

Time is Brain: Neurologic Emergencies in the OR

Martin Krause, MD

Associate Professor

University of California San Diego

no conflict of interest

no disclosures

In the next 35 minutes,...

We will discuss the perioperative management of

- intracranial pressure crisis
- intracranial hemorrhage
- status epilepticus

We will only briefly cover

- indications for seizure prophylaxis
- facilitation of neuromonitoring
- emergence techniques

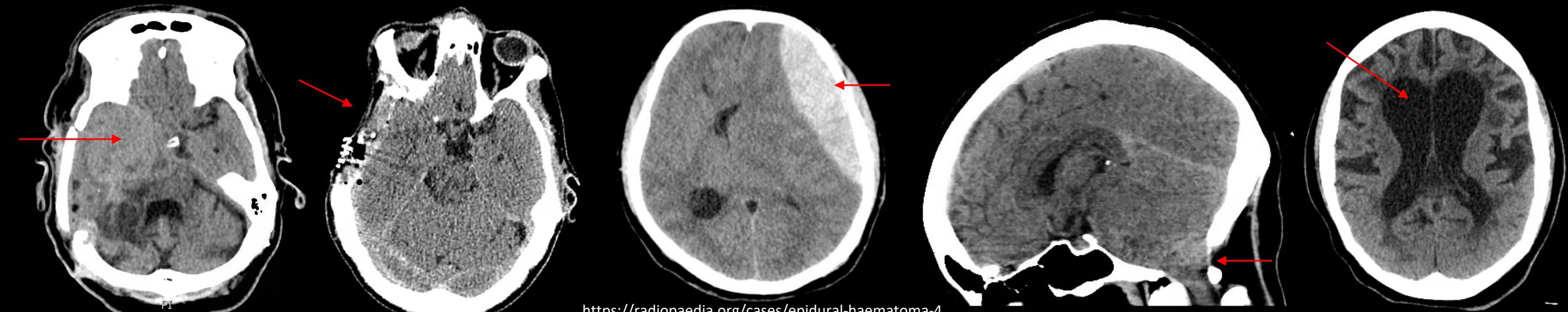
Intracranial Pressure (ICP) Crisis: Cerebral Perfusion & Brain Relaxation





Patients with ICP Crisis in the OR

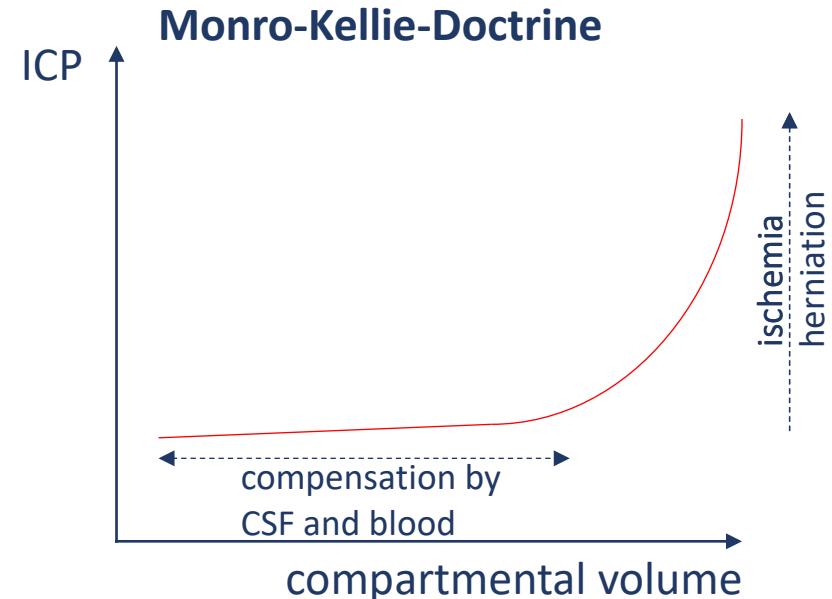
- tumor, metastasis, abscess (resections)
- malignant MCA strokes (hemicraniectomy)
- epidural or subdural hematomas (craniotomy, burr hole)
- posterior fossa strokes or bleeds (suboccipital craniectomy)
- obstructive or nonobstructive hydrocephalus (EVDs)



A Confined Space: Why ICP Matters

Sum of three compartments is constant:

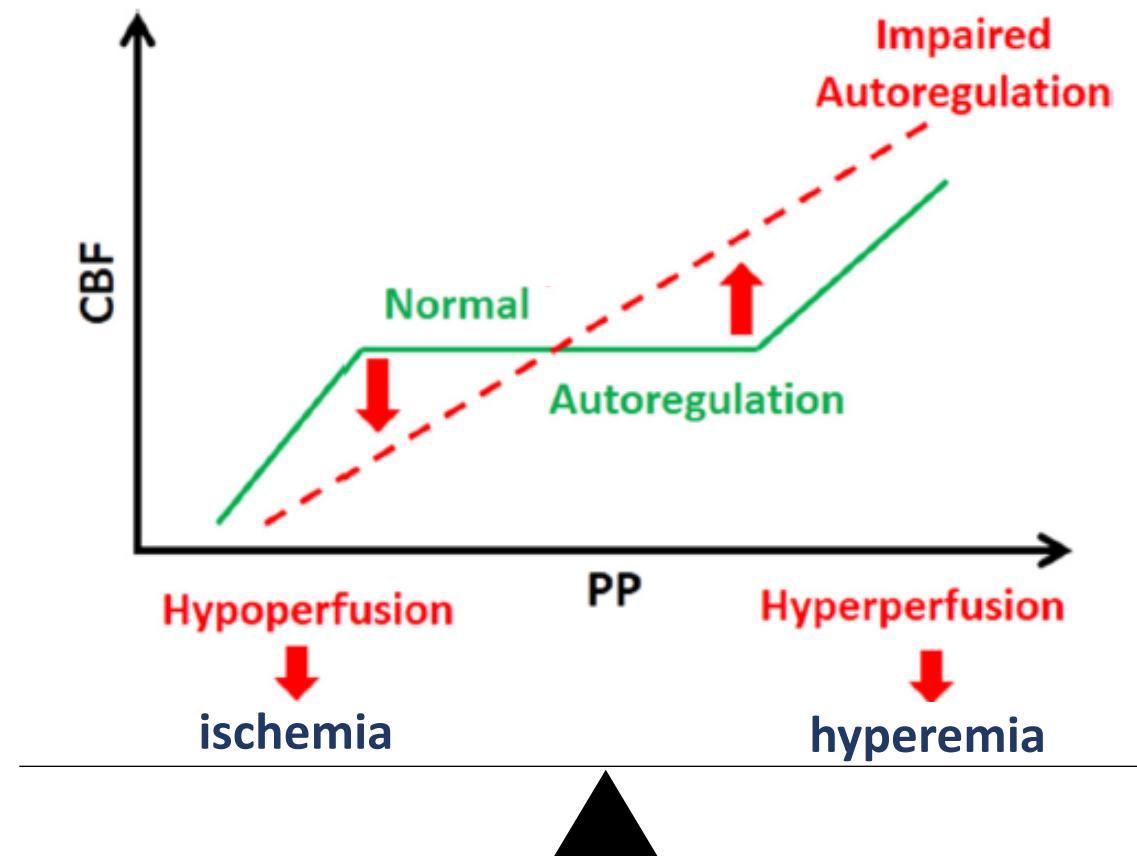
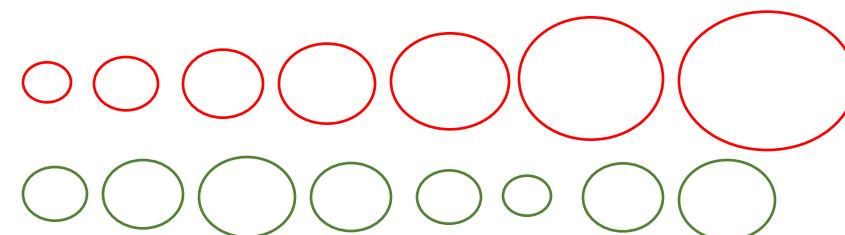
- brain tissue (approx. 80%)
 - cerebral blood (approx. 10%)
 - arterial inflow
 - venous outflow
 - cerebrospinal fluid (approx. 10%)
-
- normal ICP \leq 15 mmHg
 - sustained ICP $>$ 22-25 mmHg results in
 - a) ischemia from reduced cerebral perfusion pressure (CPP)
 - b) compression of vital structures (herniation)
 - c) neurosurgical retraction- and compression-injury



Ischemia: Why Cerebral Perfusion Matters

active vasoconstriction

intact autoregulation:
stable CBF



passive vasodilation

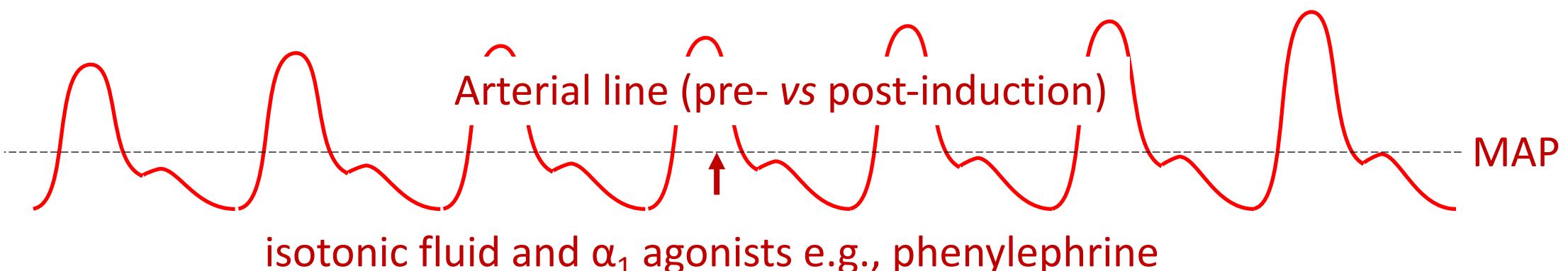
impaired
autoregulation
(e.g., TBI, ICH):
passive pressure-
flow relationship

But What's the Right Blood Pressure

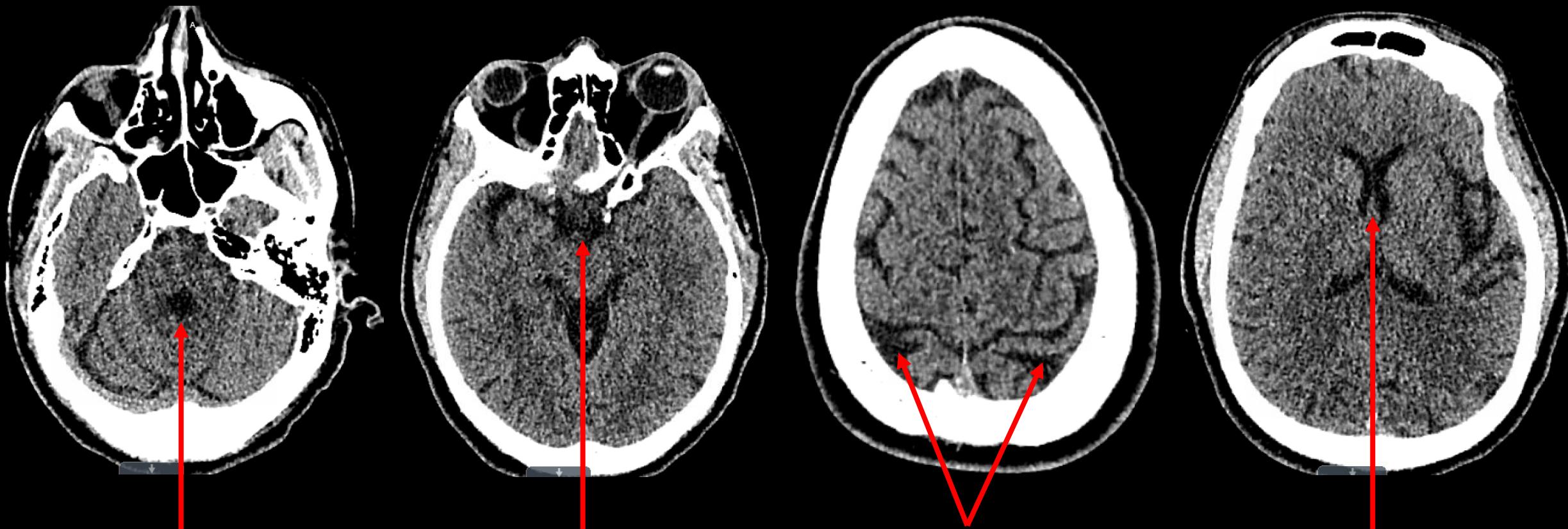
$$\text{CPP} = \text{MAP} - \text{ICP}$$

driving pressure resisting pressure

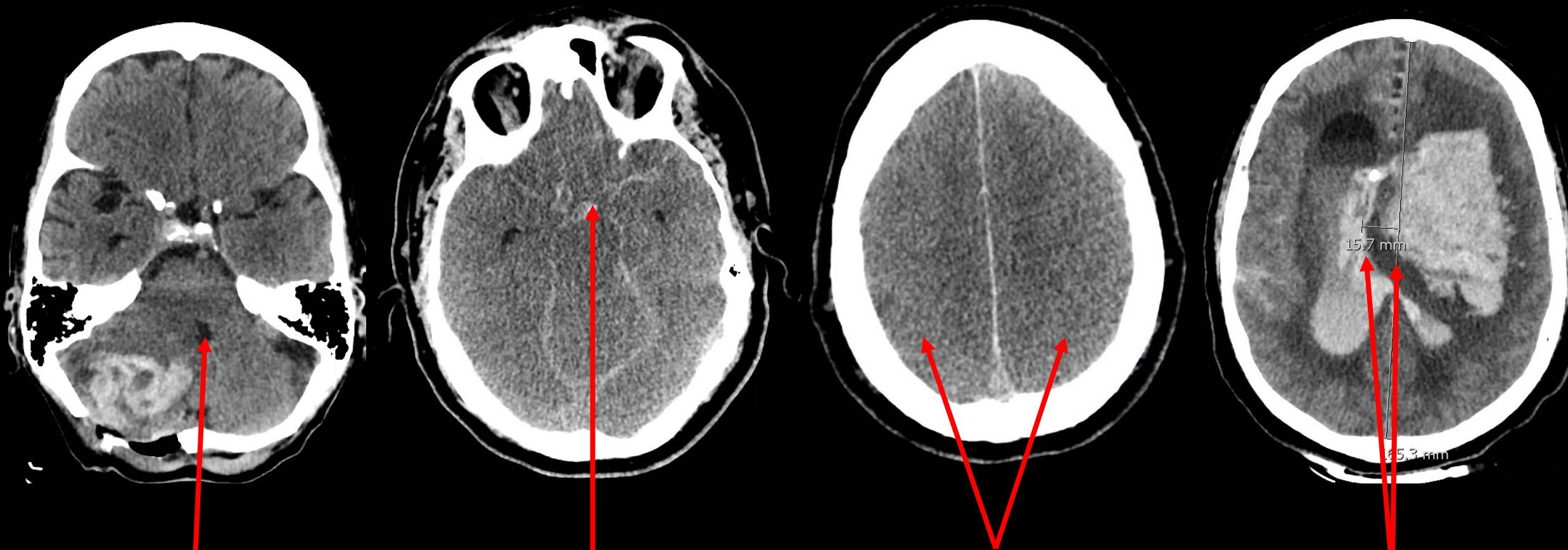
- mitigate risk of ischemia:
 - with EVD/bolt:
 - without EVD/bolt:
- cerebral perfusion pressure (CPP) >60 mmHg
CPP can be calculated
target CPP based on preop BP, clinical exam, imaging



CSF is Reassuring:
open ventricles, cisterns, sulci, no MSL



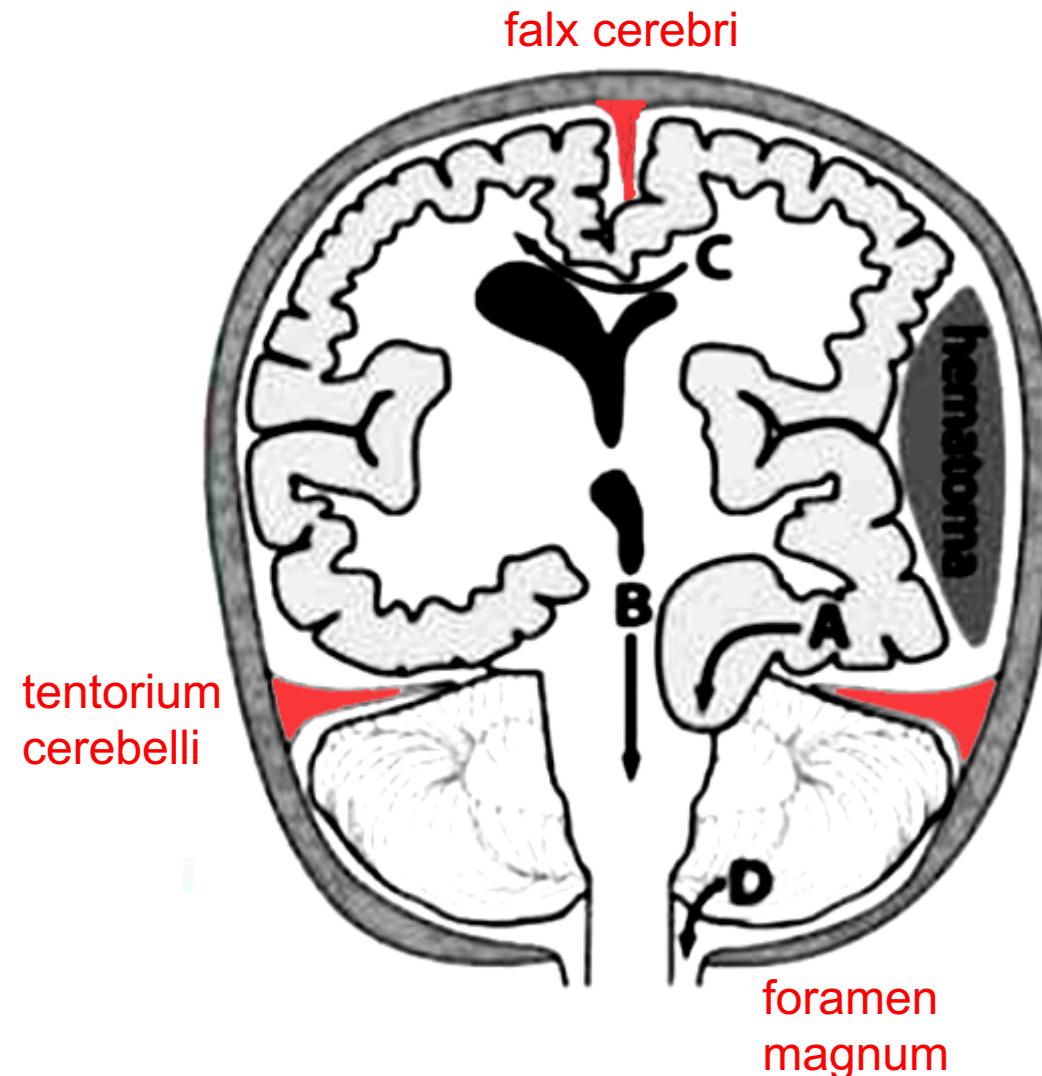
educated guess: ICP \geq 20 mmHg
(MAP goal \geq 80 mmHg)



Herniation: Compression of Vital Brain

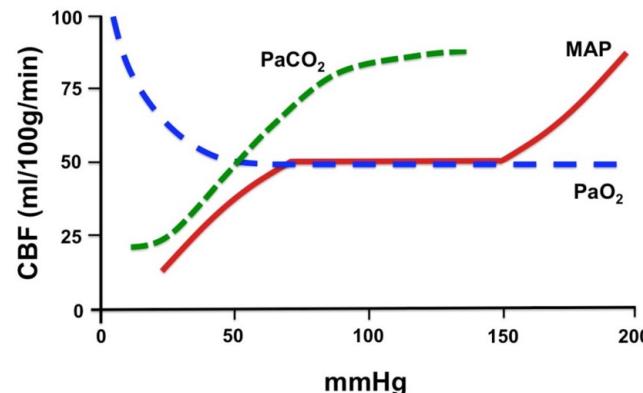
Unspecific signs: headache, nausea, late: Cushing triad (hypertension, bradycardia, irregular respiration)

- A. **uncal transtentorial:** ipsilateral blown dilated pupil (CN III), coma, late: ipsilateral weakness
- B. **central transtentorial:** bilateral miosis, coma, decerebrate posturing
- C. **subfalcine:** late: contralateral leg weakness (ipsilateral ACA infarct)
- D. **tonsillar:** lower CN symptoms, cardiovascular abnormalities, irregular respiration, late: arrest



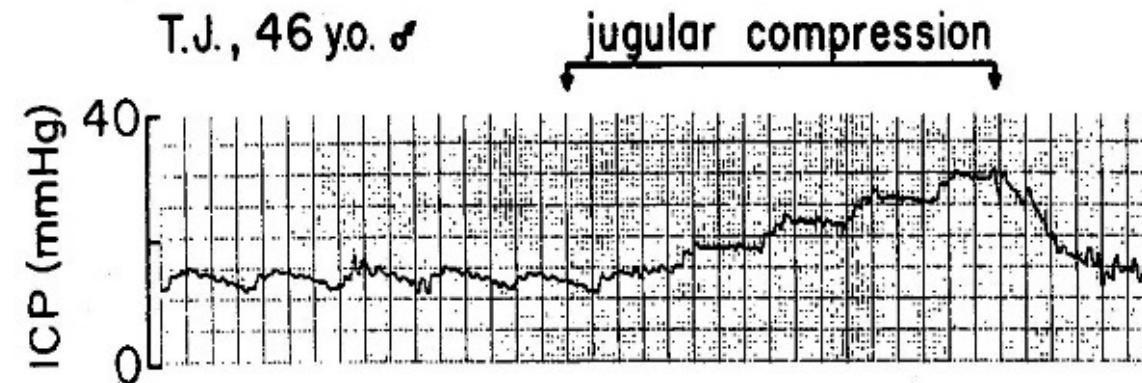
Brain Relaxation: Arterial Blood Flow

- avoid hypercapnia
 - avoid acidosis
 - avoid hypoxia (optimize oxygen-carrying capacity)
 - hyperventilation (acts quickly but only lasts 6h)
 - decrease CMRO₂ (coupled to CBF):
 - use propofol, if volatile <1 MAC, appropriate analgesia
 - avoid fever, consider hypothermia
 - avoid nitro-based anti-hypertensives, use calcium channel blocker
- } esp. during intubation
- } esp. during maintenance
- } esp. during emergence



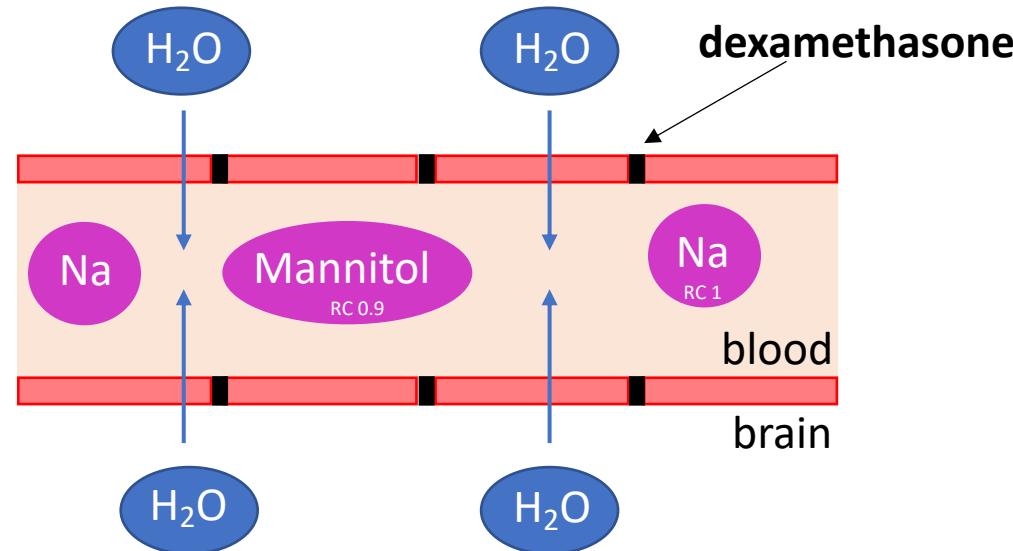
Brain Relaxation: Venous Drainage

- keep head of bed up and midline if possible
 - avoid circumferential pressure and IJ CVCs
 - limit peak airway pressure and PEEP
 - avoid gag/cough/Valsalva (use paralysis and analgesia)
- } esp. during positioning for intubation, lines, or surgery
- } esp. during intubation, pins, emergence, and extubation



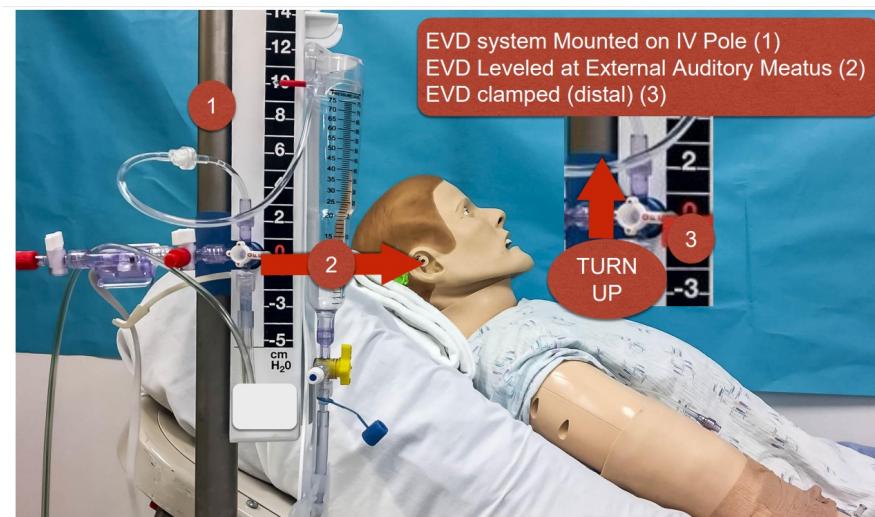
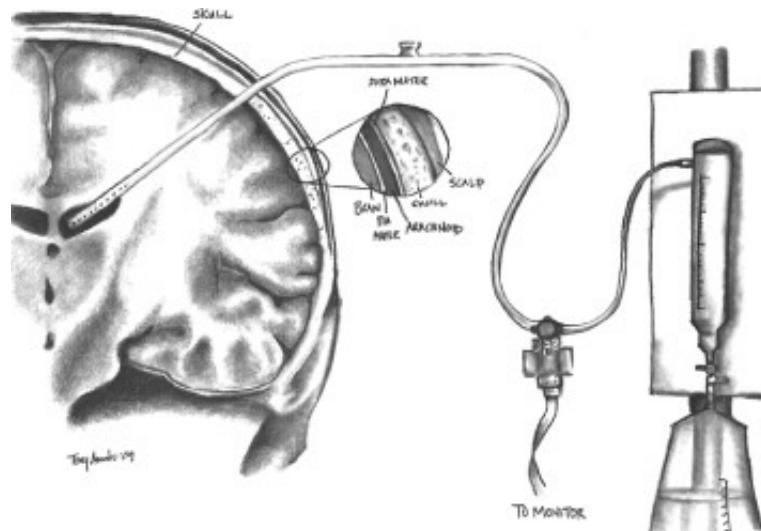
Brain Relaxation: Brain Parenchyma

- treat edema with osmotic drugs (onset in min): mannitol (20/25%), hypertonic saline (3/23%)
- treat vasogenic (not cytotoxic) edema: dexamethasone (onset in hours)
- surgical: craniectomies, hematoma evacuation, tumor resections

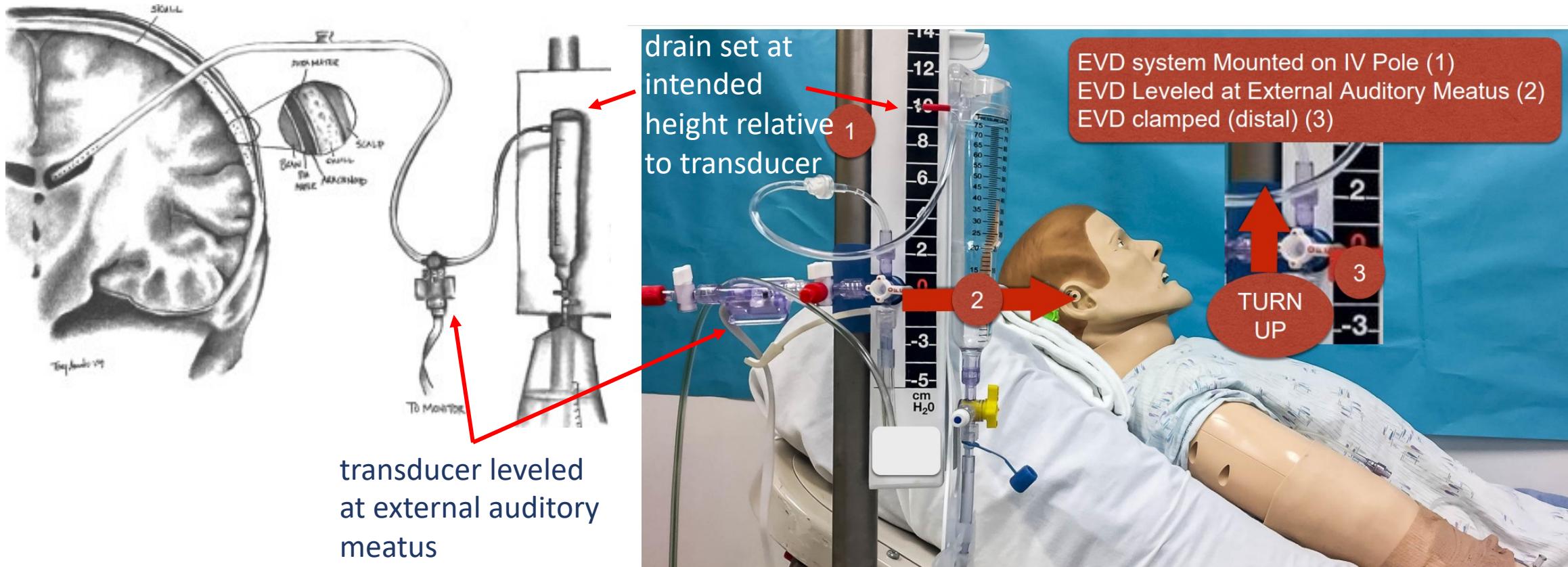


Brain Relaxation – CSF Volume

- surgical diversion of CSF:
 - extraventricular drain (EVD) for obstructive hydrocephalus
(overdrainage can lead to upward herniation)
 - lumbar drain for communicating hydrocephalus
(overdrainage with intracranial mass can lead to downward herniation)
- decreased production of CSF: sevo- and isoflurane superior to desflurane,
Diamox, Lasix (doubtful clinical relevance)

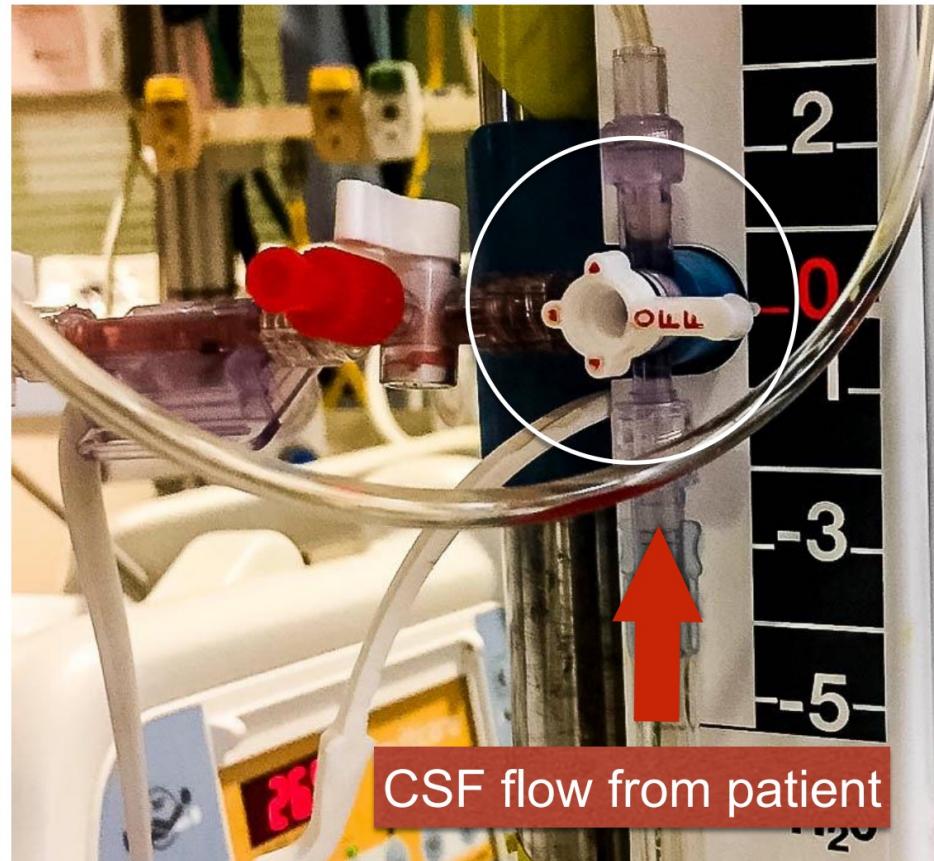


External Ventricular Drain (EVD): a stopcock, a drain, a transducer

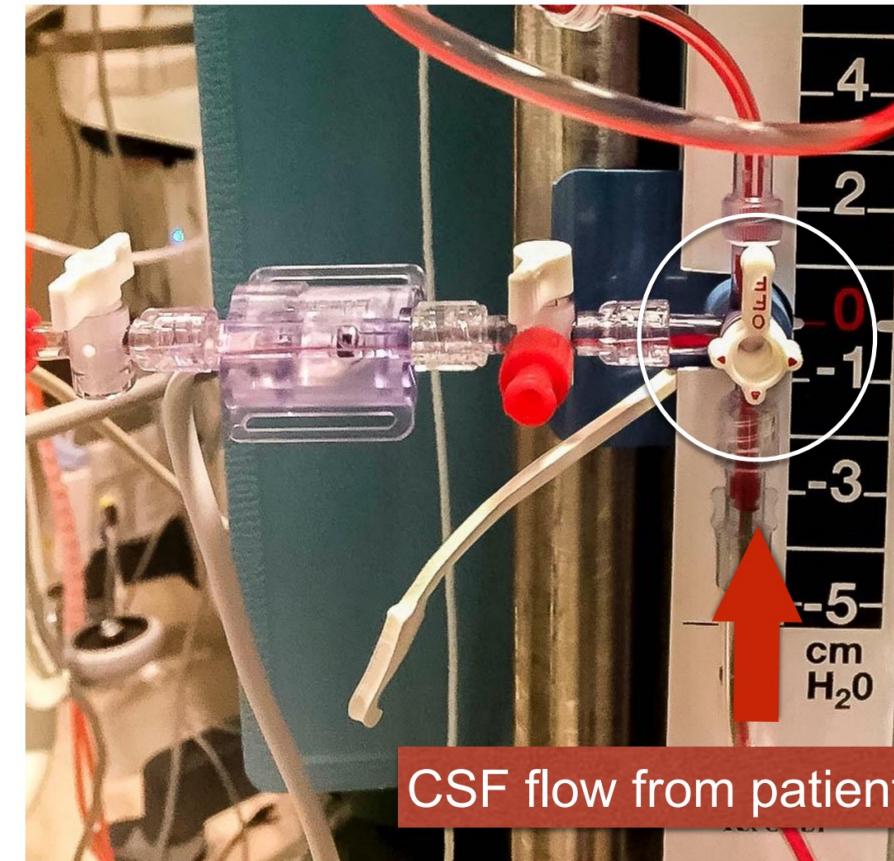


EVD in the OR: drain or transduce/clamp

open EVD: to drain CSF



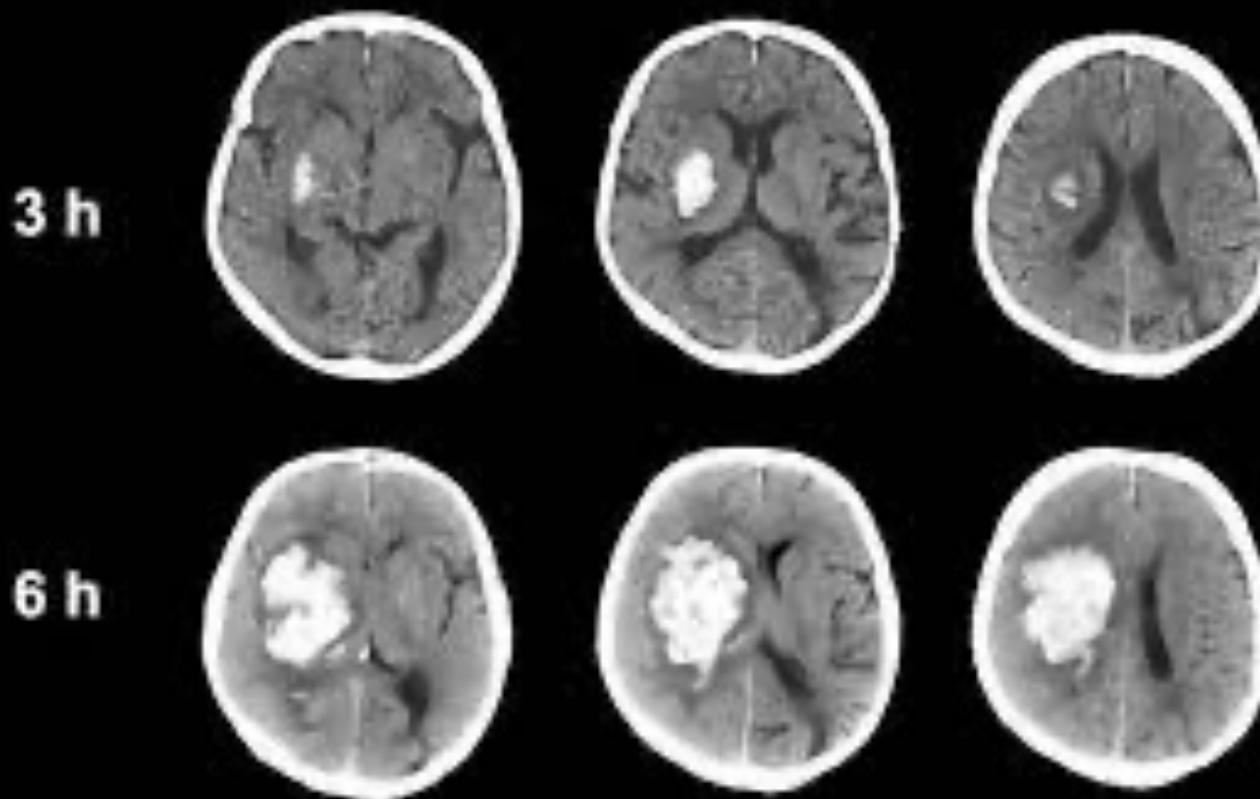
close EVD: to transduce pressure
to transport patient



Summary: Anesthetic Goals

- **augment CPP to avoid ischemia**
- **brain relaxation to lower ICP and optimize surgical field**
- **if EVD in place: CSF diversion to treat ICP**
- if underlying epilepsy, SDH, or unsecured SAH: consider seizure prophylaxis
- if requested by surgeon: facilitate neuromonitoring (e.g., TIVA, no NMB)
- emergence:
 - quick for neuro exam (e.g., titrate to raw/processed EEG)
 - smooth to avoid ICP spikes (e.g., lidocaine or remifentanil)

Intracranial Hemorrhages: Mitigating Hematoma Expansion



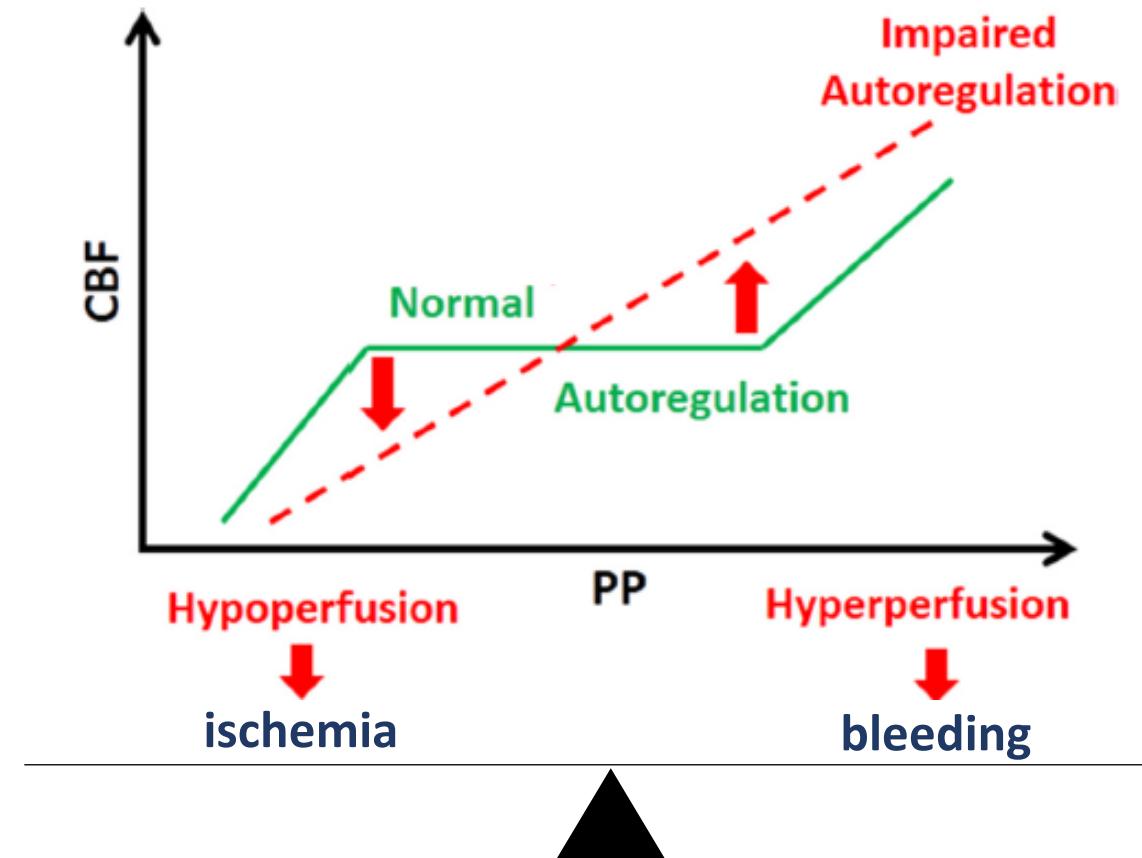


Spontaneous and Traumatic Bleeds in the OR

- intracerebral (suboccipital craniectomy)
- epidural (craniotomy, burr hole)
- subdural (acute: craniotomy, subacute: burr hole)
- intraventricular (EVDs)
- ruptured aneurysms (clipping, coiling) or AVMs (removal)

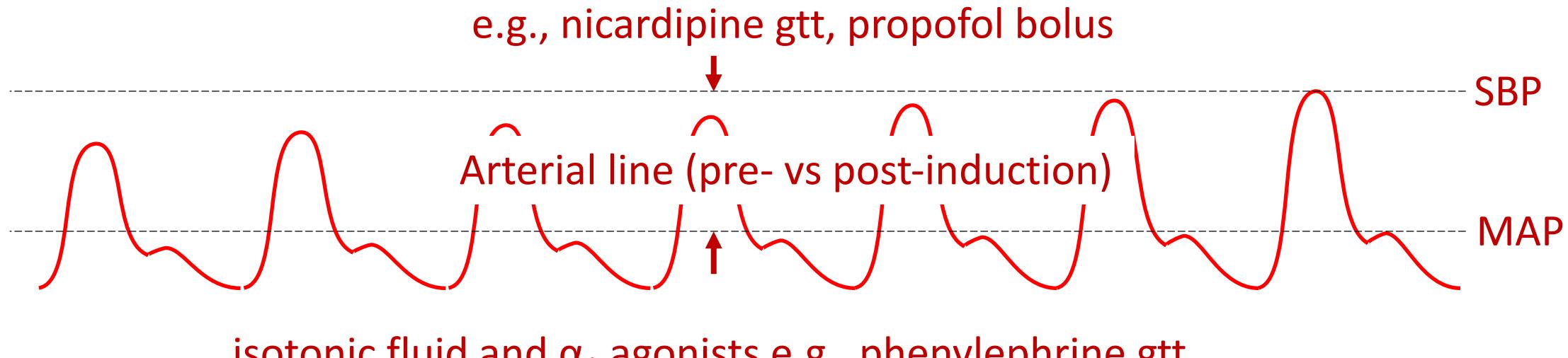


Mitigating Hematoma Expansion: Controlling Blood Pressure

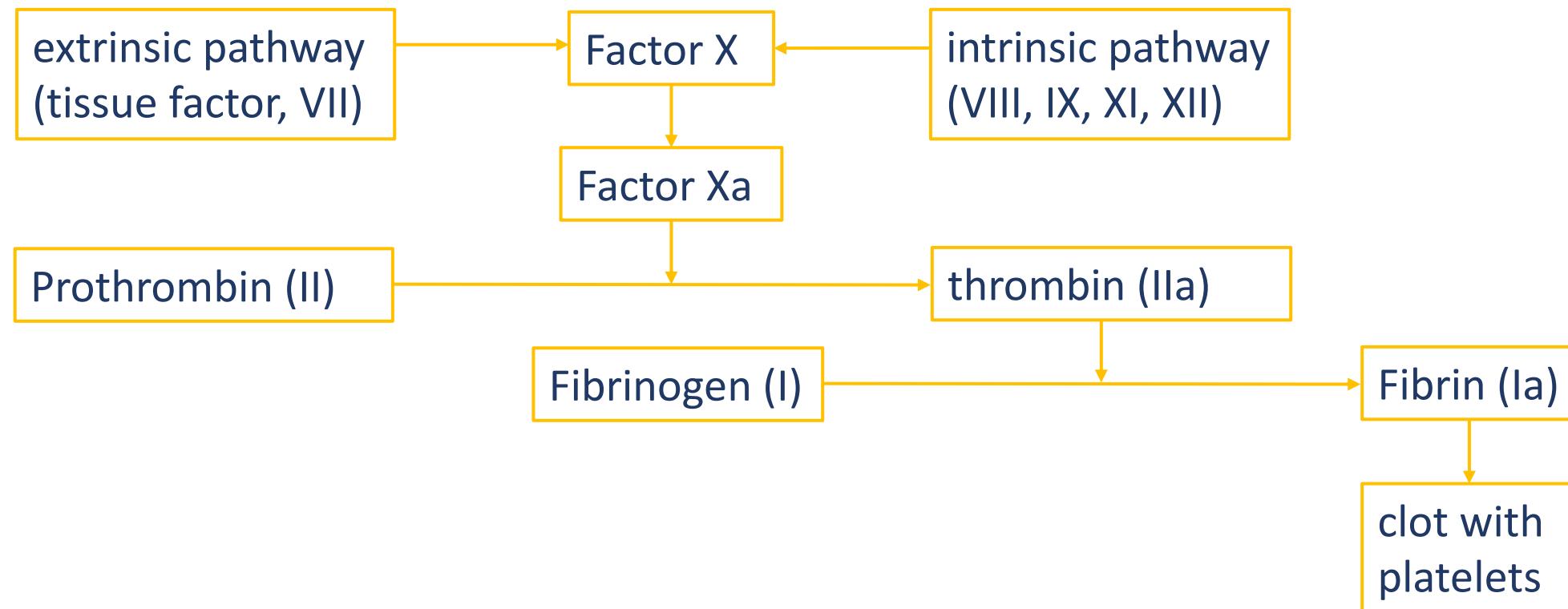


Ischemia vs Bleeding: Not too high and not to Low

- mitigate risk of ischemia (CPP>60 mmHg)
- mitigate risk of hematoma expansion by lowering SBP<140 mmHg
 - minimize sympathetic response (intubation, pins, surgical stimulation)

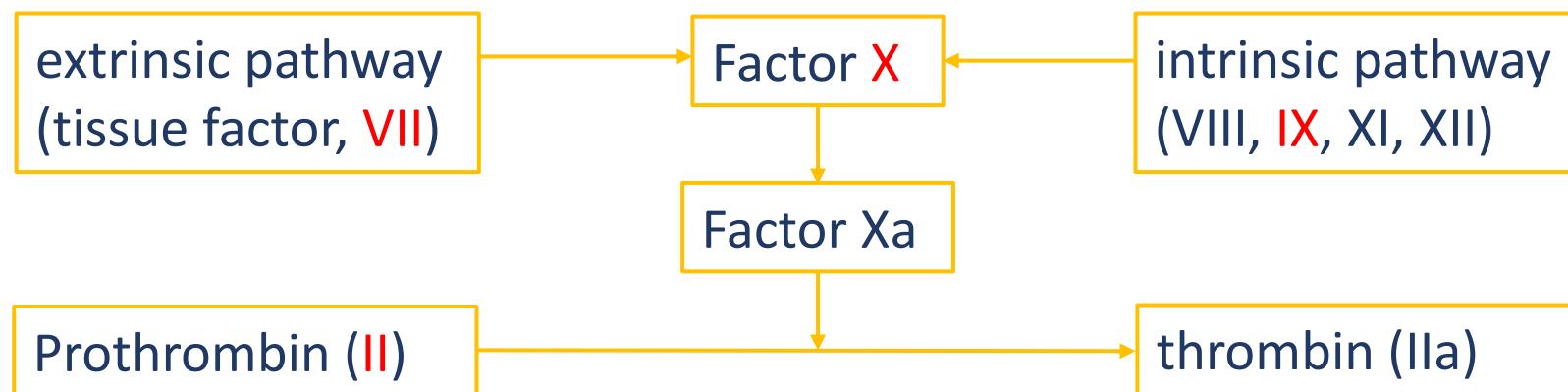


Mitigating Hematoma Expansion: Reversing Coagulopathy

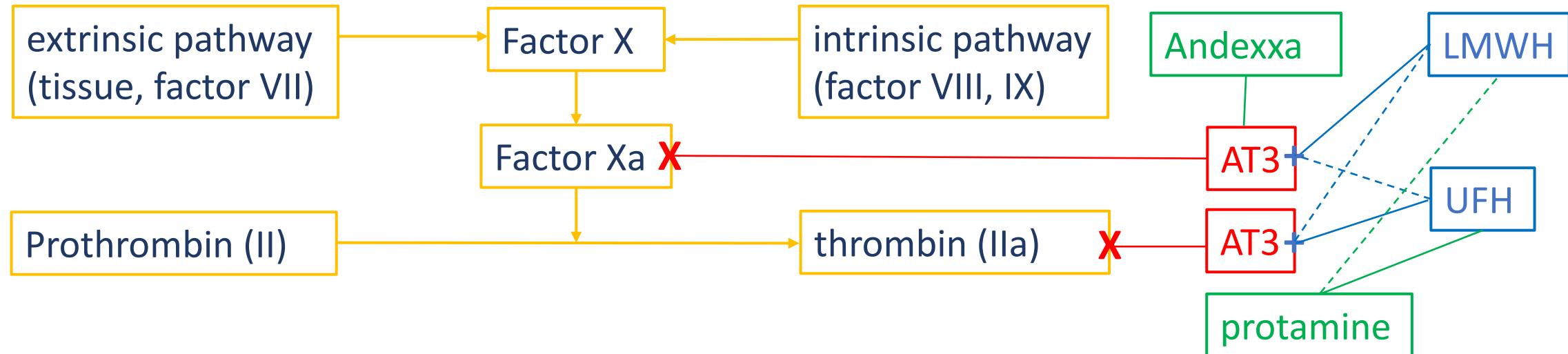


Reversing Vitamin K Antagonists

- warfarin: Vit K 10mg IV (PO: slow $t_{1/2}$, SQ: erratic $t_{1/2}$)
(Coumadin®) + Prothrombin Complex Concentrate (PCC) or FFP for INR 1.6-2
+ PCC 25U/kg for INR 2-4
+ PCC 35U/kg for INR 4-6
+ PCC 50U/kg for INR >6
- PCC vs FFP: PCC reverses faster and more reliably, PCC causes less hematoma expansion or volume overload, same rate of thrombotic AE
- PCC types: Kcentra®: 4 factors, Profilnine®: misses VII (add rVII), FEIBA: has aVII

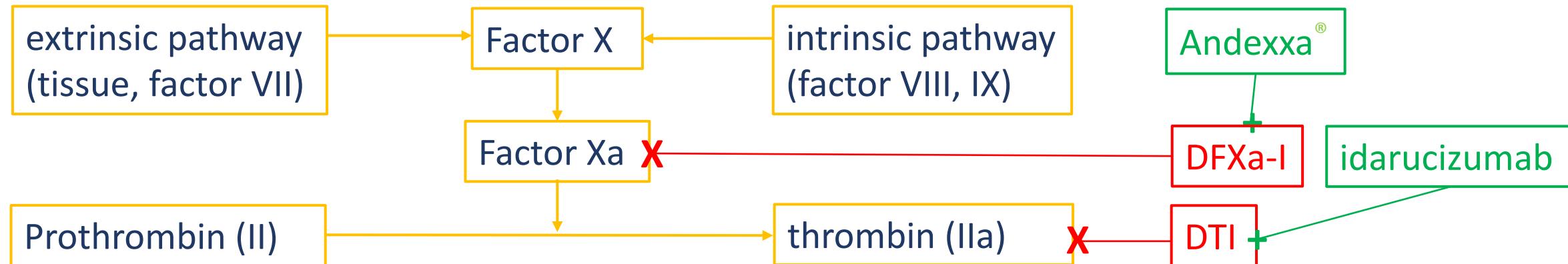


Reversing Types of Heparin



- unfractionated heparin:
- enoxaparin (Lovenox®):
- dalteparin (Fragmin®):
- protamine ($100U \rightarrow 1mg$)
- protamine ($1mg \rightarrow 1mg <8h$), andexanet α (Andexxa®)
- protamine ($100U \rightarrow 1mg <8h$)

Reversing Direct Inhibitors



Direct Factor Xa Inhibitors

- rivaroxaban (Xarelto®):
- Apixaban (Eliquis®):

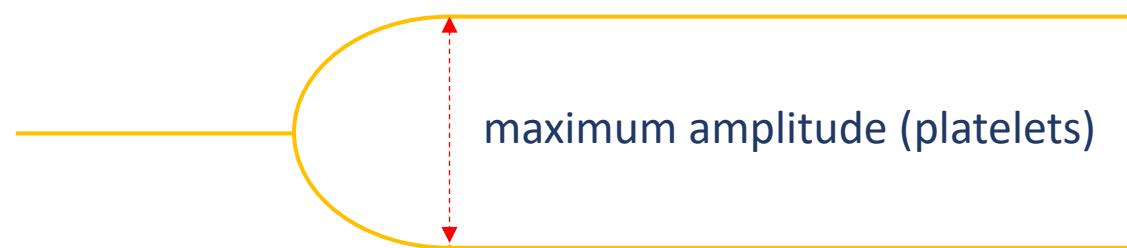
Direct Thrombin Inhibitors

- bivalirudin (Angiomax®):
- argatroban (Acova®):
- dabigatran (Pradaxa®):

- PCC, +/- andexanet α (Andexxa®)
- PCC, +/- andexanet α (Andexxa®)
- stop infusion ($t_{1/2}$ 25 min)
- stop infusion ($t_{1/2}$ 45 min)
- idarucizumab (Praxbind®), PCC

Platelet transfusions

- thrombocytopenic pts:
 - transfusion with no benefit in non-surgical pts
 - plts<100k associated with ↑bleeding in NSGY
- pts on antiplatelets:
 - worse outcome (mRS) in non-surgical pts
 - less postop bleeding in NSGY patients
 - guidance by antiplatelet assays or TEG
 - consider desmopressin (DDAVP[®]) 0.3 mcg/kg



Summary: Anesthetic Goals

- **mitigating hematoma expansion**
- brain relaxation (lower ICP, optimize surgical field, except most SDHs)
- if EVD in place: CSF diversion (either to treat ICP or tamponade bleed)
- seizure prophylaxis (for SDH or unsecured SAH)
- if requested by surgeon: neuromonitoring (not needed for burr holes)
- emergence:
 - quick for neuro exam (e.g., titrate to raw/processed EEG)
 - smooth to avoid ICP spikes (e.g., lidocaine or remifentanil)

Why is my patient not waking up? Recognizing and treating status epilepticus

Periop Risk Factors:

Anything Irritating the Brain

Neuro patients (0.5-5%)

- brain tumor
- TBI
- unsecured SAH or SDH
- acute ischemic stroke
- poorly controlled epilepsy

any patients (~0.03%)

- surgical (e.g., stress, sleep deprivation, NPO)
- intoxication from uppers (e.g., cocaine), withdrawal from downers (e.g., DT)
- metabolic (e.g., hypoglycemia, fever, hypo-Na, hyper-NH3, uremia)
- proconvulsive drugs (e.g., etomidate, tramadol, meperidine, local anesthetic)

OB patients (0.01-0.1%)

- preeclampsia

Awake



Excitatory stages
(induction, emergence)



General Anesthesia

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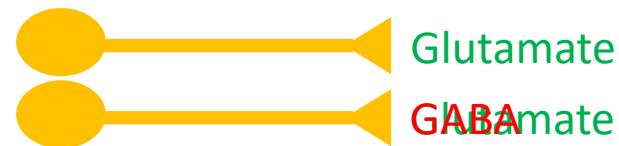
Kofke, Curr Opin Anaesthesiol. 2010 Jun;23(3):391-9.

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Seizures: Don't only Think of Convulsions

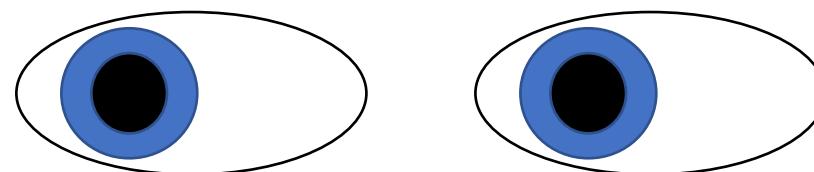


- hyperexcitable and synchronous neural electrical activity

Symptoms:

| <u>seizures</u> | tremor, shivering |
|--------------------|-------------------|
| 3 Hz | 6 Hz |
| jerky movements | fine movements |
| irregular | regular |
| increase in HR, BP | ∅ |

eye deviation away
from irritative lesion



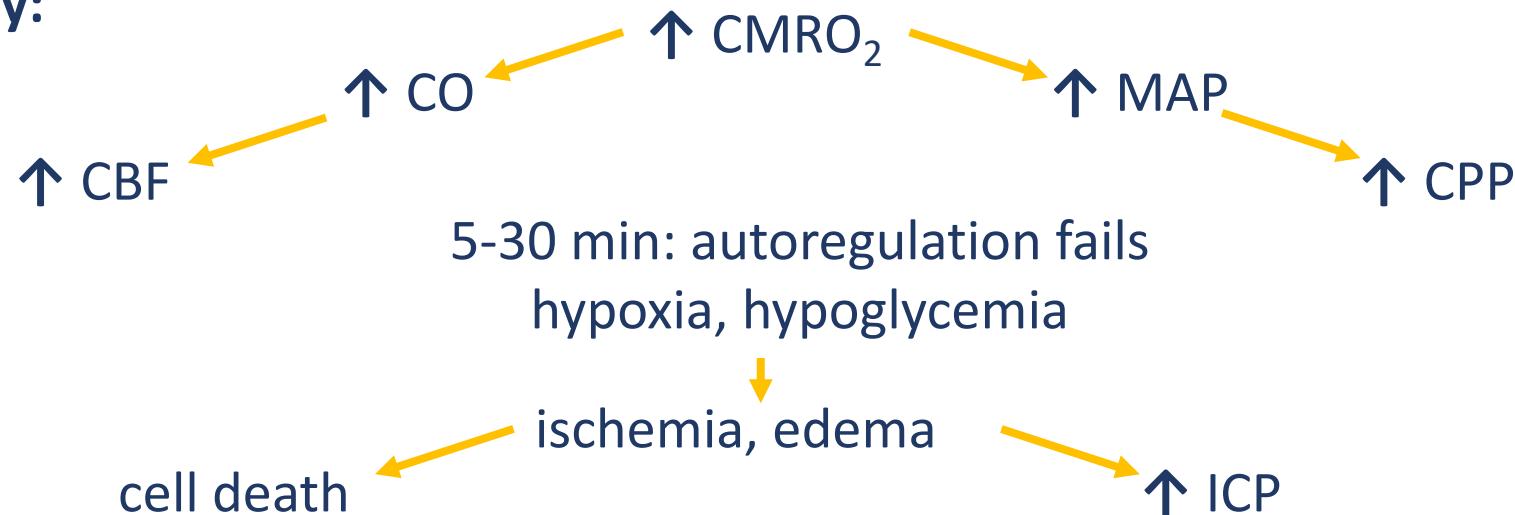
- focal onset aware: localized (e.g., motor, speech, sensory, senses), conscious, +/- aura (e.g., fear, euphoria, déjà vu, jamais vu)
- focal onset impaired awareness: localized, unconscious
- generalized: involves entire brain, unconscious

Status Epilepticus: Time is Brain

Definition: according to *ILAE 2015 and NCS 2012*:

- ≥5 min of continuous or recurrent convulsive seizures (with motor activity)
- ≥10 min of continuous non-convulsive seizures (w/o motor activity)
- success of treatment decreases, mortality increases ≥5 min

Pathology:



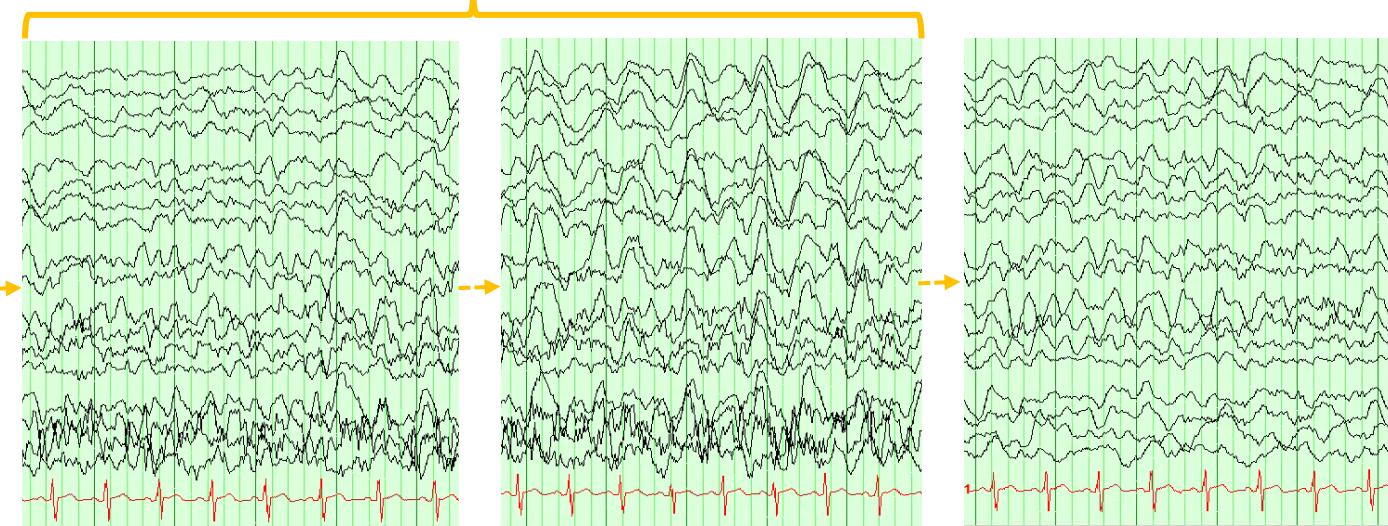
When in Doubt: Order an EEG

left: asynchronous, right: synchronous



interictal epileptiform
discharges (IEDs)

generalized: synchronous abnormal

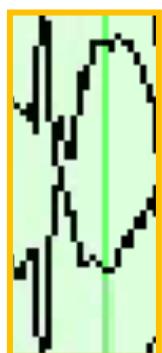


focal

spreads to left

generalized

post-ictal



- phase reversal: points towards focus of seizure
- IED: spike (2-70ms) and wave (70-200ms) pattern, predisposes to seizures
- epileptic discharges >2.5Hz or any rhythmic activity w spatiotemporal resolution

Generalized Seizure in PACU: Don't Underdose, Intubate if Needed

Airway, Breathing, Circulation



lorazepam 4mg (in PACU midazolam / propofol)

thiamine and D50 if glucose is low, call Neurology



status (>5 min)

fosphenytoin 20mg/kg / valproate 20-40mg/kg / Keppra 60mg/kg

send rainbow labs



refractory status

intubation and sedation (GABAergic drip), order cEEG



transition of care to Neurocritical Care/Epilepsy

treat
cause, CT
head
once safe

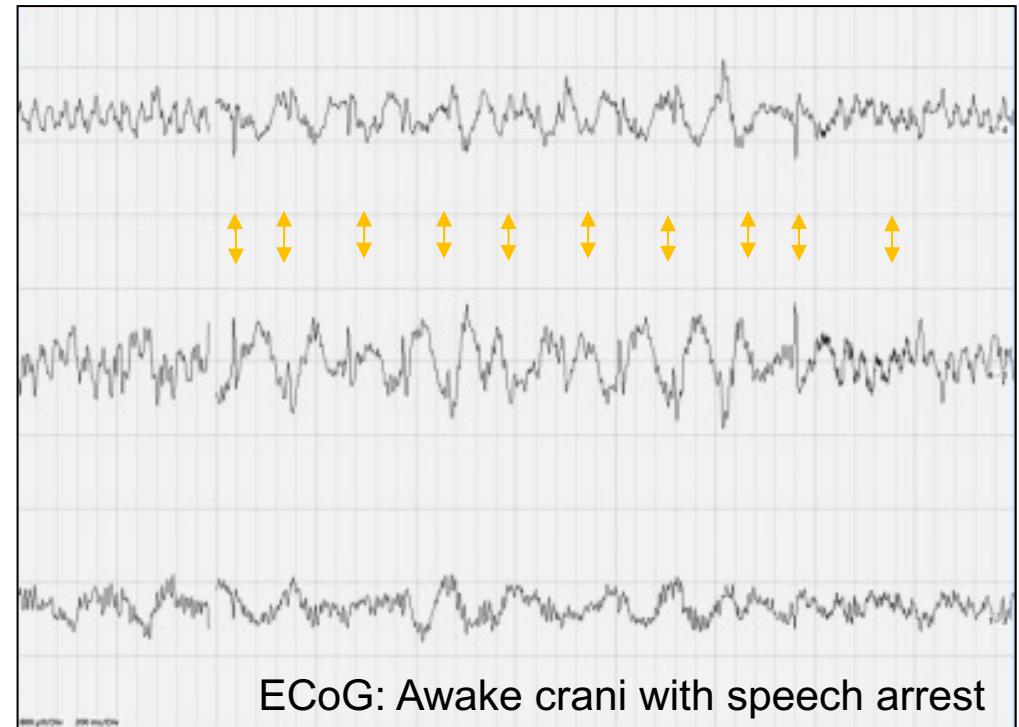
Special Circumstances

intraoperative seizures:

- rare under GA (anticonvulsive effect)
- deepen anesthetic w GABAergic drugs
- avoid paralysis to monitor muscle activity
- if altered at emergence, keep anesthetized

neurosurgical patients:

- AED prophylaxis debatable
- awake patient: airway equipment on stand-by
- cold irrigation of cortex by surgeon



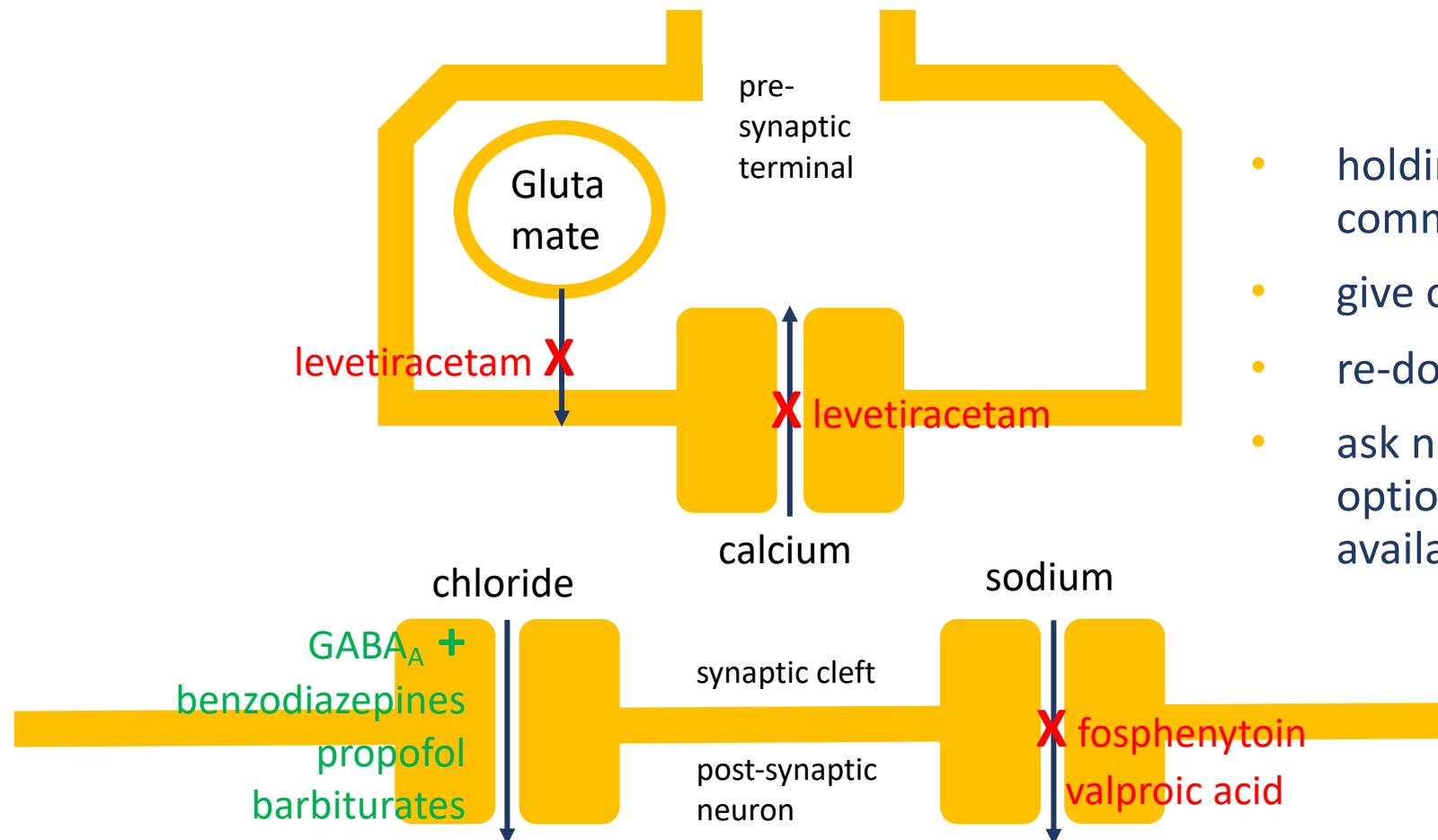
eclampsia: magnesium sulfate (1° AED): loading 6gr/15min, maintenance 2gr/h

LAST: lipid emulsion: loading 100ml/2-3min, maintenance 0.25ml/kg/min

DT: can be fully treated with benzos/barbiturates, no AED needed

Re-dose Antiepileptic Drugs

- Seizures: excitatory > inhibitory signals
- Antiepileptic Drugs (AEDs): inhibitory > excitatory signals



- holding AEDs at DOS is a common cause of seizures
- give oral dose pre-op
- re-dose intra- and post-op
- ask neurologist for other options if IV formula not available

Summary: Take Home Messages

- have a low threshold to think of seizures, even in a patient without convulsions
- have a low threshold to order an EEG and consult neurology
- time is brain: lorazepam is in the Pyxis, midazolam and propofol are drawn up in your pocket
- intubated patients can be extubated, dead neurons are dead
- don't forget to give an AED, even if a seizure subsided
- don't forget to re-dose AED in epileptic patients

Thank you for your attention

special thanks to Bradlee Bray from the University of Colorado for the images!

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