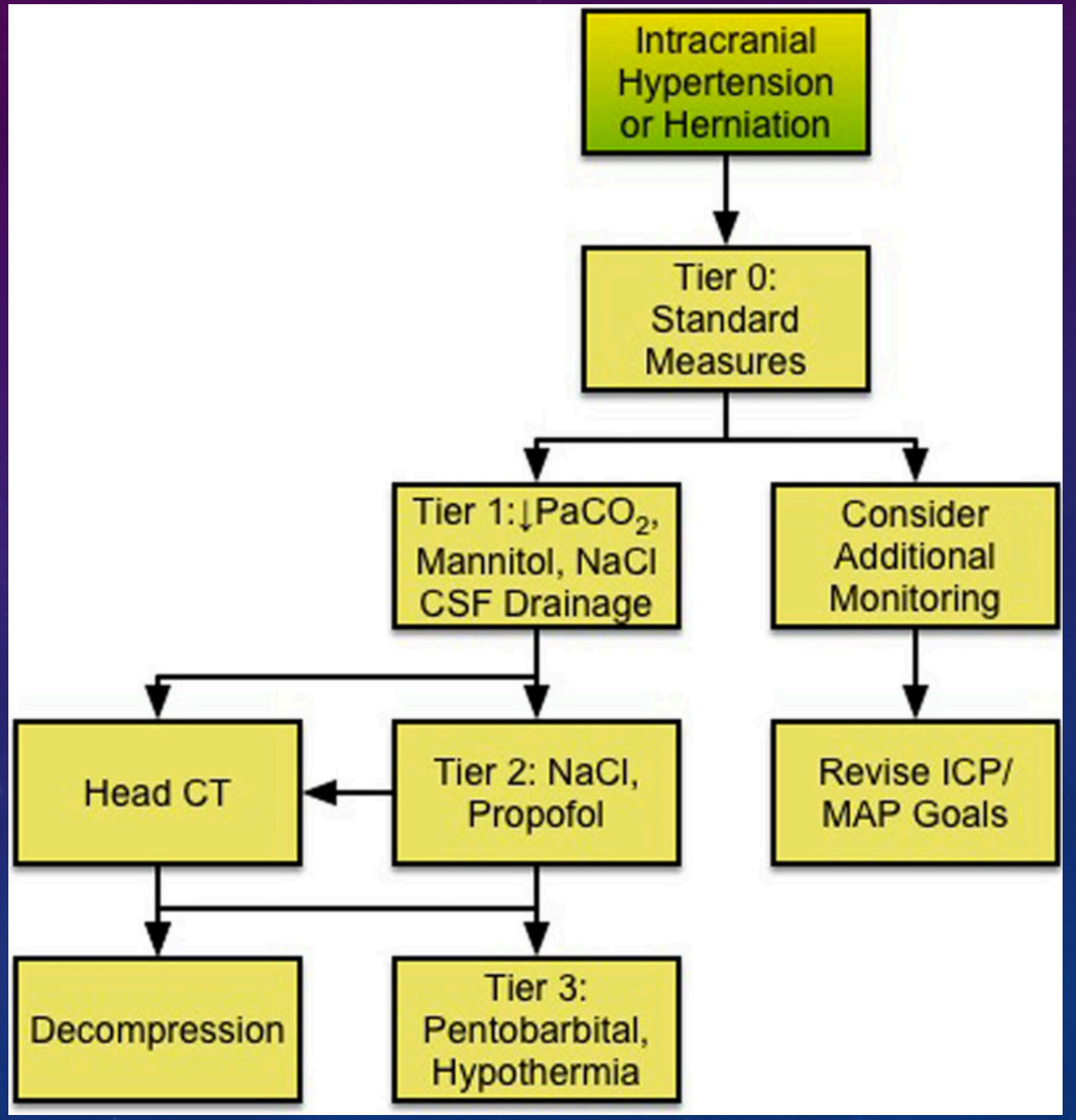
- Skull is a fixed cavity, Volume contained must remain fixed: brain, blood, csf
- In order to maintain equilibrium, a constant volume must be maintained
- Natural physiology can accommodate 100-120 ml increase in volume before ICP is affected
- An EVD shunts away CSF volume to alleviate some of the pressure
- Surgery removes mass lesions & expands the cavity by removing the skull
- OK then what??



The traditional Monro-Kellie doctrine
….it all seemed so simple back then


INTRACRANIAL COMPENSATION FOR EXPANDING MASS
Venous volume
Arterial volume
Brain
CSF
Normal state - ICP normal
Venous volume
Arterial volume
Brain
Mass
CSF
Compensated state - ICP normal
Venous volume
Arterial volume
Brain
Mass
CSF
5 ml
75 ml
Uncompensated state - ICP elevated

THE CLASSIC TIERED APPROACH

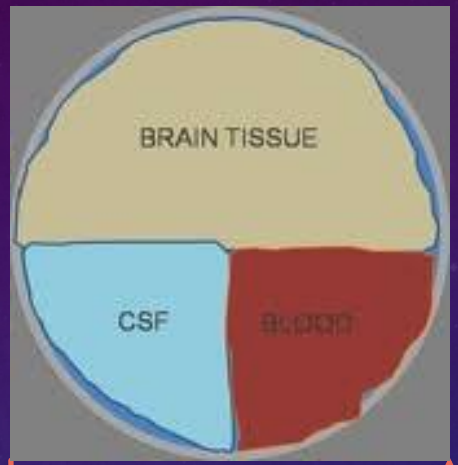


REAL WORLD


Sedation
Pressure
MAP
Venous
Stimulation
Positioing
TBI
ICP
C-collar
Outflow
PACo2
CPP
Pain
Hypertonic
obstruction
Autoregulation

Surgery – Craniectomy , clot removal

CSF and Edema
EVD
Hypertonic
Hyperosmolar



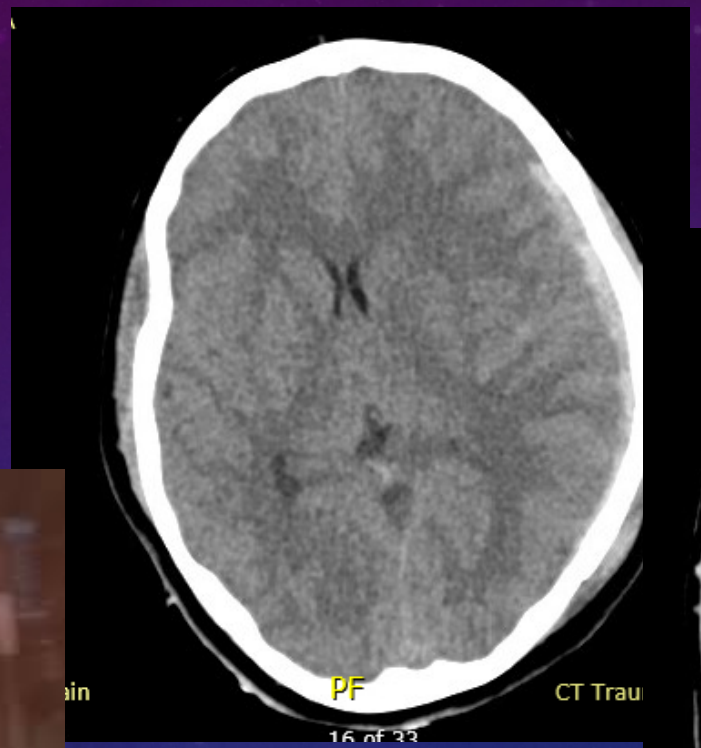
Vessel Diameter
-Autoregulation
-PaCO2

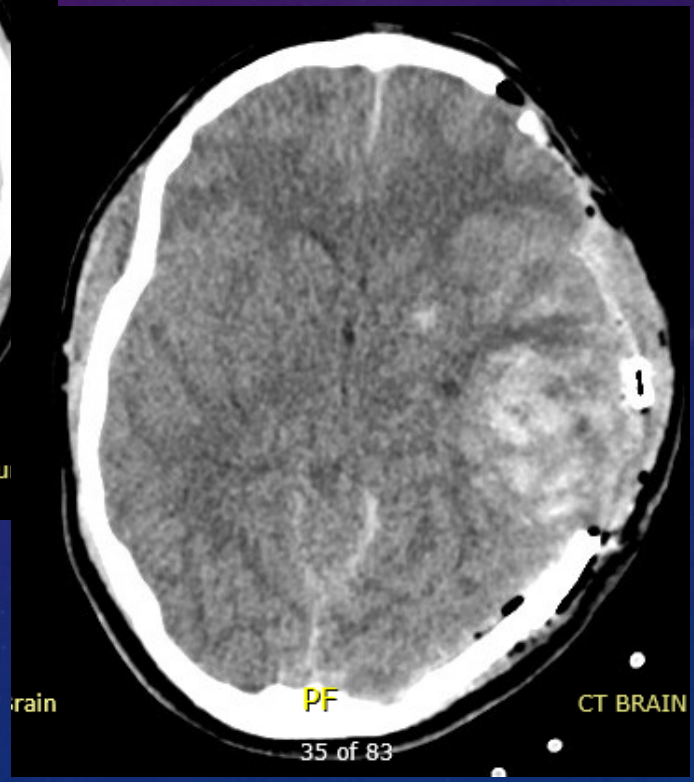
MAP/CPP

Outflow Resistance
-Clots
-Collars
-Lines
-Positioning
-Intrathoracic Pressure
-Intraabdominal Pressure

22 Y F s/p high speed PVA, GCS 5 (E1VTM3)

Taken for emergent Hemicraniectomy





Now What?

HOSPITAL DAY 2

Numbers:

ICP 18-30

CPP 60-70

PBTO2 10-12

Levophed @ from 5 -> 20

EVD 20 -> 10

CSF 100ml

Exam

Exam E1VTM3

Weak Corneals

Weak Gag

Pupils Reactive

Summary:

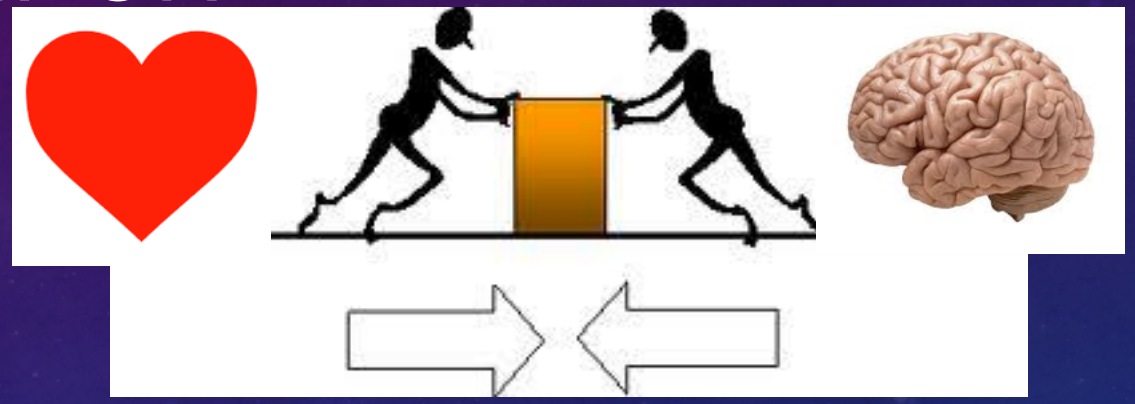
ICP has been rising, we've already done surgery and using more and more pressor to meet CPP goals

RN Says "I'm not sure she's autoregulating"

AUTOREGULATION

Wait….what?

CEREBRAL AUTOREGULATION



Key terms:

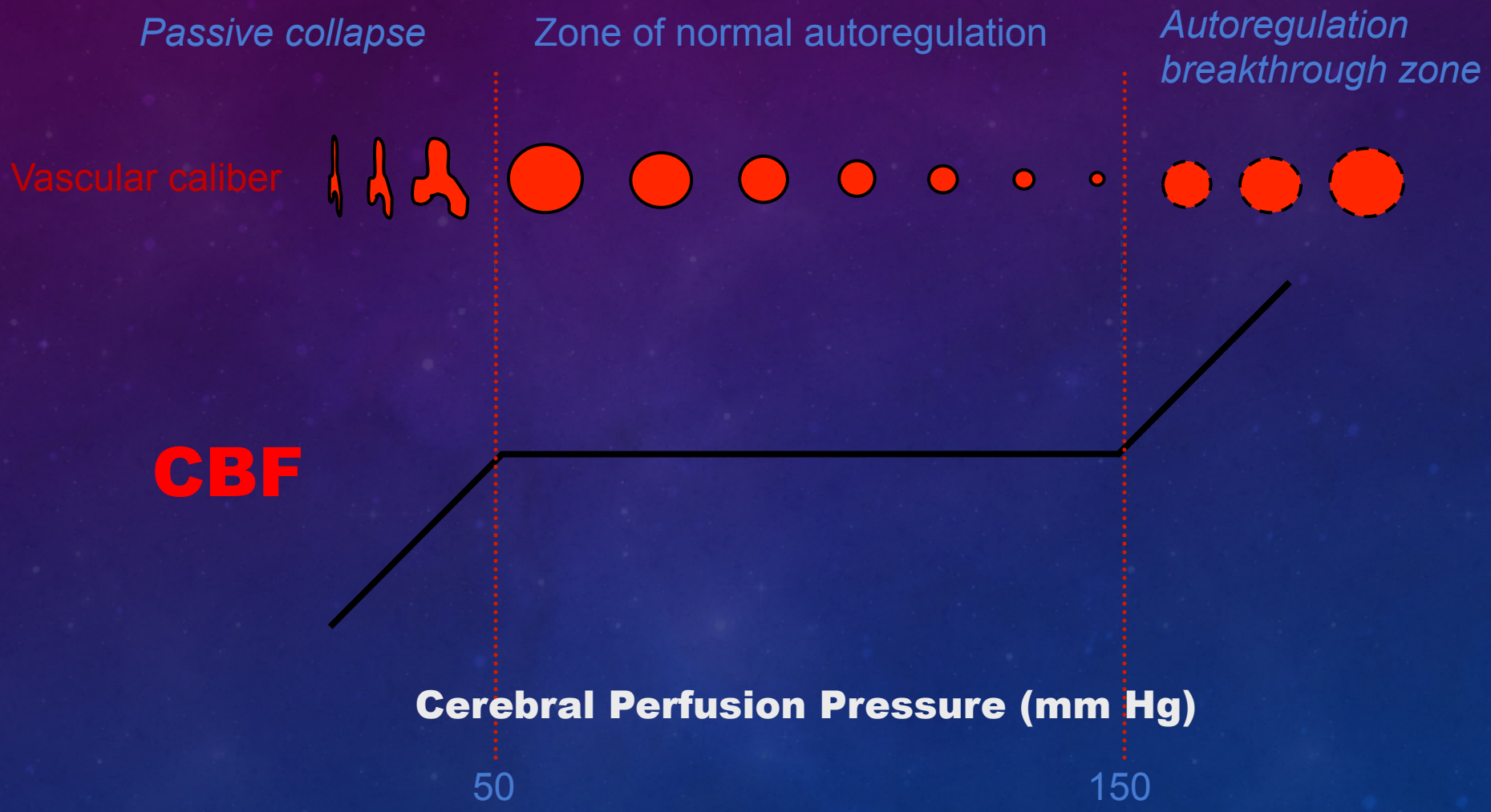
MAP = Mean Arterial Pressure – the force driving blood into the brain

ICP – Intracranial pressure - the pressure in the brain – compresses tissue and resists blood flow

CPP – Cerebral Perfusion pressure = (MAP – ICP) = The pressure perfusing the brain tissue

CBF – Cerebral Blood Flow - blood supply to brain – 15% of cardiac output-750 mL/minute

CEREBRAL AUTOREGULATION



The brain wants a constant steady flow of blood and will work hard to achieve that

BUT WAIT…..HOW ARE WE MEASURING CBF?

Ways to measure CBF:

-Transcranial Doppler

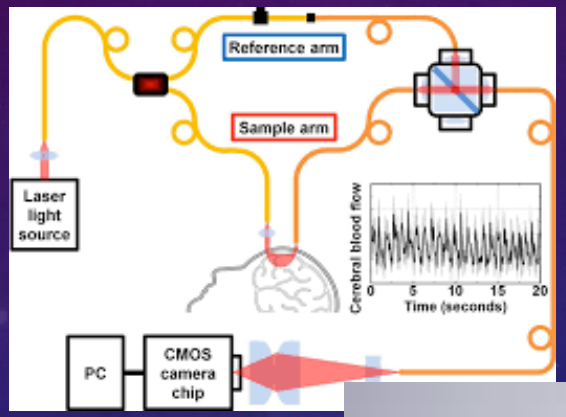
-MRI

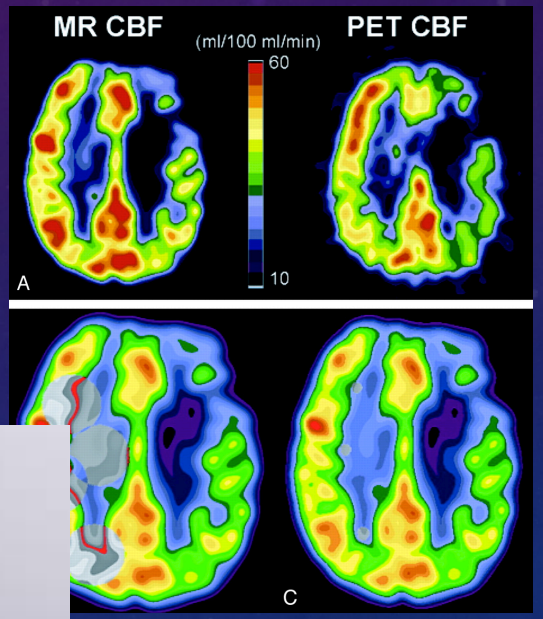
-CBF catheter

Surrogates at the bedside

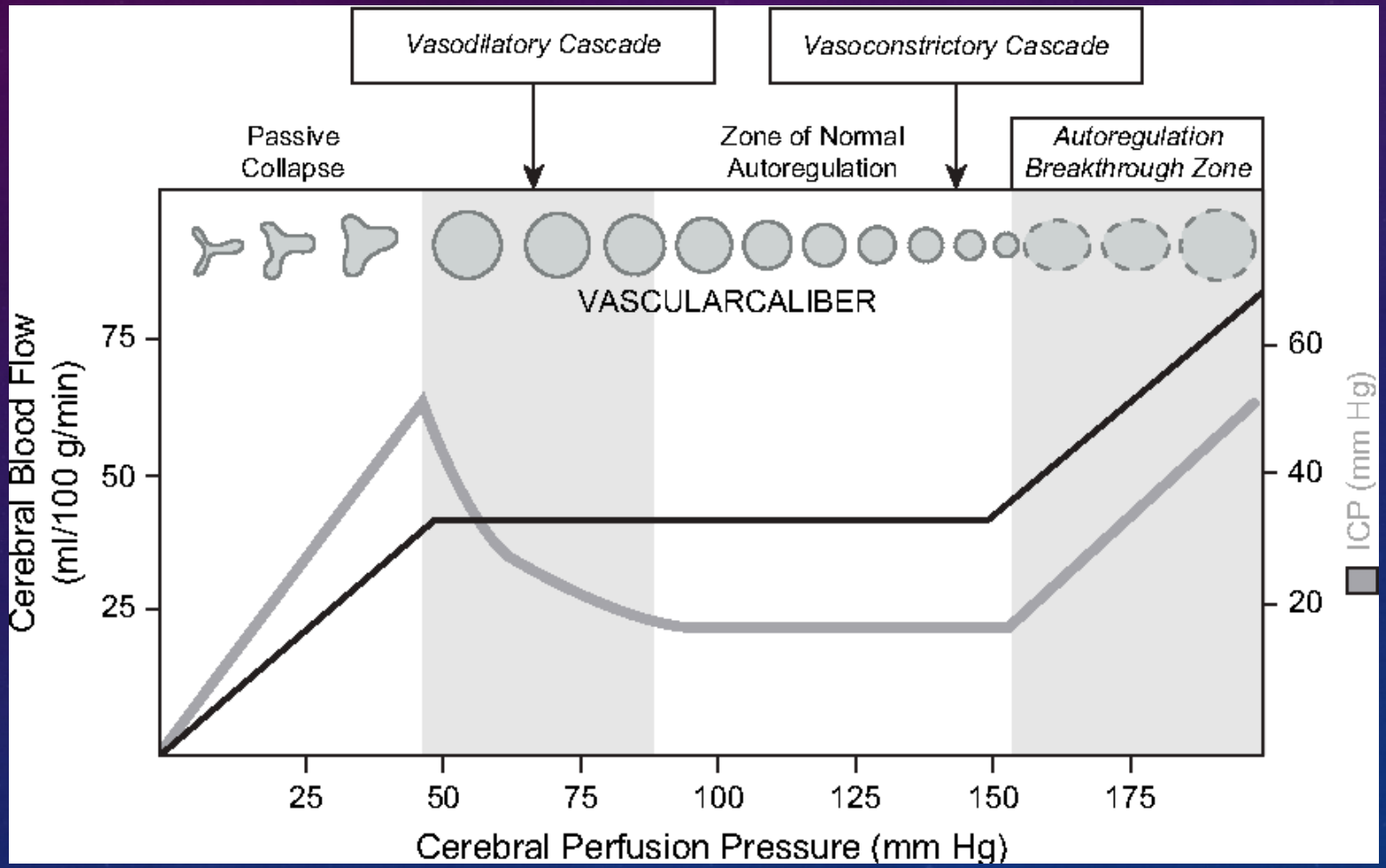
PBTO2

ICP

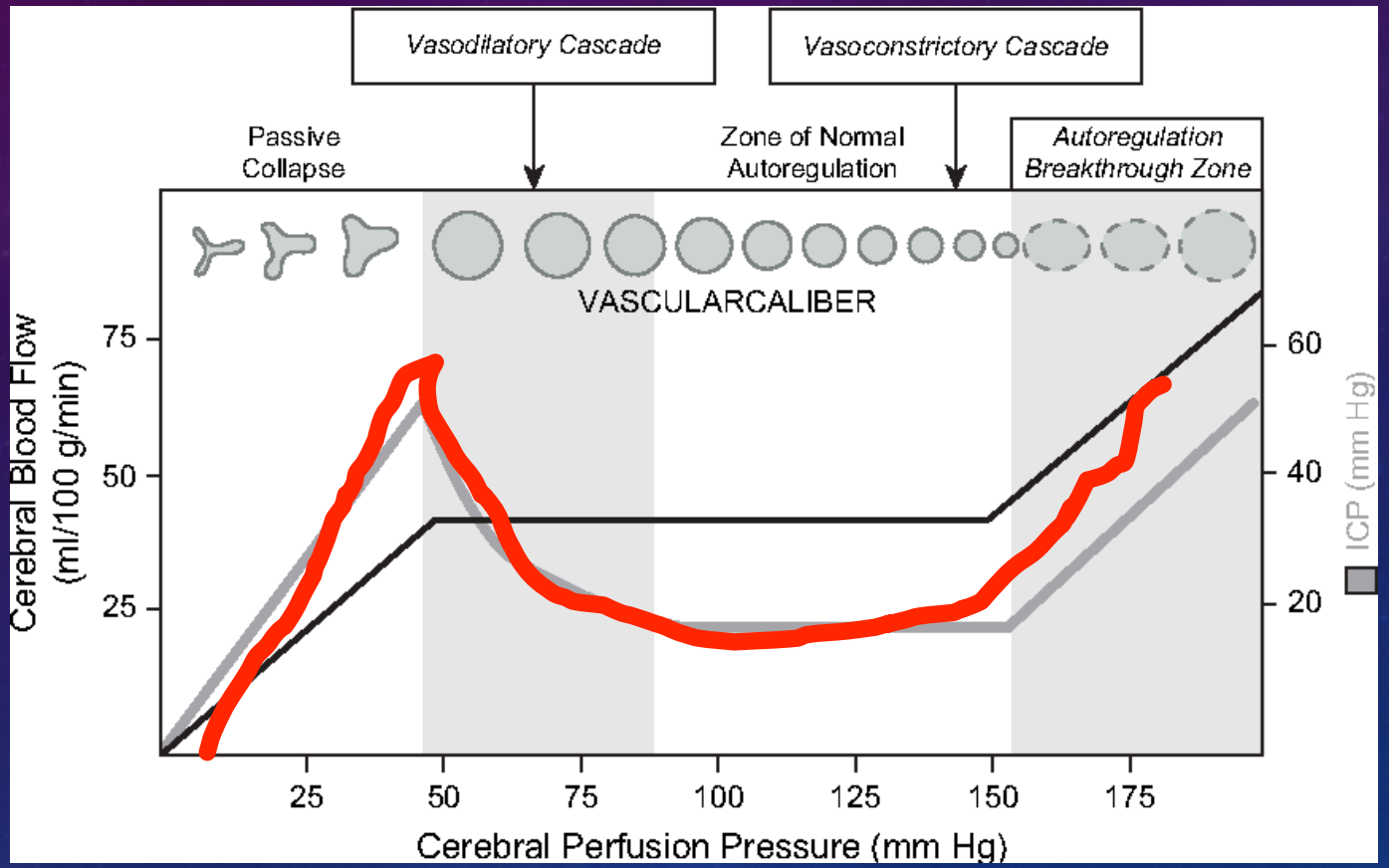




ICP AS A SURROGATE



DO A LITTLE VOODOO

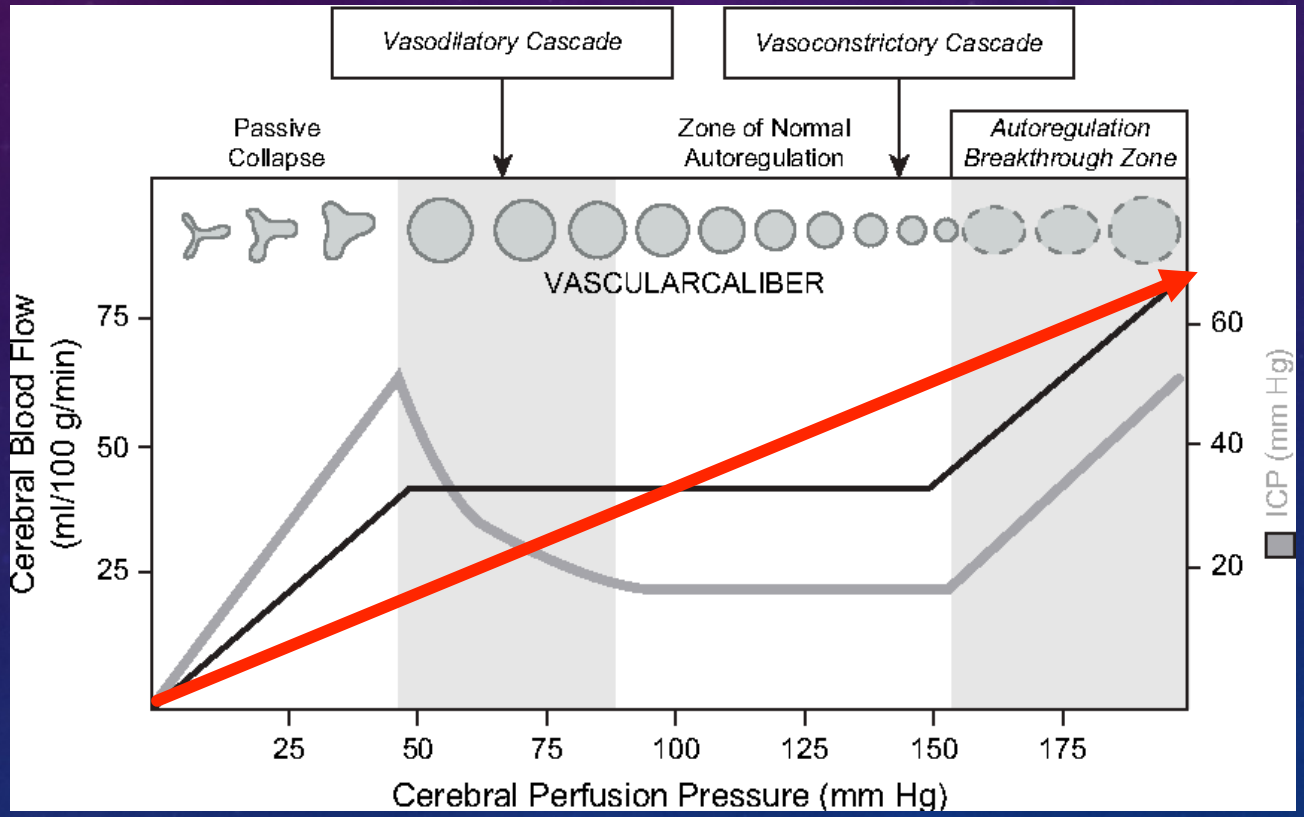


ICP

CPP = MAP-ICP

AUTOREGULATION NOT INTACT

ICP

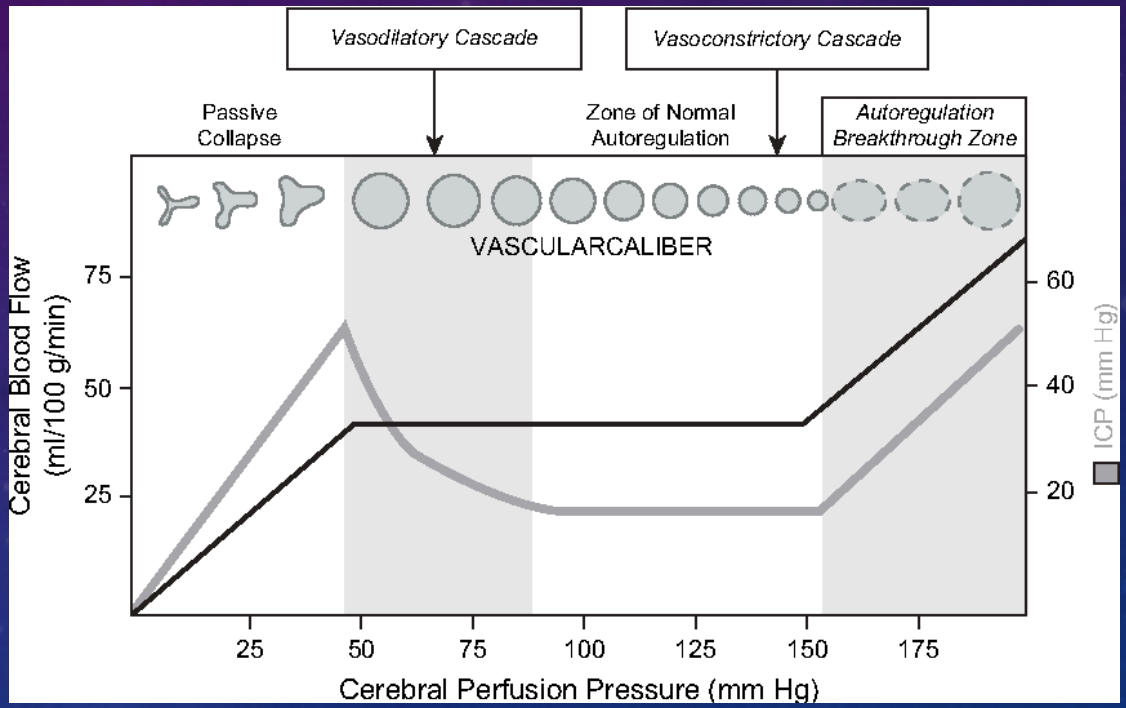


MAP

TESTING AT BEDSIDE : AUTOREGULATION CHALLENGE

1) Create a quiet and calm environment
2) Control for other variables
3) Use vasopressor to increase the MAP ~ 10 points over 10-20 minutes
4) Observe for rise in ICP or steady state

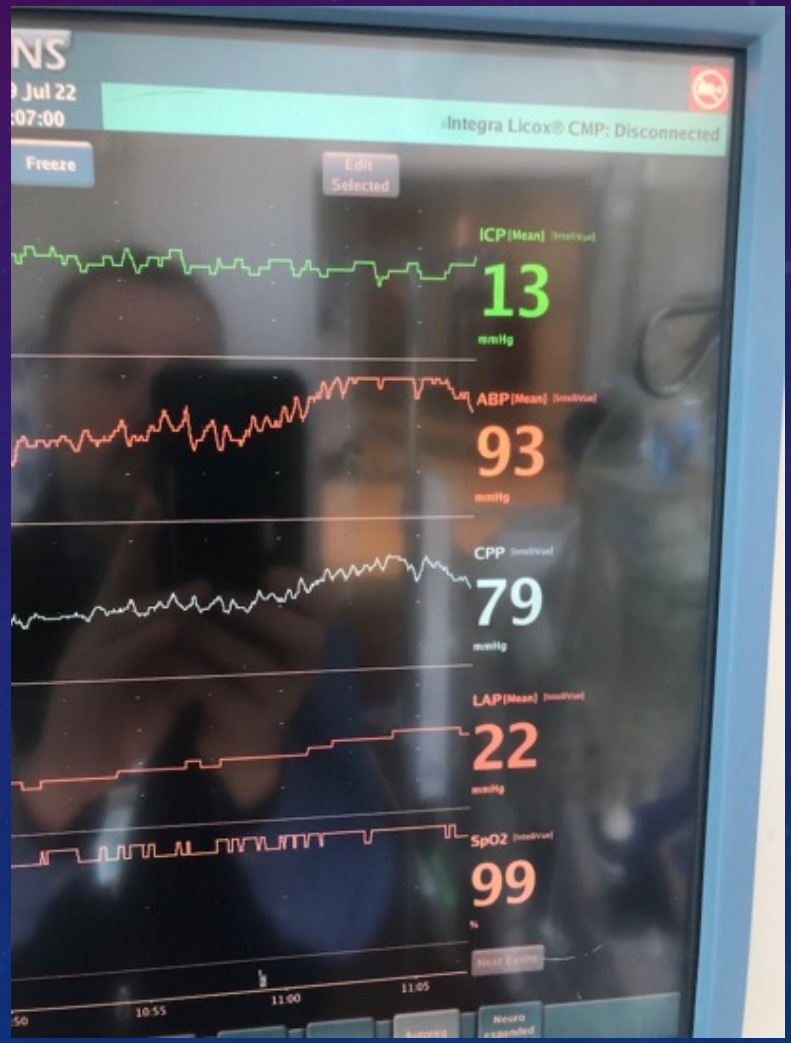
ICP



MAP

AUTOREGULATION CHALLENGE INTACT

Levophed increased from 10-20
MAP increased from 83 to 93
ICP remains 13



AUTOREGULATION NOT INTACT

Levophed increased from 10-20
MAP increased from 105 to 115
ICP increased from 20 to 30

BACK TO OUR CASE

Bedside autoregulation challenge done

MAP raised from 85 to 95 using levophe

ICP increased from 15 to 25

What to do with the info?

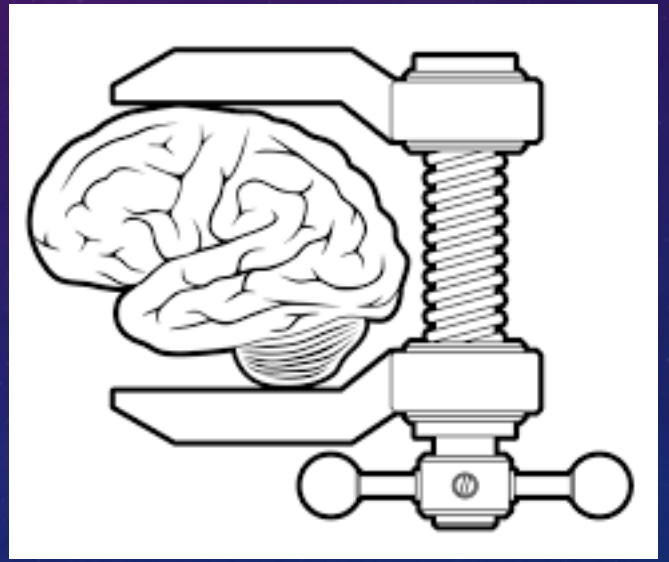
Decreased CPP goal to 50, allowing for less pressor use and lower ICP while maintaining adequate perfusion

HOSPITAL DAY 3 – AUTOREGULATION CHALLENGE

Changed back to CPP goal > 60

HOSPITAL DAY 4

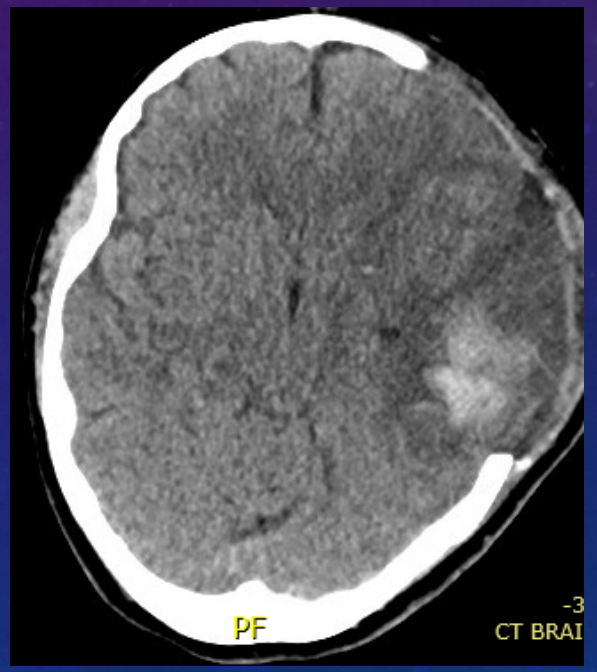
ICP increasing 20 -> 30
EVD being drained every 5-10 minutes
Autoregulation intact



RN asks – What's her pressure equalization ratio?

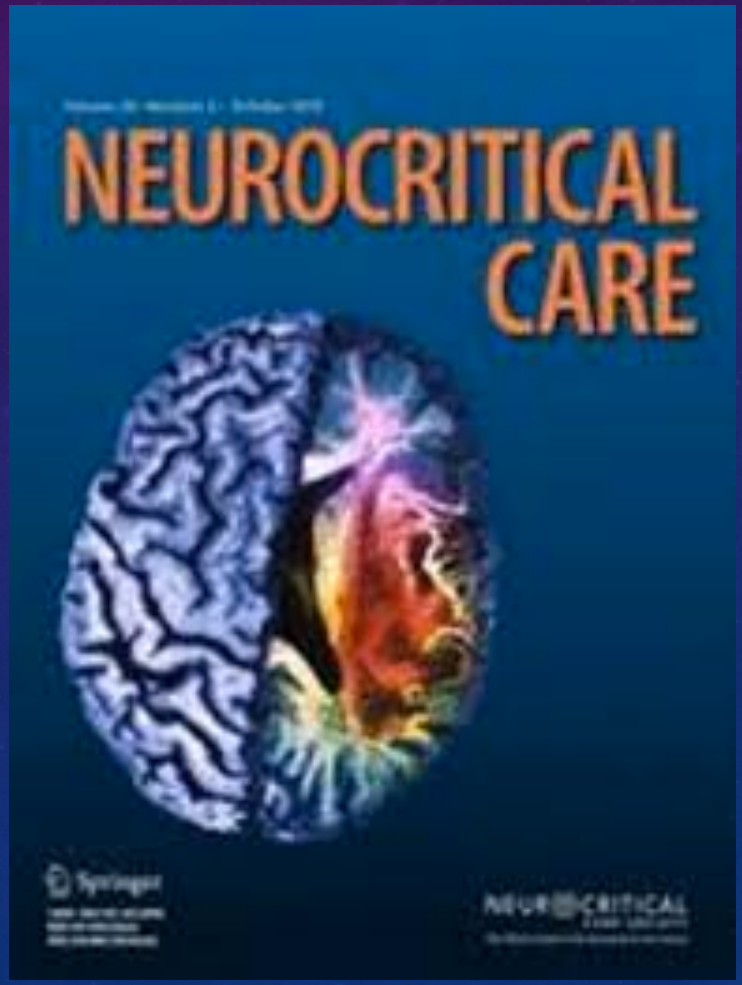
EVD DRAINAGE VS HYPERTONIC/OSMOLAR

USE A STRAW OR USE A DEHYDRATOR



PRESSURE EQUALIZATION RATIO

- Developed in conjunction with BASIC and Hadassah-Hebrew University Medical Center
- Based on 2019 paper: Characterizing the Response to CSF drainage in Patients with an EVD: The pressure equalization ration. Neurocritical Care April 2019
- Uses an index to define the response to CSF drainage in Neurocritical care patients
- Helps answer the question – straw or dehydrator



PRESSURE EQUALIZATION RATIO

Bedside test to assess the ICP response to EVD drainage

- Close the EVD and wait 30 minutes
- Measure the pre-drain ICP
- Set the EVD at the desired height (10cmH20)
- Open the EVD until it stops draining
- Measure the post drainage ICP
- Do some Math

PRESSURE EQUALIZATION RATIO

The math:

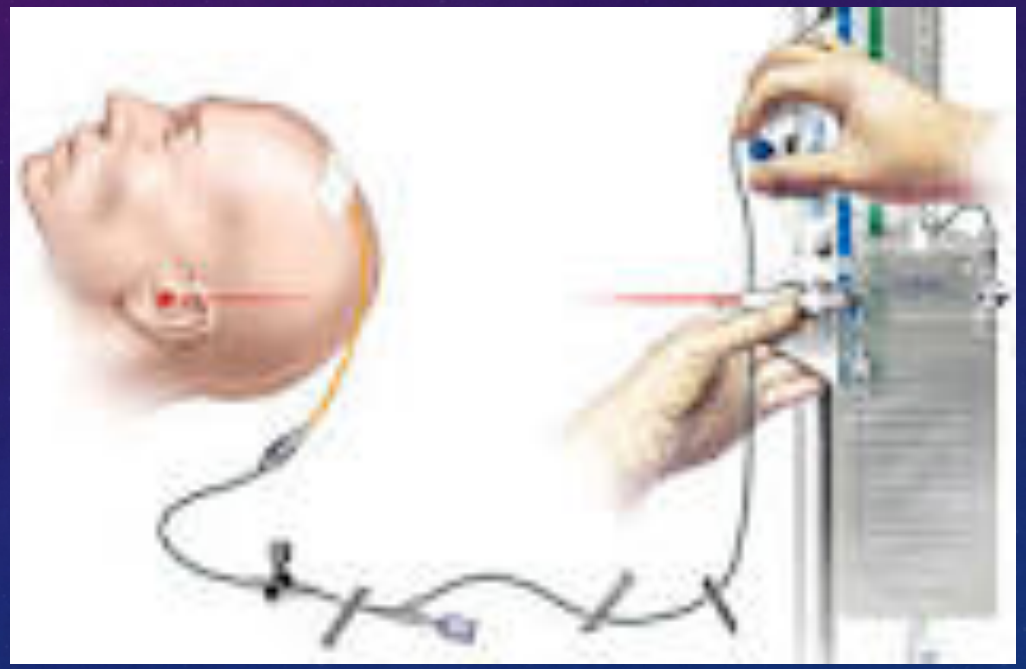
Change in ICP/Change in ICP (Expected) =

ICP(initial) − ICP(post) /ICP(initial) − EVD height

Gives a number from 0 – 1

Closer to 0 suggests edema is the driver and ICP will benefit from Hypertonic/Hyperosmolar

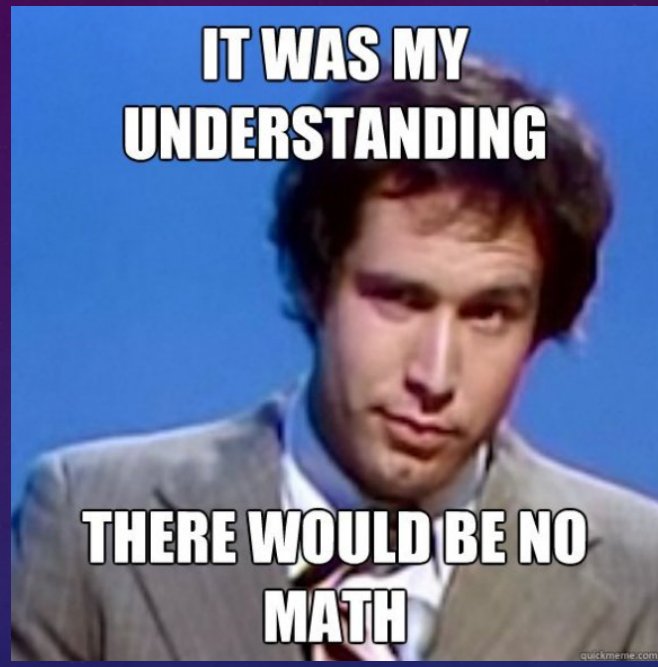
Closer to 1 suggests CSF obstruction is the problem and ICP will benefit from CSF drainage



BACK TO OUR CASE - TRYING IT OUT

Change in ICP/Change in ICP (Expected) =

ICP(initial) − ICP(post) /ICP(initial) − EVD height



ICP Initial 20mmhg ICP post 18mmhg EVD height 10mmhg

(20-18)/(20-10)=2/10=0.2

Pressure equalization ratio of 0.2

Suggests ICP may benefit more from hyperosmolar/hypertonic therapy

BACK TO OUR CASE

Pressure equalization ratio of 0.2 suggests ICP may benefit more from hyperosmolar/hypertonic therapy

Based on our bedside test, the patient is given a dose of 23.4% sodium with subsequent decrease in ICP from 30 to 15.

Over the next 24 hours she receives 2 more doses for elevated ICP

THE NEXT DAY

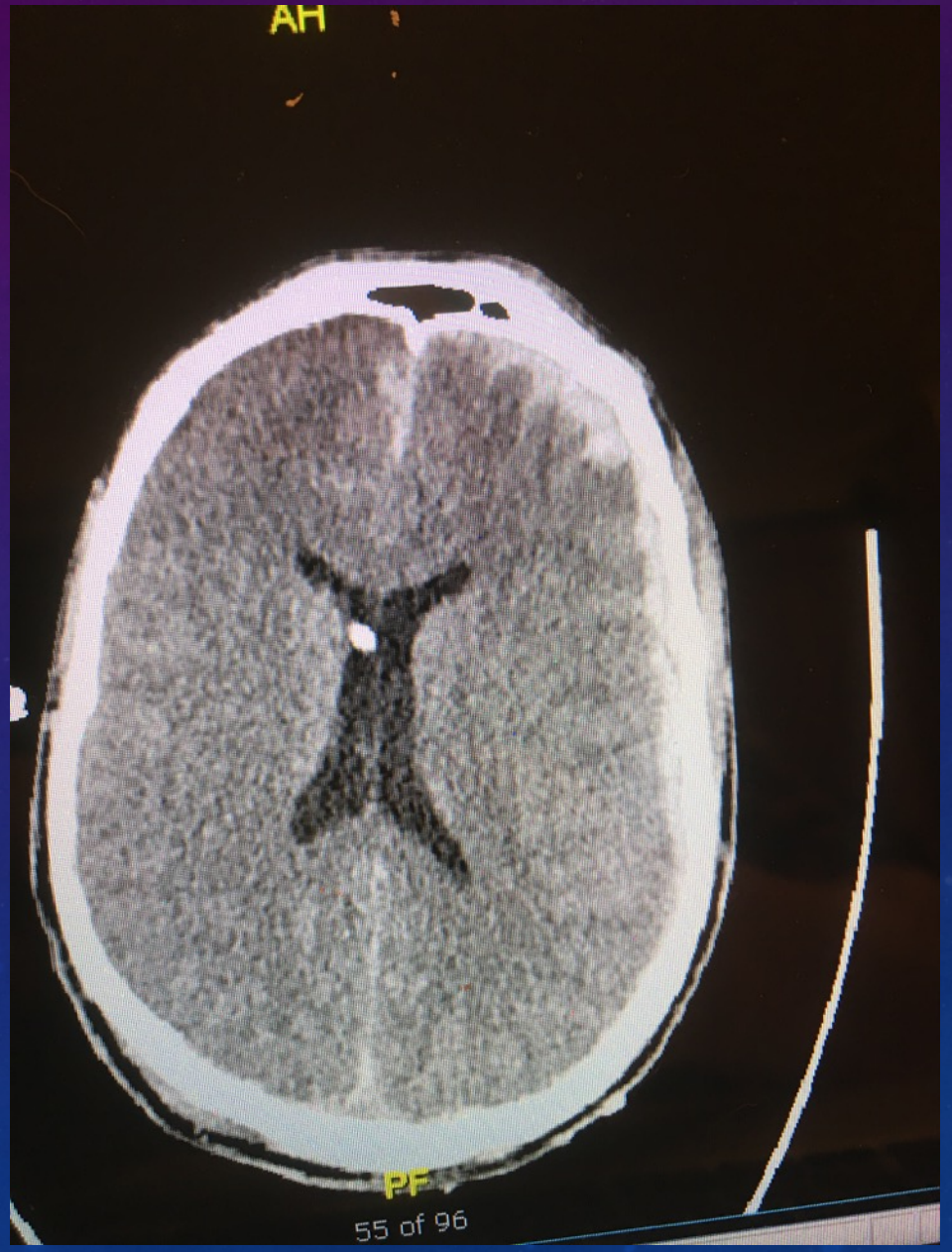
- The next day her Pressure Equalization ration is 0.8,
- Suggests her ICP will respond better to CSF drainage and her EVD is changed to open at 10 to maximize drainage.

6 MONTHS LATER

- The patient returns to the ICU with her mother, walking on her own.
- She is still undergoing intense speech therapy for persistent but improving expressive aphasia.

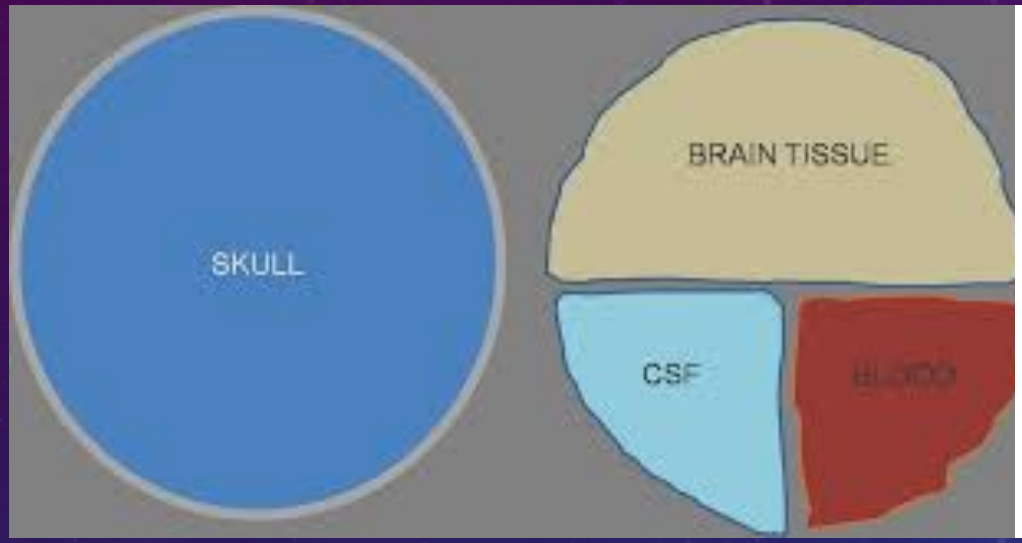
CASE STUDY #2

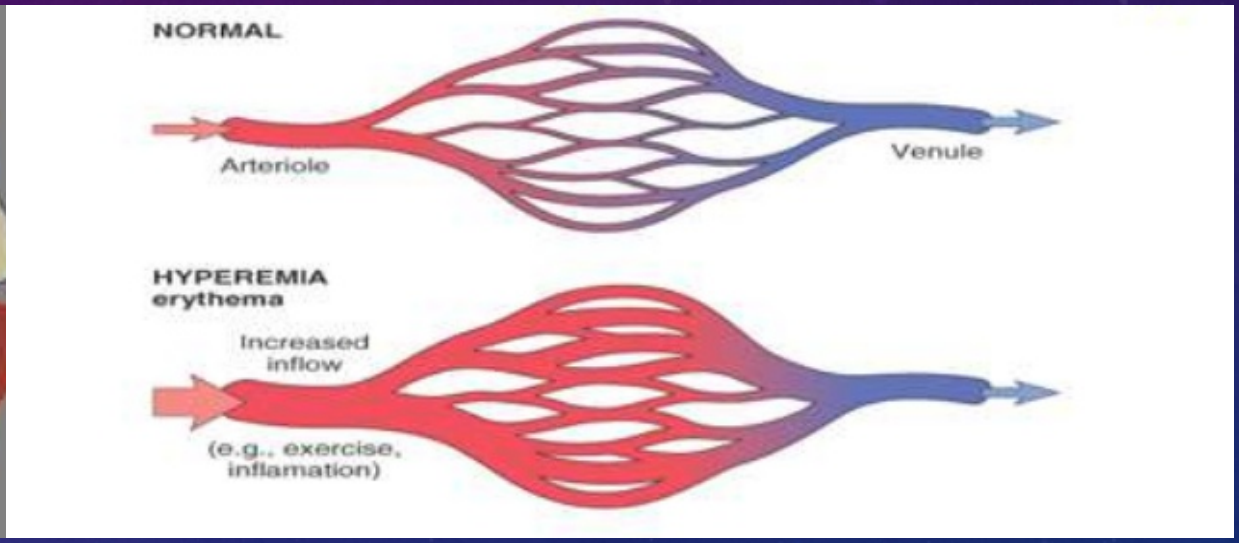
- 27 M s/p fall from skateboard, 7 mm L SDH, 11MM L anterotemporal contusion, 6mm midline shift, bilateral occipital skull fractures and L temporal bone fracture.
- In ICU with EVD, Pbt02 monitor. During morning, ICP elevated but manageable with drainage 1-2x/ hour. Mid-afternoon, ICP elevates to 38, sustained, not responsive to drainage, slowly trending down to mid-20's over approx 20-30 minutes



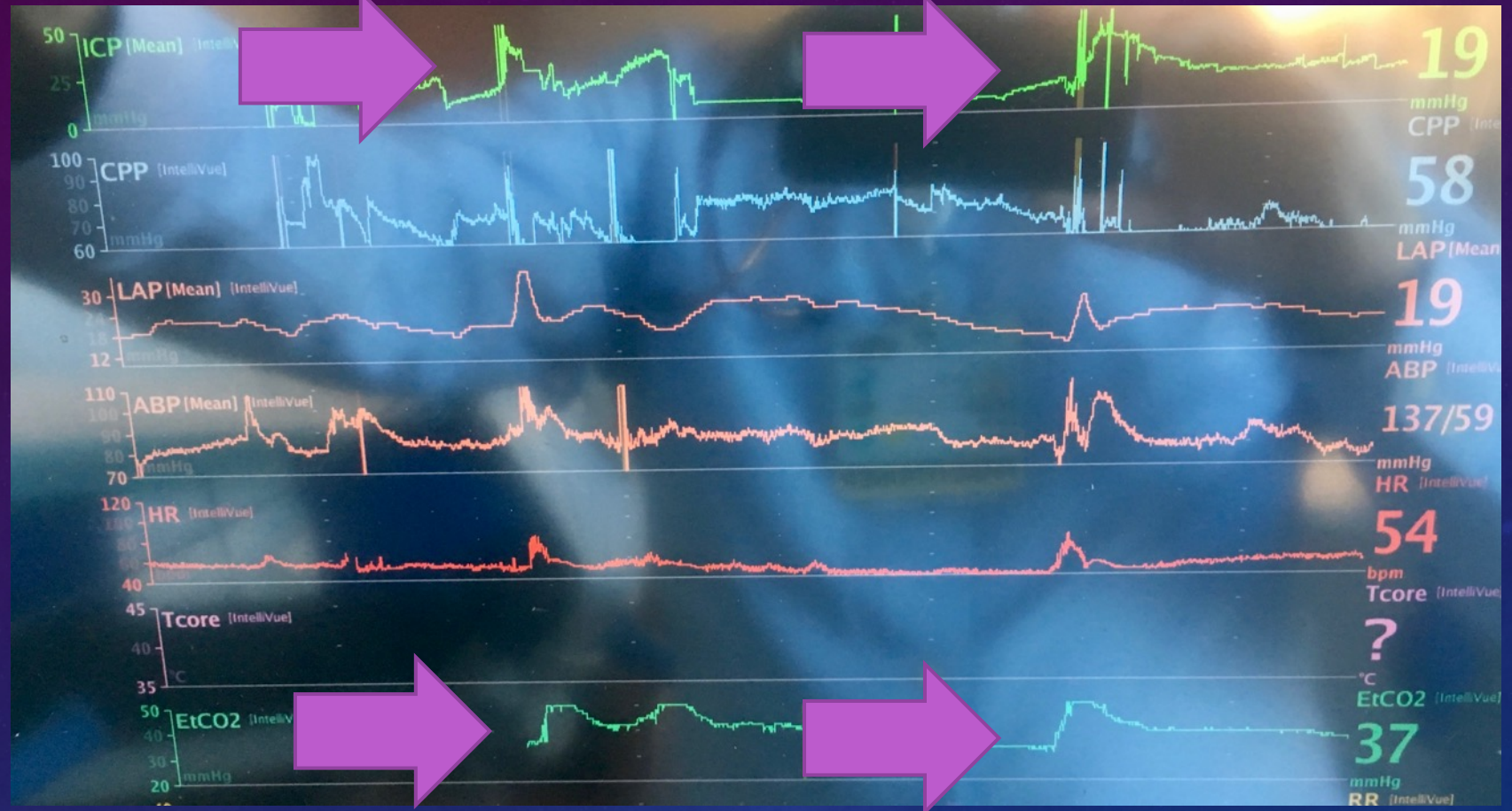
LOOKING AT THE TRENDS

RELATION OF PACO2 TO ICP





MOBERG DATA WITH ETCO2



EtCO2 data pulled up on Moberg,

6 HOURS LATER

CASE #3 – So many ways to fall

- 34yo M s/p unhelmeted scooter accident
- GCS E3V4M5 → BIBA → E2V3M5 in ED, E1V2M3 upon NSU arrival.
- L frontal contusion, temporal bone fracture
- Intubated→ ICU after scans for multimodal monitor placement

HELMET, ANYONE?

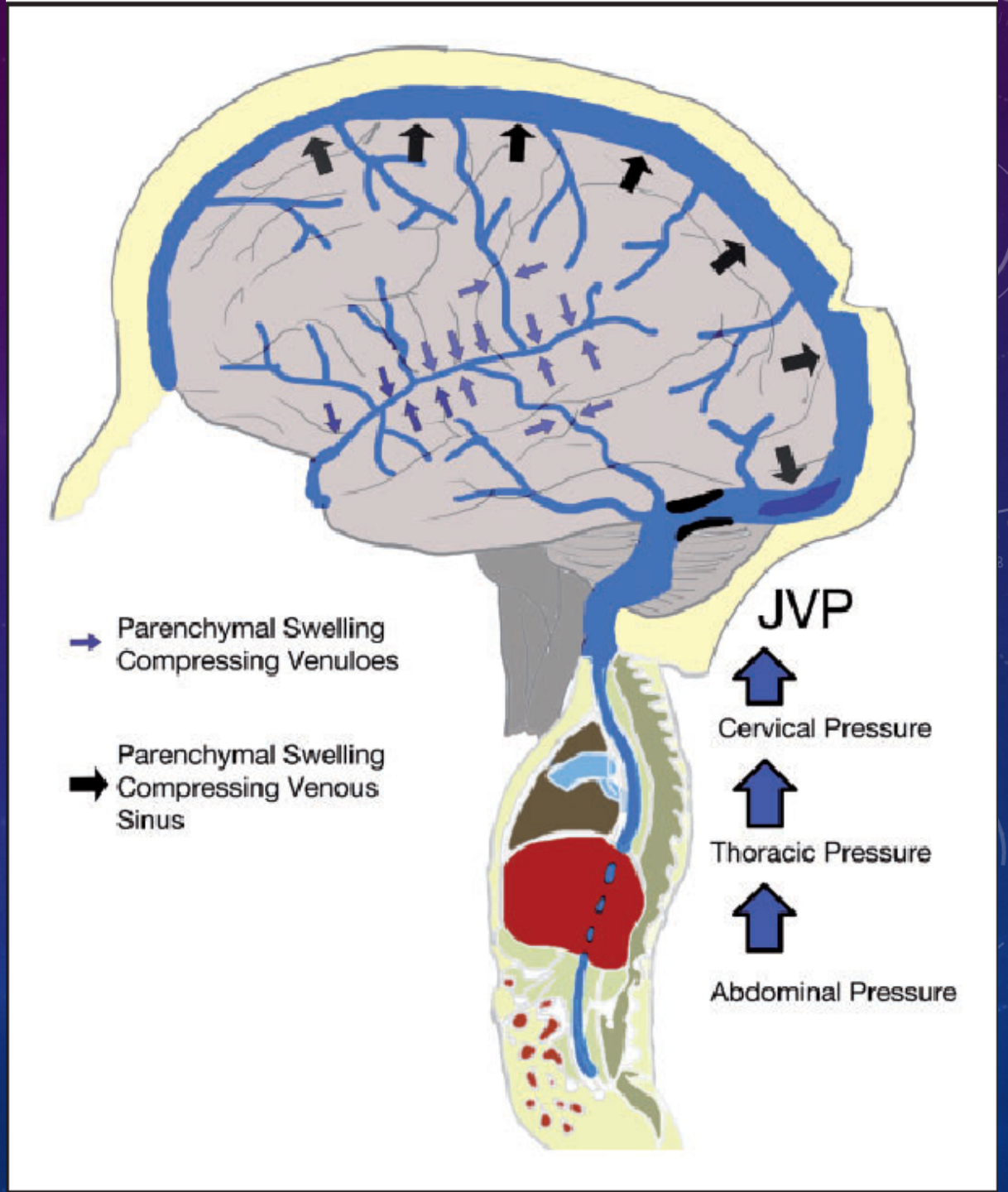
Numbers	Exam -
ICP 18…24…35	E2VTM4
CPP 60-70	+Corneals, Cough, Gag
PBTO2 17	NPI 3.5-4 bilaterally
Na 144	
EVD open @10	
CSF 75mL/8hrs	

- Summary:
- EVD initially brisk, now is dripping slowly, ICPs are increasing but are much less responsive to drainage by end of shift
- WHAT'S WRONG?!

THE PRESSURE IS MOUNTING

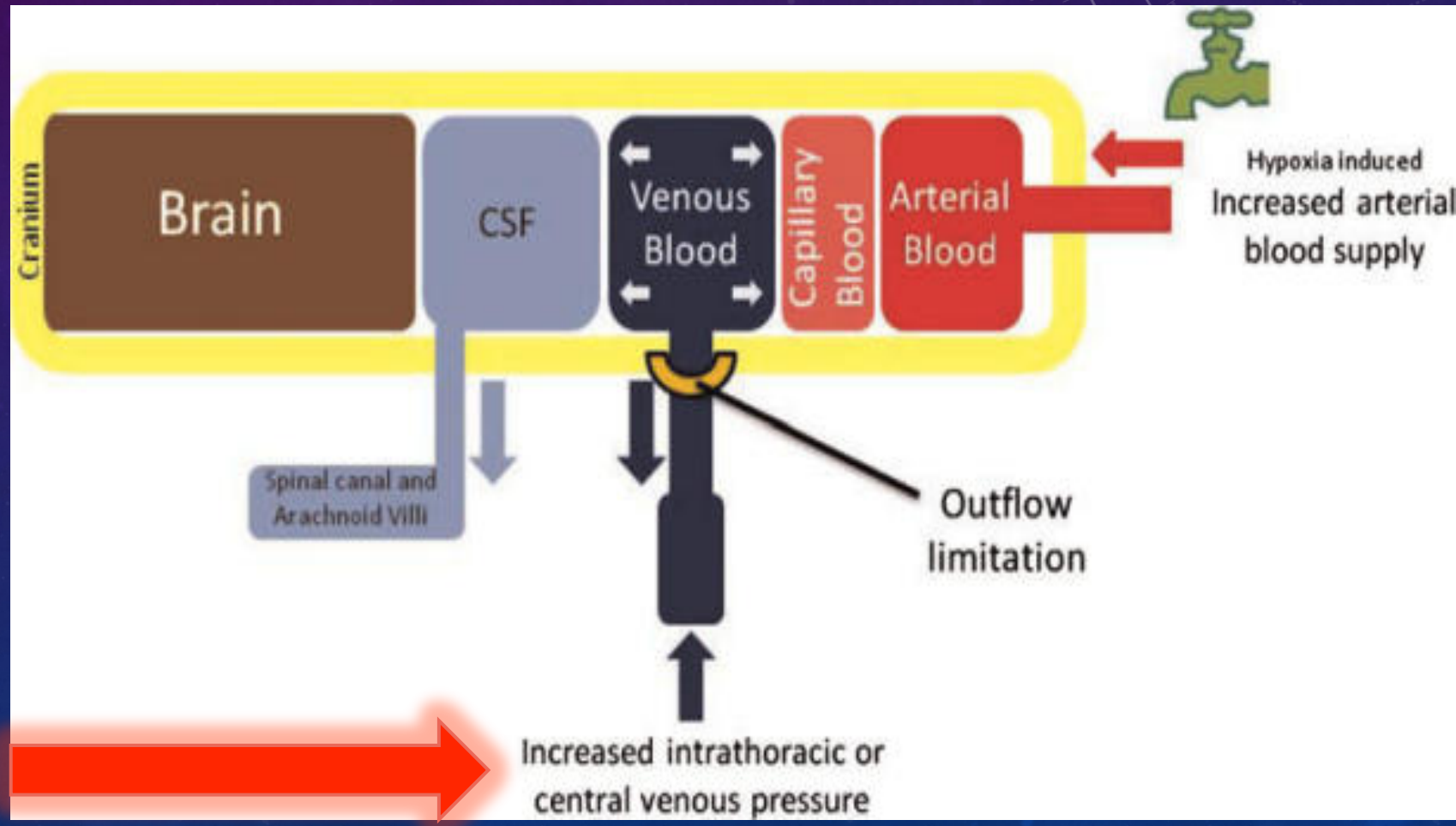
- Pathologies in the neck, chest, and abdomen all contribute to intracranial pressure
- Q4h CVP checks
- Another reason for a central line!
- Bedside ultrasound to assess IVC collapsibility, hydration status
- Accurate initial and daily weights

MH Wilson, et al J Appl Physiol 120: 244–250, 2016



DRAIN MORE CSF, RIGHT??

- Produce 0.35mL CSF/ min.
- Minute volume of blood flow to the brain is 700mL – brain can only handle about 120mL extra before ICP problems occur.
- CSF drainage can only help so much – it's the blood flow that can really overwhelm the system



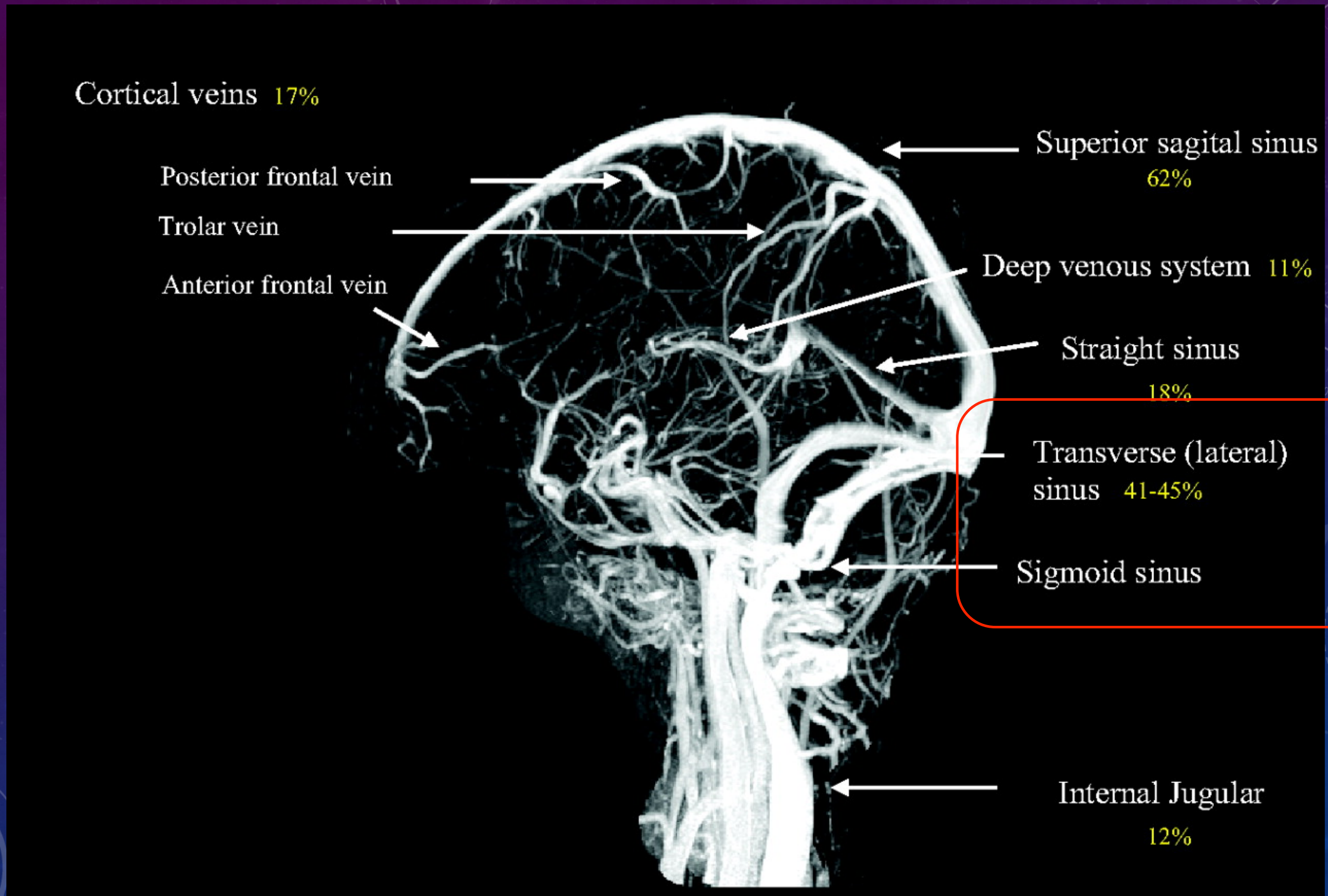
IMPROVING VENOUS OUTFLOW

- HOB ≥ 30 degrees
- Taping of ETT non-circumferentially
- Removing cervical collar
- Minimizing peep
- Maximizing poop (i.e. Decompressing abdomen)
- Don’t underestimate the power of positioning!

What can you do at the bedside?

FINAL READS ARE IN!

- Due to multiple skull fractures, CTA was completed. Radiologists recommend CTV…
- CT venogram shows Venous sinus thrombosis
- Causes congestion in the venous outflow system
- Leads to cerebral edema, increased ICP
- Eventually will cause ischemia --> stroke
- Very hard to treat in trauma – when can we start heparin?


Cortical veins 17%
Posterior frontal vein
Trolar vein
Anterior frontal vein
Superior sagital sinus
62%
Deep venous system 11%
Straight sinus
18%
Transverse (lateral)
sinus 41-45%
Sigmoid sinus
Internal Jugular
12%

VENOUS SINUS THROMBOSIS

- <30% can be seen on non-con CT, so usually get vascular imaging in setting of skull fracture
- CTV or MRV for definitive diagnosis
- Tissue congestion caused by outflow obstruction
- CSF resorption impaired
- “Virchow triad” risk factors:
  - Changes in vessel wall
  - Blood stasis
  - Changes in the composition of the blood

TREATMENT FOR SINUS THROMBOSIS?

- Unfortunately, the only treatment is HEPARIN
- So we have to focus heavily on improving outflow with all our other measures
- Timing for heparin start will depend on repeat scans, other injuries, overall coagulopathy profile
- Watch exam closely, infarct is very possible

IN CLOSING…THINK LIKE JOE!