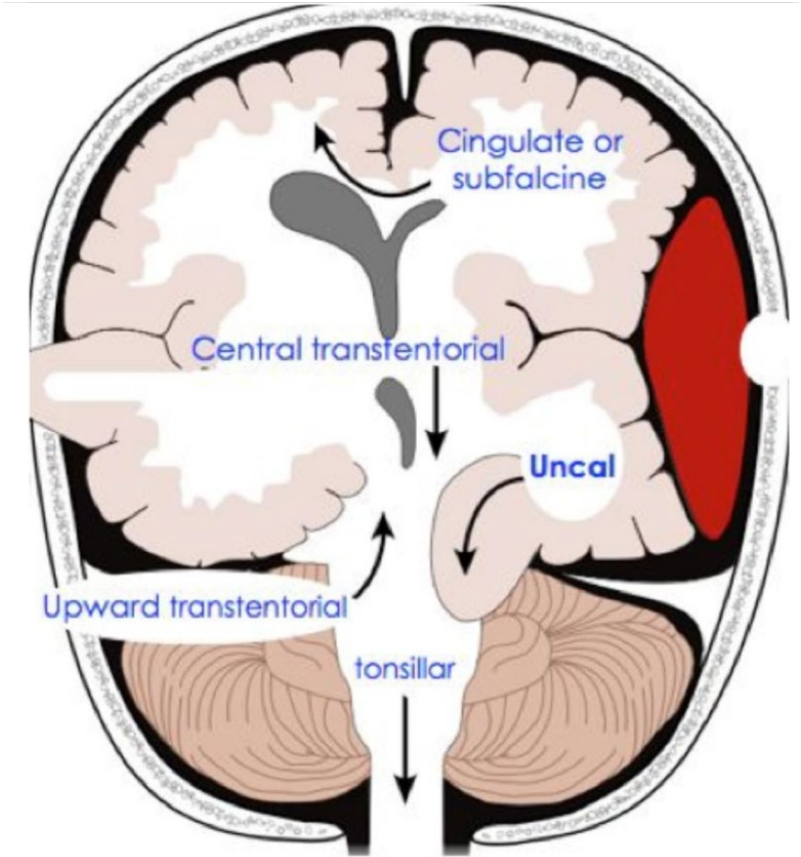
Management of acute cerebral herniation syndromes

Craig A. Williamson, MD, MS
Clinical Associate Professor
Neurocritical Care Fellowship Director

1. Overview of Herniation Syndromes
2. Comparison of herniation and ICP
3. Case Presentations
4. A practical treatment algorithm

Cerebral Herniation Syndromes

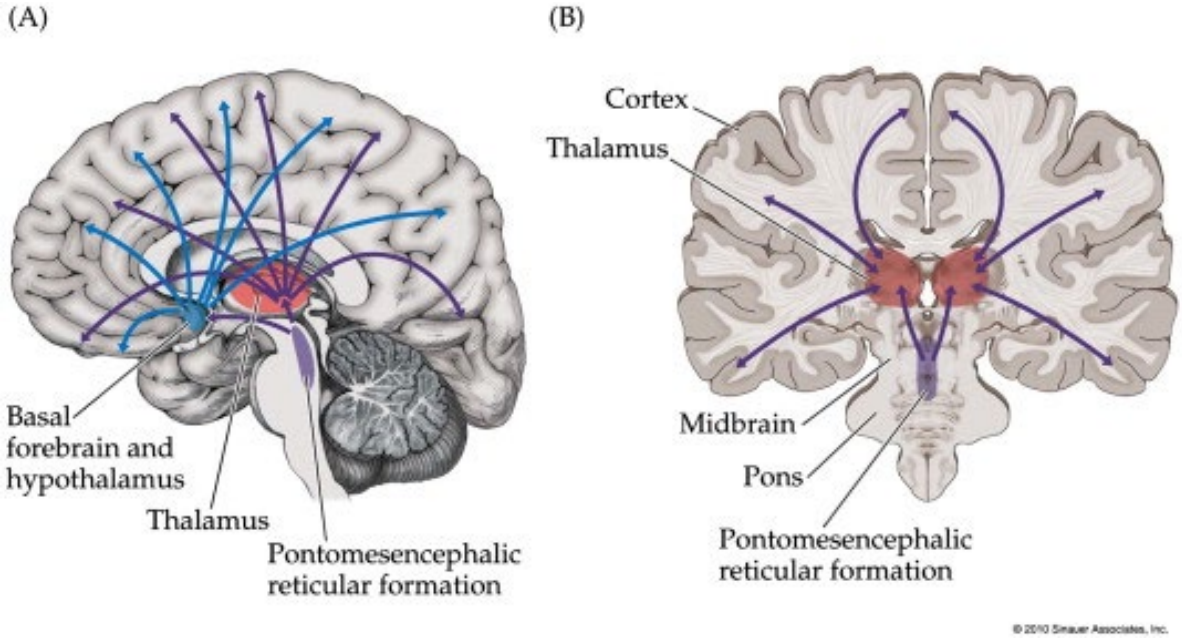


Why are uncal and tonsillar herniation syndromes so bad?

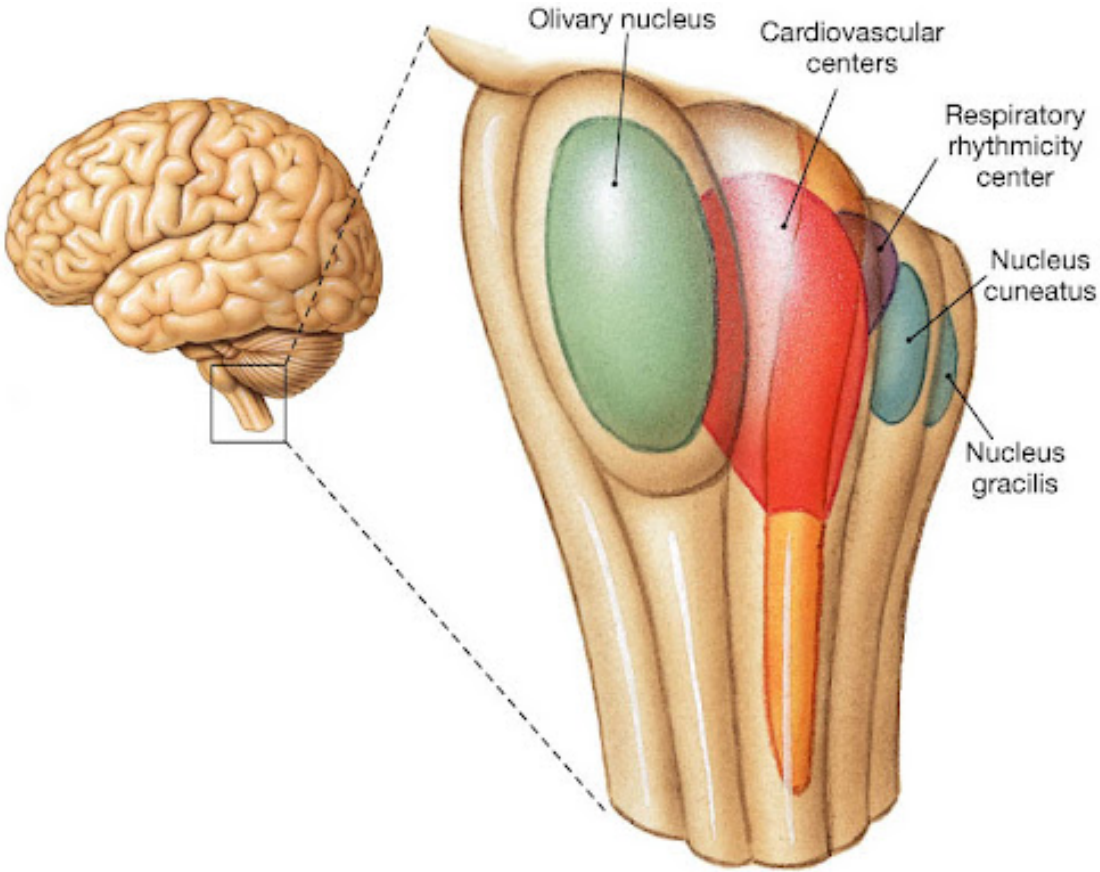
Why are uncal and tonsillar herniation syndromes so bad?

- It’s all about the anatomy

Basic Anatomy of Arousal



Blumenfeld H. Neuroanatomical basis of consciousness. In the Neurology of Consciousness, 2nd ed. Laureys S, Gosseries O, Tononi G (eds.). Academic Press. 2016.

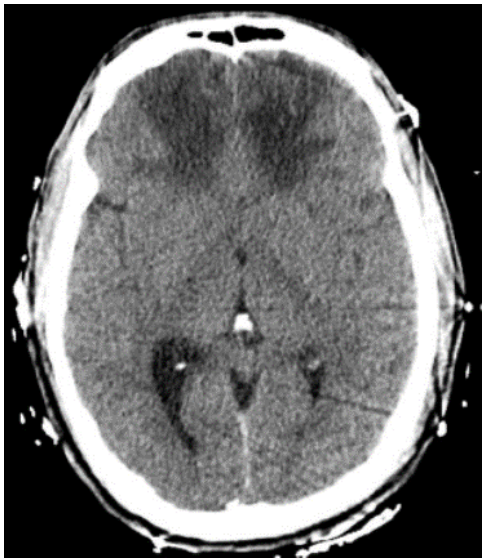

Olivary nucleus
Cardiovascular centers
Respiratory rhythmicity center
Nucleus cuneatus
Nucleus gracilis

Conditions associated with acute herniation syndromes

- Traumatic Brain Injury
  - Extra-axial Hematomas
    -Subdural Hematoma
    -Epidural Hematoma
- Cerebral Contusions/Intraparenchymal Hemorrhage
- Spontaneous Intracerebral Hemorrhage
- Malignant Cerebral Edema following Hemispheric Stroke
- Any space-occupying mass lesion (tumor, abscess, demyelination
  -Much more likely to present subacutely

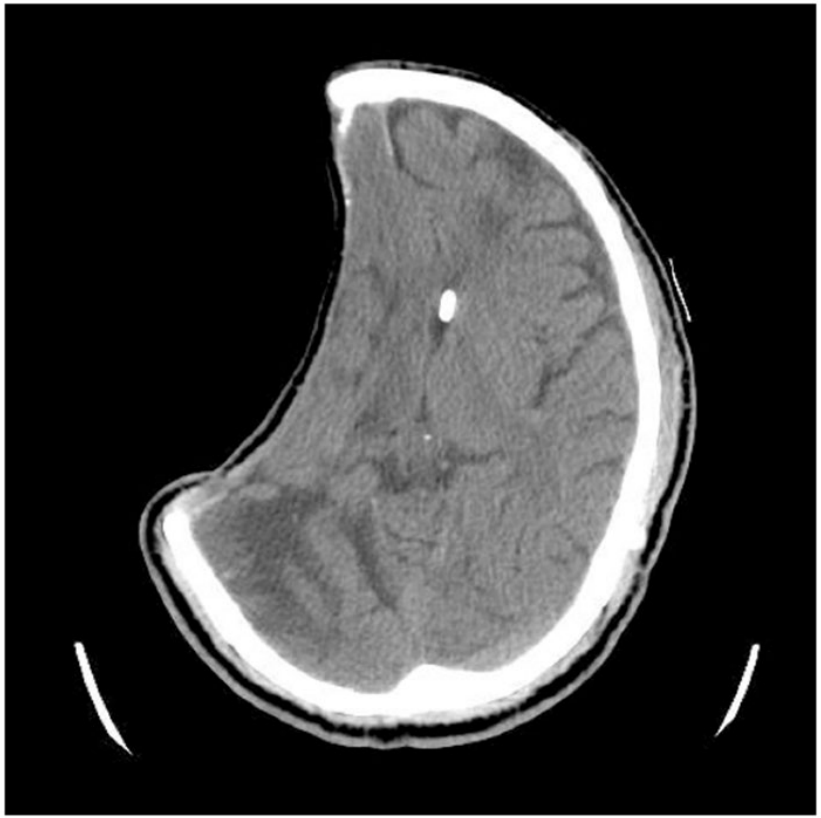
Conditions with global elevation in ICP

- Traumatic Brain Injury
  - Typically in young patients with “tight” brains
- Subarachnoid Hemorrhage
- Hypoxic-Ischemic Injury
- Acute Hyponatremia
  - Marathon Runners
  - MDMA (ecstasy) use
- Fulminant Hepatic Failure
- Meningitis
- Hydrocephalus



Are ICP and Herniation Always Associated?

Are ICP and Herniation Always Associated?

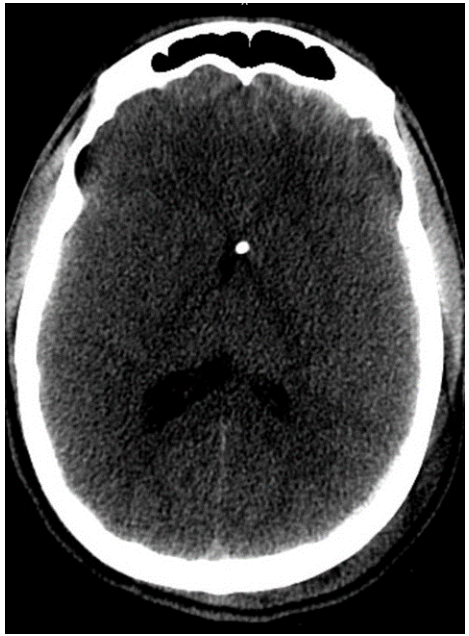


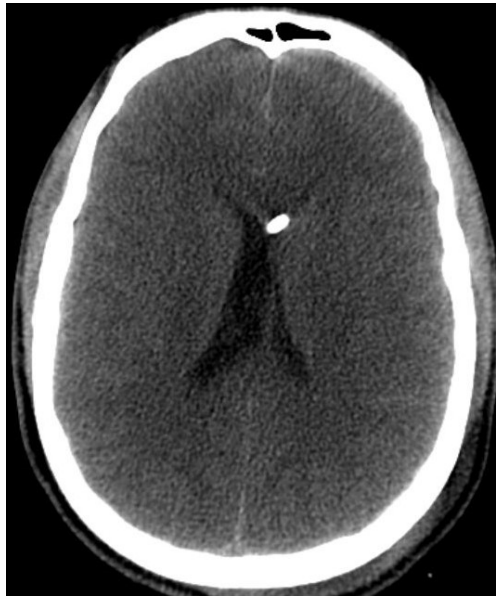
Clinical Signs of elevated ICP and/or impending herniation

"EARLY"	"LATE"
Headache	Changes in level of consciousness or ↓ GCS or FOUR Score ≥ 2 points
Irritability	Ipsilesional change in pupillary size, shape and light-responsiveness
Vomiting	Contralesional hemiparesis (new or worsening)
Photophobia, nystagmus, diplopia	Contralesional change in pupillary size and ipsilesional hemiparesis (Kernohan's phenomenon)
Lethargy	Cushing's triad: ↑ SBP (widened pulse pressure), bradycardia, irregular respirations
Seizure	

Management Case

- 23 year old male unhelmeted cyclist is struck by an automobile on Halloween in downtown Ann Arbor
- Glasgow Coma Scale (GCS) 6 in field and on ED arrival. Intubated.
- CT head showed L frontal subdural hematoma (SDH), small bifrontal contusions and temporal bone fracture
- Briskly localizing upon arrival to ICU. GCS E1V1TM5. Ventriculostomy is placed





First-tier neuroprotective measures

- Elevate head of bed
- Control pain and agitation
    - Dexmedetomidine permits closely following exam
- Target normothermia
- Avoid hypotension
- Avoid hypercarbia, hypocarbia and hypoxia

-Approximately 12 hours after admission ICP sustains between 20 and 25 mmHg, mean arterial pressure (MAP) is 85 mmHg

-Arterial blood gas (ABG) on 30% FiO2: 7.47/34/137

-Head CT shows no interval change in SDH or bifrontal contusions

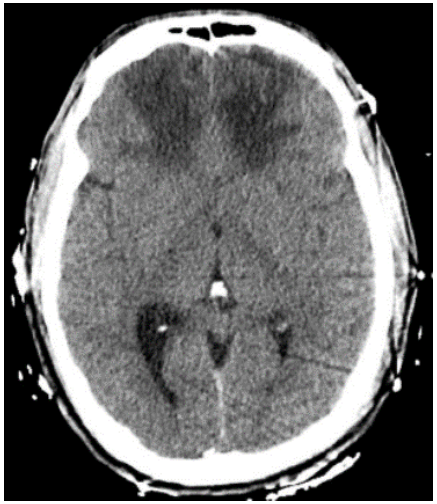
Next management step?

- Sedation transitioned to propofol. ICP transiently decreased as did systolic blood pressure

- Started on norepinephrine to maintain cerebral perfusion pressure (CPP) > 60

- ICP abruptly increases to 36 mmHg during tracheal suctioning→ normalizes with administration of 30 cc 23.4% saline.

- A few hours later ICP again spikes to 36 mmHg
- Normalizes with mannitol administration
- Portable head CT obtained after bolusing propofol and fentanyl



- Patient continued on propofol 80 mcg/kg/min and fentanyl infusion is uptitrated to 200 mcg/hr.
- Bolused 23.4% sodium (Na) alternating with mannitol during ICP spikes. Na increases to 155 and serum osm to 330
- ICPs consistently sustaining above 25 mmHg with transient spikes into 30s and even low 40s anytime pt is stimulated
- CPP maintained > 60 mmHg except very brief periods during ICP spikes.

Remaining management options?

Decompressive Craniectomy?

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 APRIL 21, 2011 VOL. 364 NO. 16

Decompressive Craniectomy in Diffuse Traumatic Brain Injury

D. James Cooper, M.D., Jeffrey V. Rosenfeld, M.D., Lynnette Murray, B.App.Sci., Yaseen M. Arabi, M.D., Andrew R. Davies, M.B., B.S., Paul D'Urso, Ph.D., Thomas Kossmann, M.D., Jennie Ponsford, Ph.D., Ian Seppelt, M.B., B.S., Peter Reilly, M.D., and Rory Wolfe, Ph.D., for the DECRA Trial Investigators and the Australian and New Zealand Intensive Care Society Clinical Trials Group*

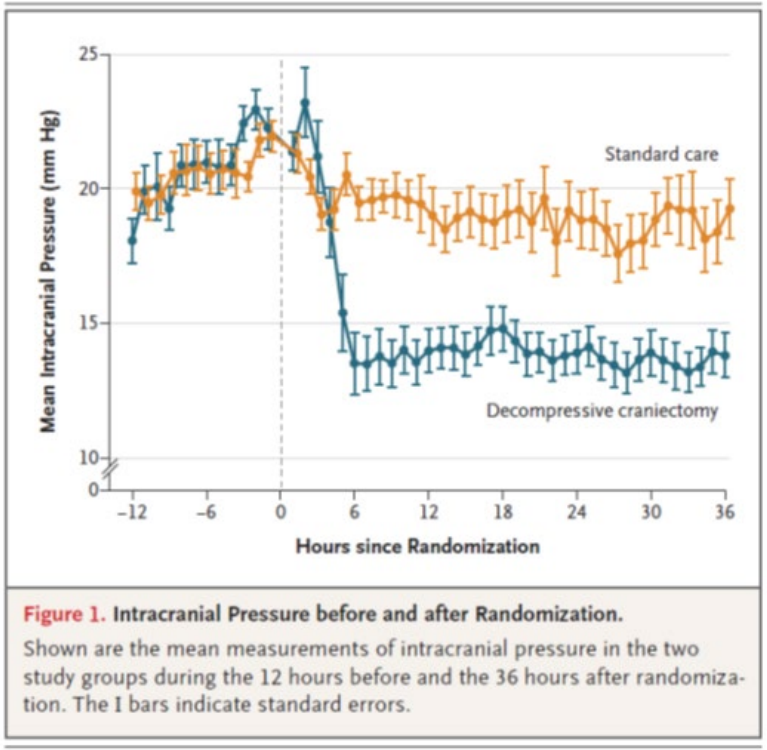
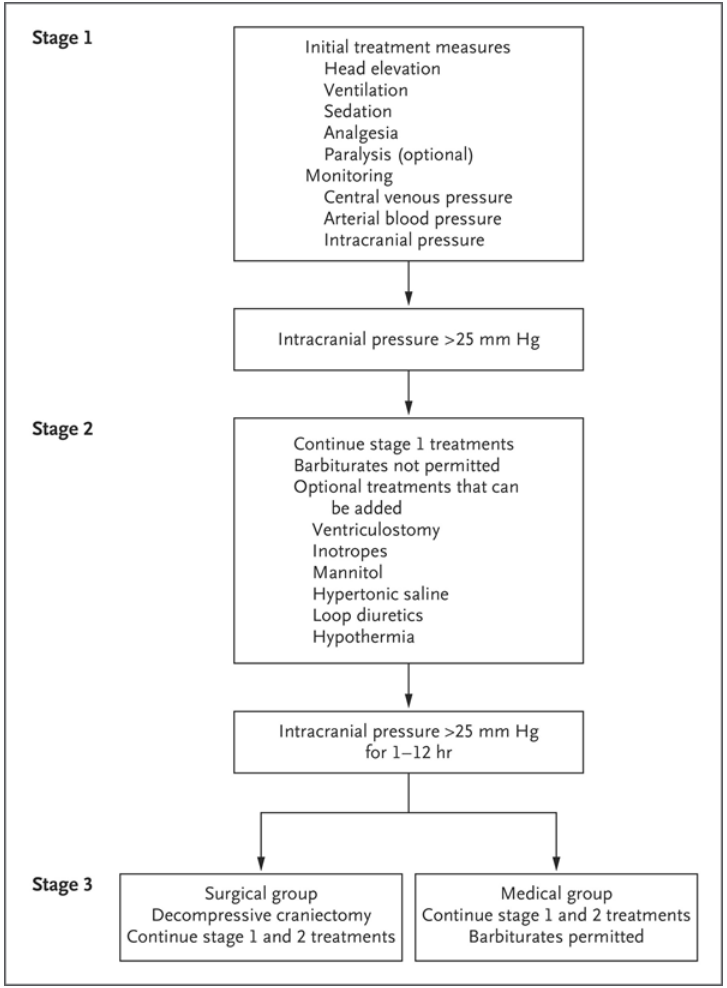
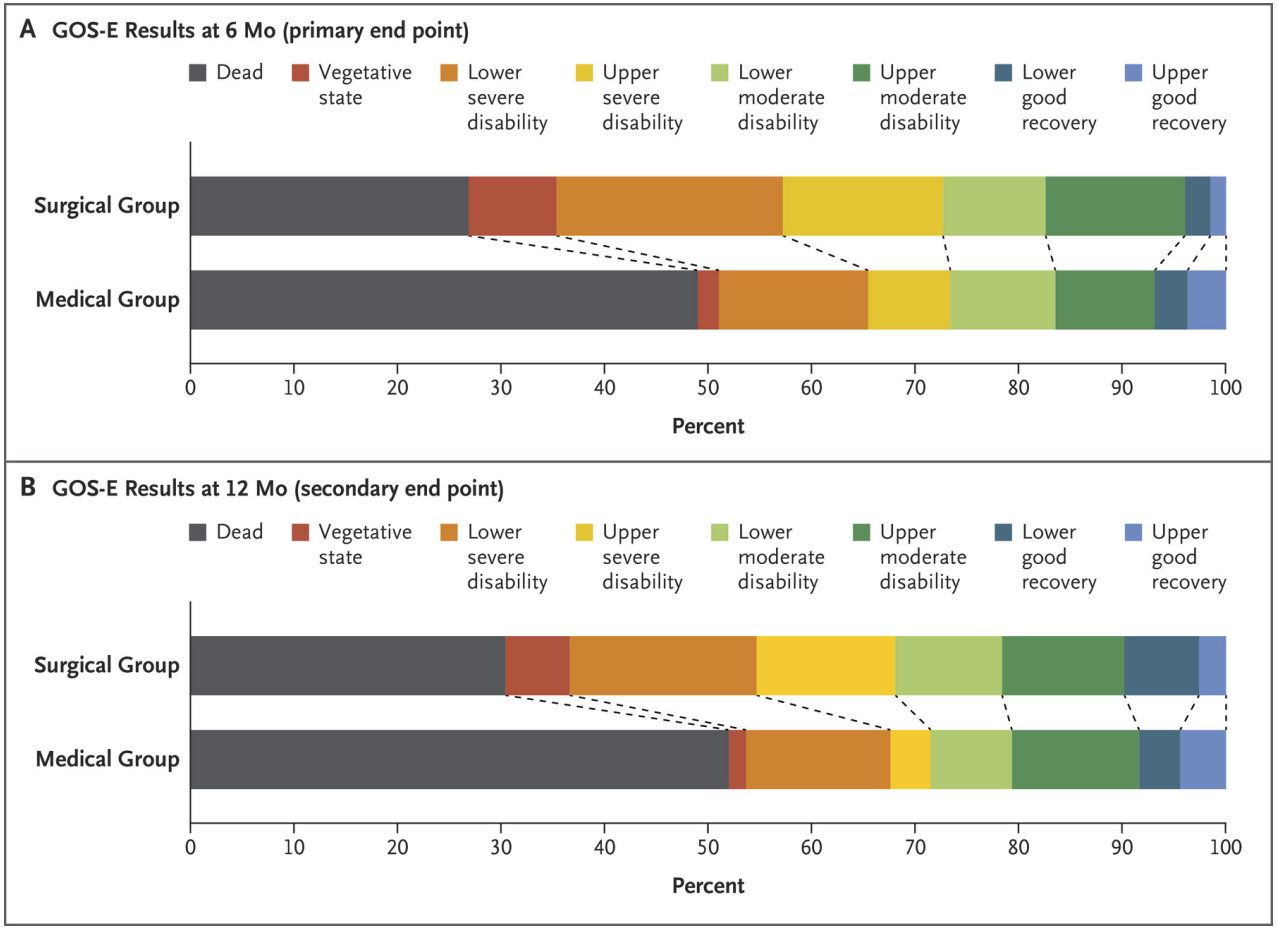


Figure 1. Intracranial Pressure before and after Randomization.

Shown are the mean measurements of intracranial pressure in the two study groups during the 12 hours before and the 36 hours after randomization. The I bars indicate standard errors.


Stage 1
Initial treatment measures
Head elevation
Ventilation
Sedation
Analgesia
Paralysis (optional)
Monitoring
Central venous pressure
Arterial blood pressure
Intracranial pressure
Intracranial pressure >25 mm Hg
Stage 2
Continue stage 1 treatments
Barbiturates not permitted
Optional treatments that can be added
Ventriculostomy
Inotropes
Mannitol
Hypertonic saline
Loop diuretics
Hypothermia
Intracranial pressure >25 mm Hg for 1–12 hr
Stage 3
Surgical group
Decompressive craniectomy
Continue stage 1 and 2 treatments
Medical group
Continue stage 1 and 2 treatments
Barbiturates permitted



Hutchinson et al. NEJM. 2016;375(12):1119

- Started on pentobarbital infusion titrating to deep EEG burst suppression:
  - Load with 10 mg/kg x 1 hr
  - 5 mg/kg x 1 hr
  - 1mg/kg and titrate to desired level of burst suppression

- ICPs ~ 20-30 with continued brief spikes with nursing care: treated with mild hypothermia and intermittent hyperosmolar therapy

- Develops pneumonia, atelectasis, abrupt mucus plugging leading to severe desaturation

- Tracheostomy placed on post-trauma day 15 when first able to tolerate reverse Trendelenberg positioning

- ICPs normalize by day 18 and pentobarbital weaned

- Subsequently develops recurrent pneumonia → severe ARDS requiring paralysis and prone positioning

- Discharged to acute rehab after 34 days.
- Improves rapidly → initial neurocognitive performance in the average to above average range. Decannulated.
- Neurocognitive scores all above average at the time of discharge from rehab 24 days later
- Patient discharged home and cleared to return to work without restrictions

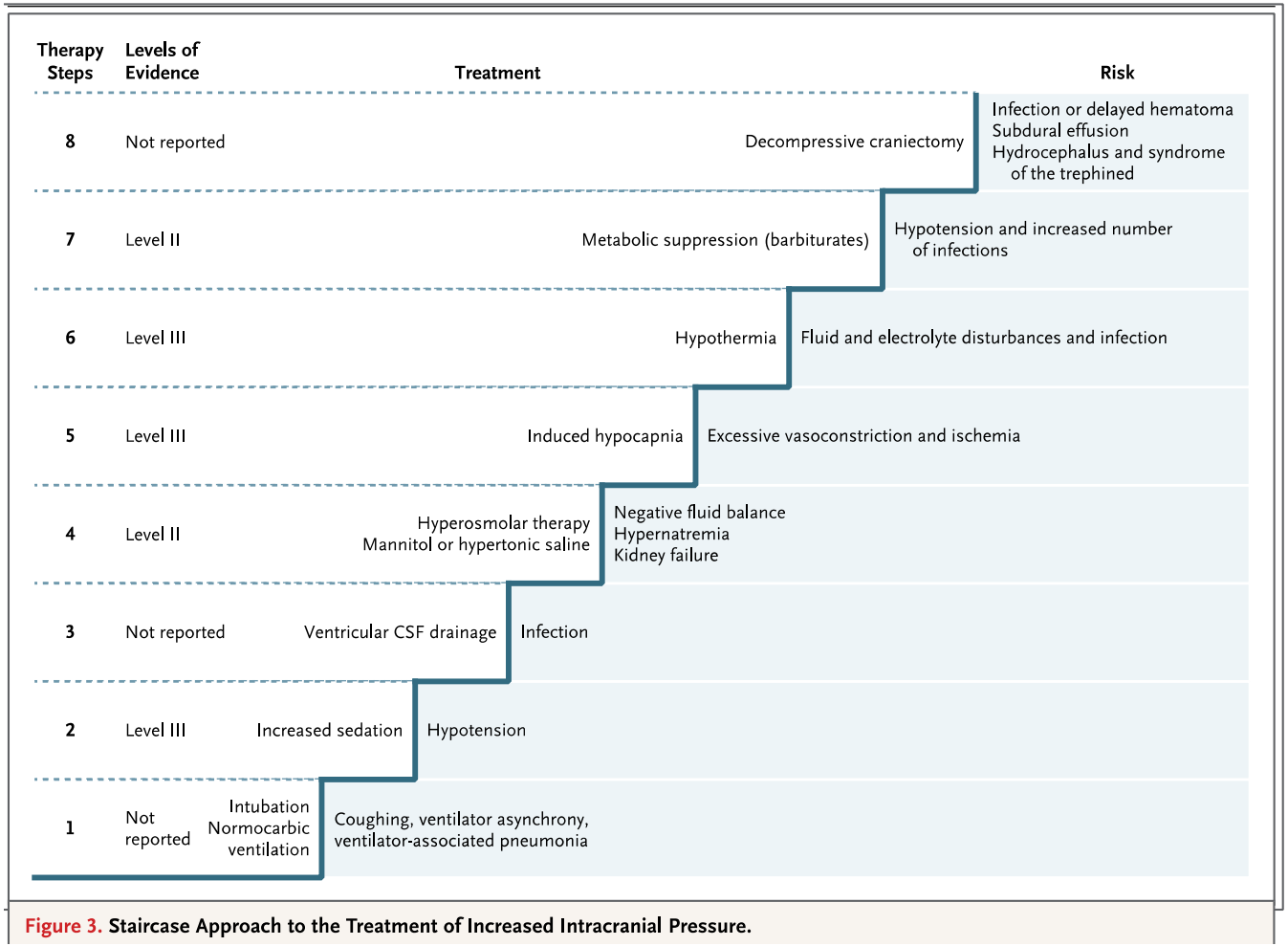
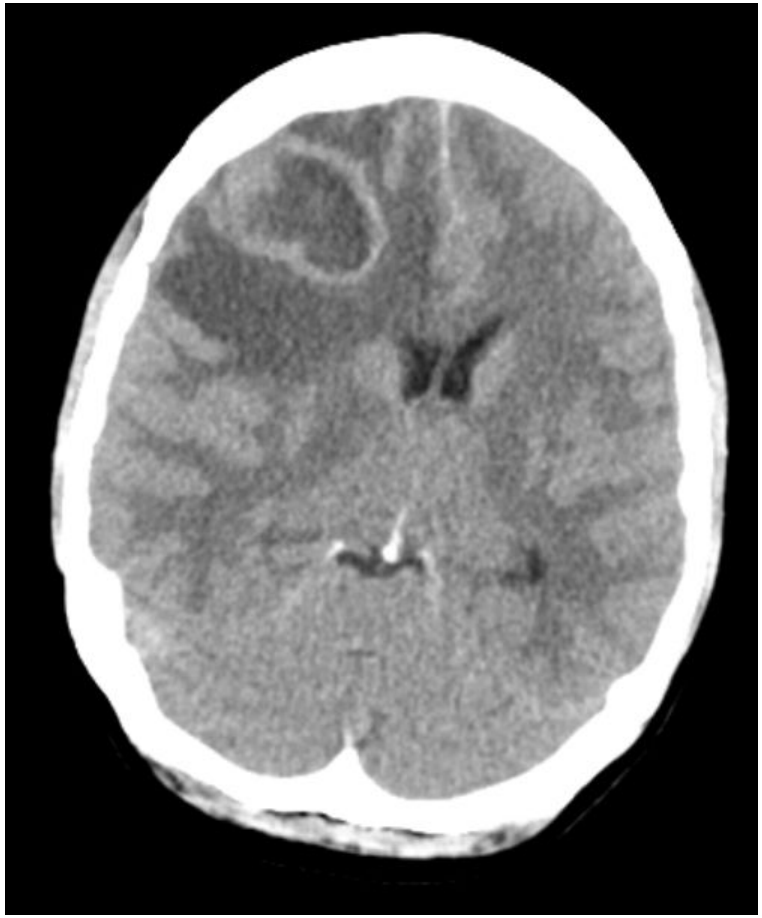


Figure 3. Staircase Approach to the Treatment of Increased Intracranial Pressure.

NEJM. 2014;370:2121

Case 2

- A 49 yo female with PMH of antiphospholipid antibody disease on warfarin following recurrent pulmonary emboli who presented with headache and mild photophobia x 6 days. She was otherwise awake and alert with GCS of 15.



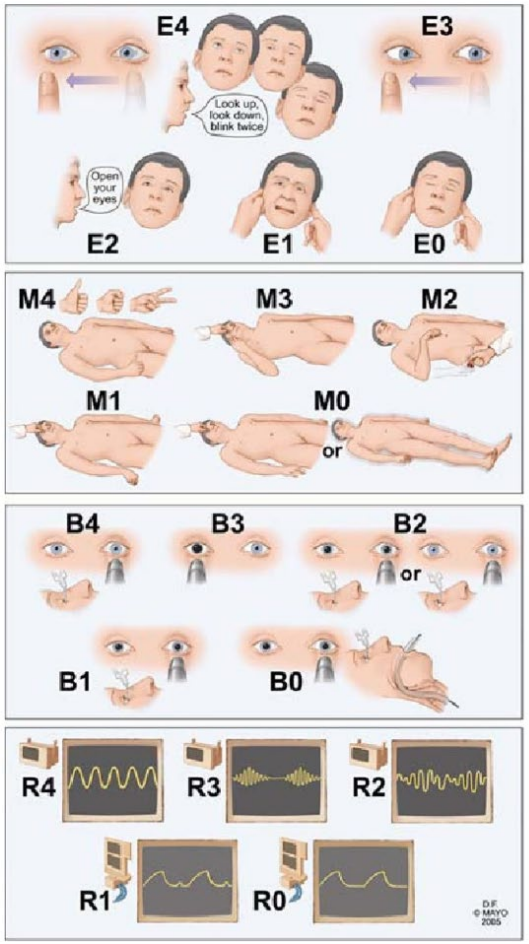
Case 2 continued

- On rounds the next morning she was somewhat sleepy, but woke up and answered basic orientation questions and followed commands.
- Was noted to have intermittent bradycardia during the day, then abruptly became unresponsive in the late afternoon and was transferred to the ICU.
- En route to the unit her pupils became 4mm and unreactive. GCS was 3.

Approach to managing “brain code”

1. Recognize that you are dealing with a time-sensitive medical emergency.
2. Perform a focused neurological examination
    - GCS
    - Four Score
3. Cardiac-code style management, simultaneously:
    - Initiate treatment
    - Call for back-up
    - Formulate differential diagnosis
    - Initiate diagnostic studies

Glasgow Coma Scale (GCS)	
Eye opening	
Spontaneous	4
To speech	3
To pain	2
No response	1
Best motor response	
Obeys	6
Localizes	5
Withdraws	4
Abnormal flexion	3
Abnormal extension	2
No response	1
Best verbal response	
Oriented	5
Confused conversation	4
Inappropriate words	3
Incomprehensible sounds	2
No response	1



b

EYE RESPONSE

4 = Eyelids open or opened, tracking or blinking to command
3 = Eyelids open but not to tracking
2 = Eyelids closed but opens to loud voice
1 = Eyelids closed but opens to pain
0 = Eyelids remain closed with pain stimuli

MOTOR RESPONSE

4 = Thumbs up, fist, or peace sign
3 = Localizing to pain
2 = Flexion response to pain
1 = Extension response
0 = No response to pain or generalized Myoclonus status

BRAINSTEM REFLEXES

4 = Pupil and corneal reflexes present
3 = One pupil wide and fixed
2 = Pupil or corneal reflexes absent
1 = Pupil and corneal reflexes absent
0 = Absent pupil, corneal, or cough reflex

RESPIRATION

4 = Regular breathing pattern
3 = Cheyne-Stokes breathing pattern
2 = Irregular breathing
1 = Triggers ventilator or breathes above ventilator rate
0 = Apnea or breathes at ventilator rate

Widjicks et al. Ann Neurol. 2005;58:585-593

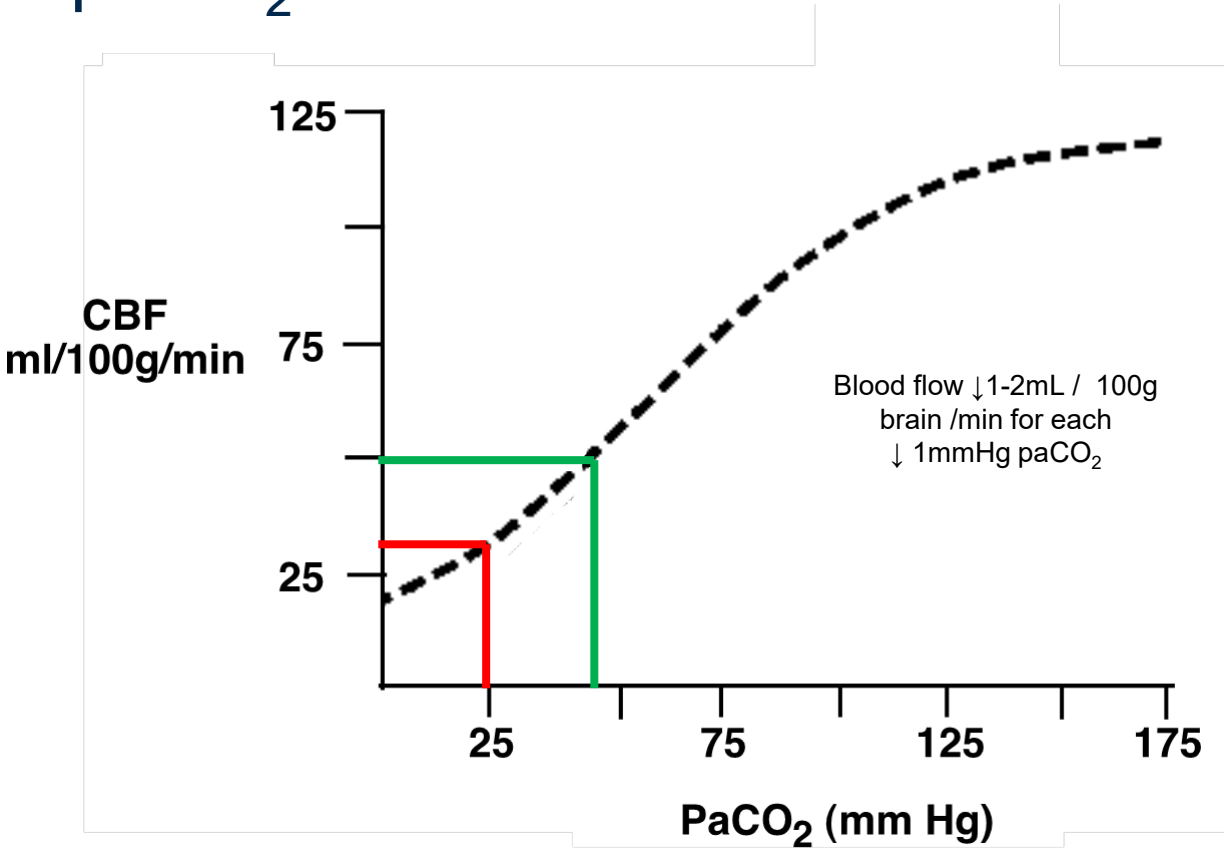
Just think “O HITT”

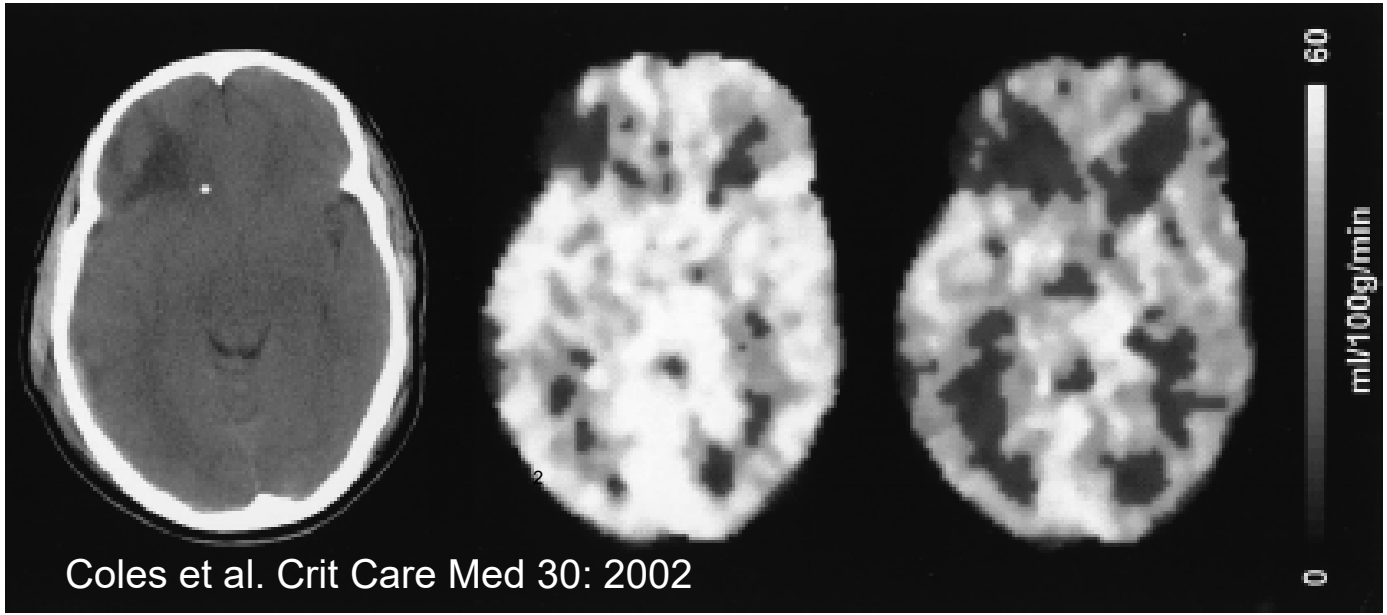
- Os – osmotherapy
  - Mannitol 1 g/kg
  - 23.4% NaCl 30cc
- Hyperventilate
- Intubate
- Transport to CT
- Treat the underlying etiology

	Mannitol	2% Hypertonic Saline	3% Hypertonic Saline	23.4% Hypertonic Saline
Dose recommendations	0.25 g/kg/dose to 1 g/kg/dose IV bolus over 1 min to 30 min	Initial infusion at 1 mL/kg/h to 2 mL/kg/h, 250 mL bolus over 30 min may be administered	Initial infusion at 1 mL/kg/h to 2 mL/kg/h, 250 mL bolus over 30 min may be administered	Refractory elevated intracranial pressure (ICP): IV (30 mL to 60 mL) given over 2 min to 20 min
	May be given repeatedly every 4 h to 8 h	Bolus can be repeated after 30 min	Bolus can be repeated after 30 min	Bolus can be repeated after 15 min
Recommended maximum dose	2 g/kg/dose	1 mEq/kg/h = 2.9 mL/kg/h	1 mEq/kg/h = 1.9 mL/kg/h	May be repeated in 6 h if target sodium level not met
Route	Peripheral IV or central IV	Peripheral IV or central IV	Central IV	Central IV
Osmolarity	1098 mOsm/L	684 mOsm/L	1027 mOsm/L	8008 mOsm/L
Onset and duration of action	Onset: diuretic effect 1 h to 3 h	Onset: rapid	Onset: rapid	Onset: rapid
	Reduction of ICP: 15 min	Duration: 2 h to 6 h	Duration: 2 h to 6 h	Duration: 2 h to 6 h
	Duration: diuretic effect 4 h to 6 h			
	Reduction of ICP: 3 h to 8 h			

[a] Adapted from Mariano GSL, Fink ME, Hoffman C, Rosengart AJ. Intracranial pressure: monitoring and management. In: Hall J, Schmidt G, Wood L, editors. Principles of critical care. 4th ed. New York, NY: McGraw-Hill, 2012.[1]

CBF and $paCO_2$





CT

PET

$PaCO_2$ = 35

ICP = 21

CPP = 74

$SjVO_2$ = 70%

<10 = 141 ml

PET

$PaCO_2$ = 26

ICP = 17

CPP = 76

$SjVO_2$ = 58%

<10 = 428 ml

Case 2 - continued

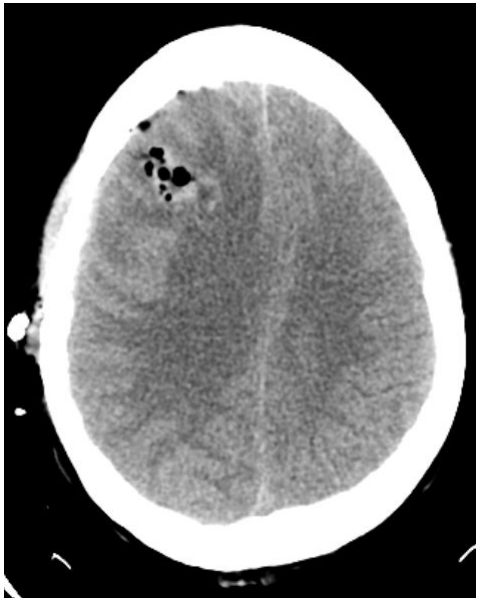
- The patient was intubated and hyperventilated
- 30cc 23.4% NaCl simultaneously ordered
    - Immediately following these steps pupils became reactive
- Differential diagnosis was formulated

1. Progressive cerebral edema from abscess leading to uncal herniation
2. Hemorrhage into abscess 2/2 anticoagulation leading to uncal herniation
3. Regardless, definitive therapy will require surgical intervention

- Patient sent down for head CT for preoperative planning
- OR was booked for patient immediately following CT

Case 2 continued

- Initial head CT confirmed worsening edema and herniation. No intracerebral hemorrhage
- Craniotomy was performed and large volume of pus stereotactically aspirated.
- Patient returned to the ICU postoperatively.
- The next morning she was awake and following commands with residual left hemiparesis and was extubated



Case 2 – Key Points

- Acute coma and actual or pending herniation is a potentially reversible medical emergency
- This situation is best conceptualized as a “brain code”
- As in a code situation, the initial approach should consist of near simultaneous:
  - Focused physical examination
  - Request for back-up
  - Begin resuscitative measures (osmotherapy, hyperventilation, intubation)
    - Don’t forget naloxone or D50 if appropriate
  - Formulation of differential diagnosis, focusing on potentially reversible causes
  - Diagnostic testing, always check glucose and then head **CT once pt is appropriately stabilized**
  - Definitive treatment (craniotomy, craniectomy, ventriculostomy, etc.)

Summary

- Elevated ICP and Cerebral Herniation are related, but distinct pathophysiological states
  - -Herniation is the end-point of refractory ICP elevation and results in coma (uncal herniation) or cardiorespiratory collapse (tonsillar herniation)

- Uncal herniation can occur with normal or even low ICPs

- Herniation is an acute medical emergency (“Brain Code”) that can sometimes be reversed using a rapid, structured approach
  - -Just think “O HITT”

THANK YOU

Questions?