Gizmos and Gadgets in the Stroke Patient

Mary Kay Bader RN, MSN, CCNS, CNRN, CCRN, FNCS, FAHA
Neuro Critical Care CNS
Mission Hospital Mission Viejo CA
Badermk@aol.com

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Disclosures

- Neuro Critical Care Society
  - President/Board of Directors
- Honorarium
  - Bard
- Scientific Advisory Board/Stock Options
  - Ceribell (Stock Options
  - Neuroptics (Stock)

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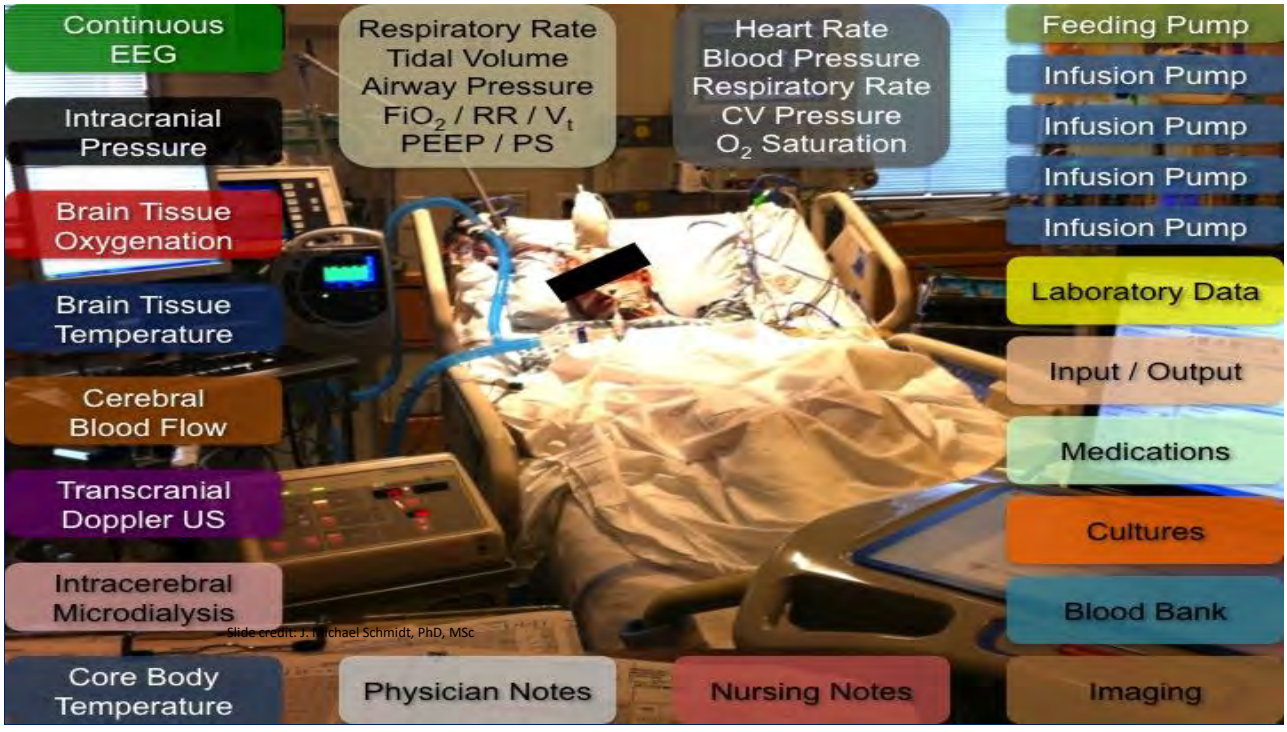

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Introduction: Clinical Exam

- Case Introduction…the importance of the clinical exam
- Physiology of the injured brain
- Monitoring Tools
  - Clinical Exam
  - Technology
  - MMM Guidelines
  - Application Case Studies

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The Importance of the Clinical Exam

- 18 year old female rollover MVA
  - Tier 1 red trauma
  - Unrestrained front seat driver of a vehicle in a high speed chase at about 90 mph when she lost control of the car ejecting the patient.
  - Heroin and methamphetamine were found on scene.
  - Scene assessment
    - Severe injuries to the back of her head and fixed, dilated pupils.
    - Incontinent of urine.
    - Paramedics were unable to establish a blood pressure on scene, however, the patient had good femoral pulses bilaterally.
    - Significant trauma to the back of her left shoulder and a road rash to the back and buttocks
    - No further history is obtainable due to the severity of the patient's condition.

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Emergency Department 2346

- Status
  - GCS 4 with palpable posterior skull fracture and a large posterior scalp laceration.
  - Left pupil is 4 mm & right is 4 mm and both non-reactive
  - Large tension pneumothorax
    - Chest tube placed
  - Brief cardiopulmonary arrest on arrival which resolved after 1mg epinephrine, and her BP stabilized
  - Intubated, lines placed, and stabilized
  - Hypertonic saline bolus given
  - TXA given

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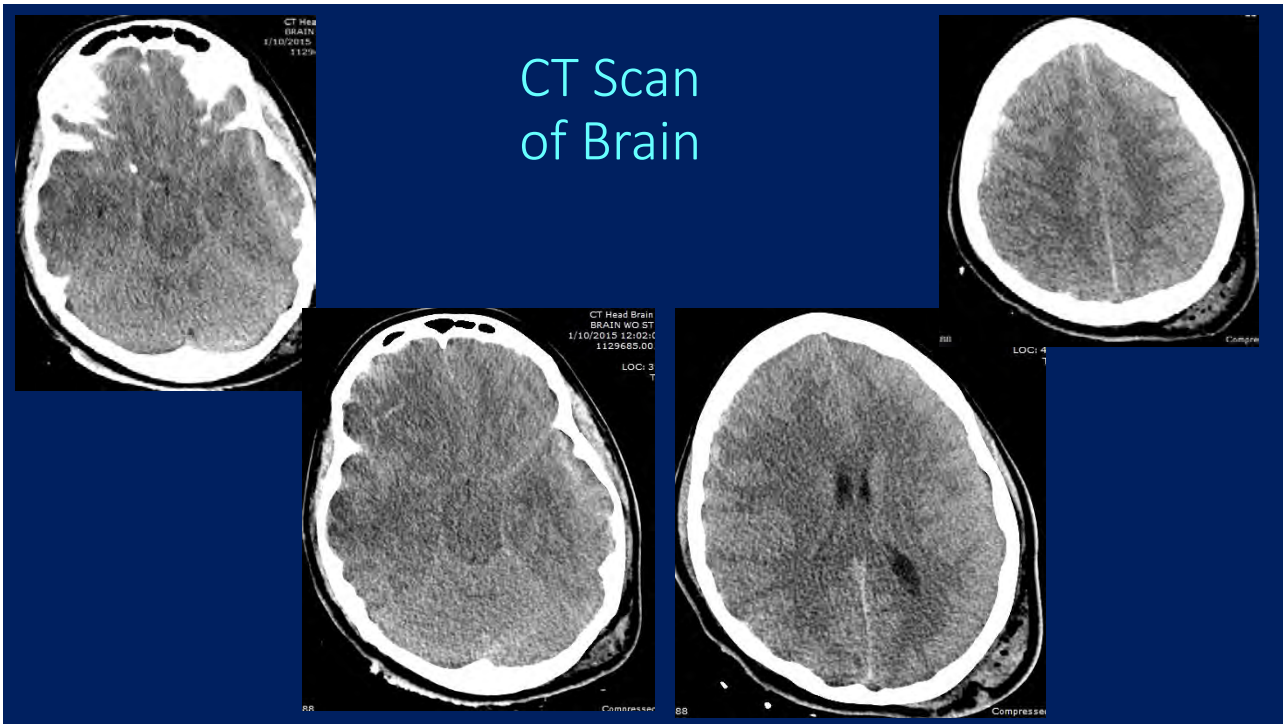
CT Scan of Brain



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Operative Intervention

- Wound debridement of cranium/sutured
- No ICP No multimodality monitors
- Neurosurgical dictation
  - H & P
    - CT scan of the head reveals multiple skull fractures, left-sided epidural hematoma, tonsillar herniation and effacement of cisterns, significant cerebral edema, subarachnoid hemorrhage
  - Operative Note
    - "Cerebral herniation, fatal injury, no craniotomy performed"
- To SICU Post op
  - Other injuries include left open humerus fracture and right pelvic fracture

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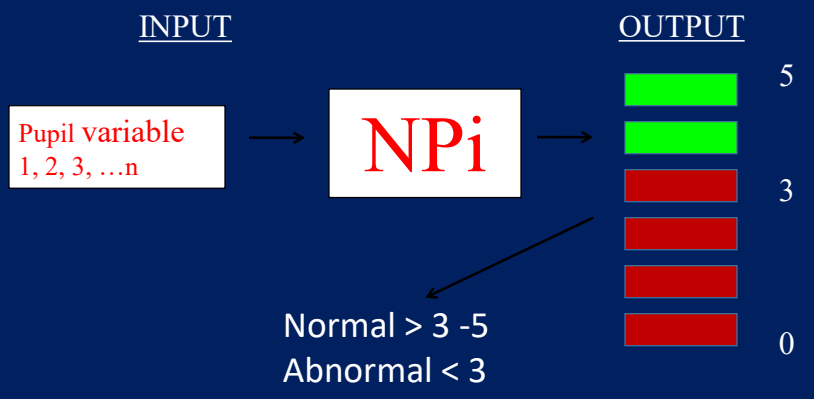
NPI™ (Neurological Pupillary Index) ICP

NPi™ is an algorithm developed after many years of research in the modeling of pupil dynamics.



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- NPi
- MAX/MIN mm
- %CH % Constriction % or Percentage Change
- LAT Seconds
- Latency Constriction Velocity (CV)
- Maximum Constriction Velocity (MCV)

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Data: Trending Significant Values

Parameter	Normal	Abnormal
Pupil Size	Equal size R and L	> 1 mm difference in size after baseline assessment of equal
% Pupil Change	> 10% with normal population having 20- 30% pupil change	< 10% (decrease in % pupil change suspicious of changes in intracranial dynamics
NPI	3 to 5	< 3 represents or a difference of 0.7 between the two eyes indicates increased ICP or possible impending elevations in ICP
Constriction Velocity	> 0.8 mm /sec	< 0.8 mm/sec = increase in brain volume < 0.6 mm /sec correlates with ICP > 20 mm Hg or potential for rise in ICP within 15-30 min

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	9/5/18 20:00
Right Eye Pupil Reactivity	4.7
Right Eye Max Aperture	3.04 mm
Right Eye Min Aperture	2.13 mm
Right Eye Percent Change	30 %
Right Eye Constriction Velocity	1.78 mm/sec
Left Eye Pupil Reactivity	4.7
Left Eye Max Aperture	2.87 mm
Left Eye Min Aperture	2.08 mm
Left Eye Percent Change	28 %
Left Eye Constriction Velocity	1.91 mm/sec

Pupils…
Detecting Small Changes

9/5/18 23:57	9/6/18 00:02	9/6/18 01:05	9/6/18 01:06	9/6/18 01:30	9/6/18 01:50	9/6/18 02:00
Internal	Internal	Internal	Internal	Internal	Internal	
No - Ventric not draining. MD aware	No - Ventric not draining. MD aware	No - Ventric not draining. MD aware	No - Ventric not draining. MD aware	No - Ventric not draining. MD aware		
Dampened	Dampened	Dampened	Dampened	Dampened	Dampened	
Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	
4.3	4.3	3.5	3.0	3.2		
2.25 mm	2.25 mm	2.80 mm	2.90 mm	2.79 mm	7 mm	
1.98 mm	1.98 mm	2.62 mm	2.82 mm	2.69 mm		
12 %	12 %	6 %	3 %	4 %		
0.60 mm/sec	0.60 mm/sec	0.31 mm/sec	0.17 mm/sec	0.17 mm/sec		
4.4	4.4	4.2	4.1	3.7		
2.26 mm	2.26 mm	2.21 mm	2.31 mm	2.34 mm	2.5 mm	
1.94 mm	1.94 mm	1.97 mm	2.11 mm	2.20 mm		
14 %	14 %	11 %	9 %	6 %		
0.86 mm/sec	0.86 mm/sec	0.36 mm/sec	0.37 mm/sec	0.32 mm/sec		
Speiginer, Denise R RN	Speiginer, Denise R RN	Speiginer, Denise R RN	Speiginer, Denise R RN	Speiginer, Denise R RN	S	

9/6/18 01:50
* Ventriculostomy / Pupillometry

Ventriculostomy Pupilometry Comments

R pupil 7mm non reactive. notified Dr, Rao.

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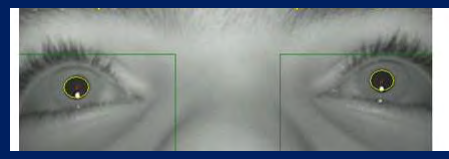
SICU 0200



- Nursing Clinical Exam
  - Pt is intubated
    - FIO2 50% PC
  - Neuro Exam
    - GCS 1-1-1
    - No movement
  - Hemodynamic
    - HR 150
    - BP 115/70 to 66/40 (6am)
    - R 28

Time	Parameter	Right Pupil	Left Pupil
0200	NPI	3.2	2.5
	Size	4.9	4.8
	CV	2.39 mmsec	1.7 mmsec
0400	NPI	3.3	0.9
	Size	2.6	4.2
	CV	0.3 mmsec	0.01 mmsec
0500	NPI	3.3	1.1
	Size	2.66	4.23
	CV	0.53 mmsec	0.22 mmsec

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Day 1

- 0600
  - Fluid bolus 1000 ml
  - BP increased to 110s HR to 90s
- 0800
  - Phone call to Mary Kay with report
    - Pupils are responsive and normal
    - GCS 1-1-1 with no motor response
  - Call to Neurosurgery on action plan
    - Told there is no hope
- Nurses provide 24/7 care maintaining BP and Oxygenation

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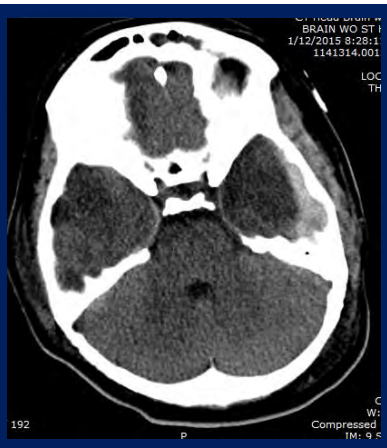
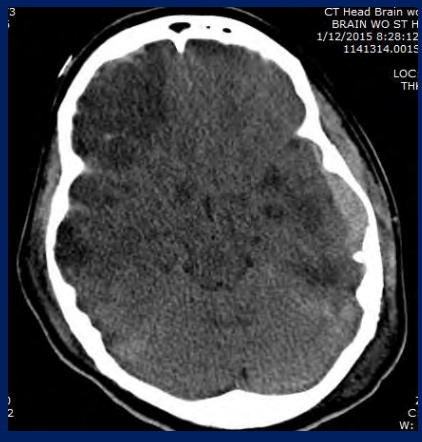
CT Scan Day 2





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Days 2-3

- Physicians maintain terminal outlook
  - Awaiting loss of brainstem reflexes but…pupils still reactive and breathes over ventilator
  - Nurses continue extraordinary care monitoring clinical exam and pupillary reactivity
    - Day 3 nurse notes withdrawal to deep painful stimulus
    - CNS discusses situation with physician team (intensivist and neuro intensivist)
  - Family agrees to make comfort care and agrees to organ donation if progresses to brain death

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Day 4

- Physician Team and family discussed on Day 4
  - "DCD" (Donation after Cardiac Death) with plan to take to the OR on Day 5
- Exam
  - GCS 1-4-1T
    - Movement noted when suctioned
      - Left arm moves up toward ET tube
      - Head movement side to side
- Call for Ethics Consult by CNS

Time	Parameter	Right Pupil	Left Pupil
1000	NPI	4.5	4.3
	Size	2.4	2.5
	CV	1.47 mmsec	1.39 mmsec

Notes by Trauma Team

1/11: Off sedation, patient possibly purposeful to deep noxious stimuli. Continue Keppra, supportive care per NS. Neurologic prognosis remains poor. d/w parents at bedside.
1/12: supportive care. sedated. family would like to move forward w/ organ donation.
1/13: supportive measures. Plan for comfort care at 5pm per Dr. P
1/14: as of now pt is "donation after cardiac death" status

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Day 5 Ethics Consult

- Discussed key assessment findings by nurses
  - GCS 1-4-1
  - Pupils reactive
  - Motor movement
    - Left arm moving purposefully
- Group recommended reconsideration of organ donation
- Physician team discussed with family
  - Family agrees to moving forward with aggressive treatment

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Clinical Course

- Day 6 opens eyes and tracking
- Day 8 OR for orthopedic fracture repairs
- Day 11 extubated
- Day 13 While cleansing road rash….
  - "Ouch …you b____….sorry"
- Day 32 Transferred to Acute Rehab

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If you put in the Gizmo….You have to know the Physiology too!

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Physiology of Brain Injury

Primary and Secondary Injury

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Primary Injury Stroke

- Ischemic Stroke
  - Cerebral Edema
- Hemorrhagic Stroke
  - ICH
    - Edema
    - Intraparenchymal Bleeding
  - SAH
    - Edema
    - Blood in SAS
    - Vasospasm leading to ischemia

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Secondary Brain Injury

- Secondary Head Injury
  - Extracranial causes
    - Hypotension
    - Hypocapnia and Hypercapnia
    - Hypoxia
    - Anemia
    - Acidosis
    - Hyperglycemia and Hypoglycemia
    - Hyperthermia

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Cerebral Blood Flow

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Physiology: Cerebral Blood Flow

Autoregulation

- Vasomotor control
  - Intact: Increase in CPP causes vasoconstriction and decrease in ICP
  - Vasomotor reactivity failure: Increase in CPP causes vasodilation and inc ICP
- Flow metabolism
  - ↑ metabolism ↑ CBF
- Metabolic substances
  - PaO2
  - PaCO2
  - pH i.e., acidosis = vasodilatation

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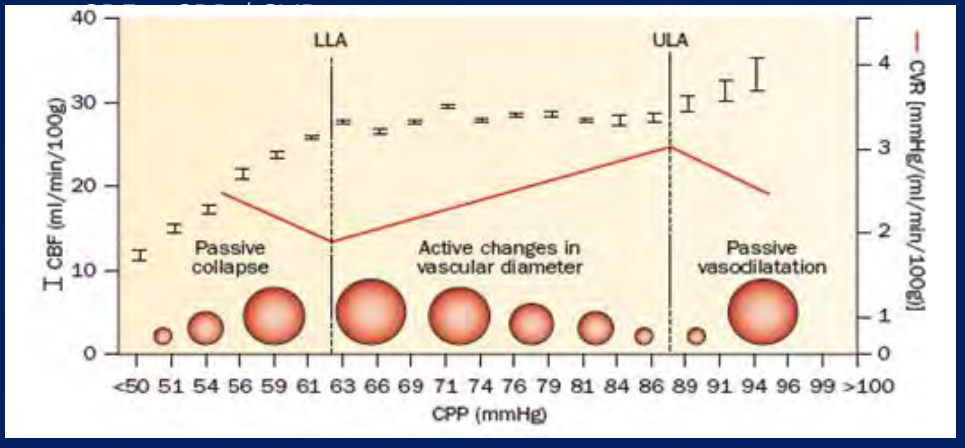
Physiology: Cerebral Blood Flow



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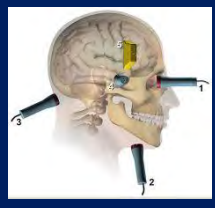
Cerebral Blood Flow



- Transcranial Doppler
  - Useful to trend vasospasm
- Transcranial color-coded Duplex Sonography
- Thermal dilution flowmetry
  - Limited literature on use or impact on outcomes

NCS MMM: C Miller

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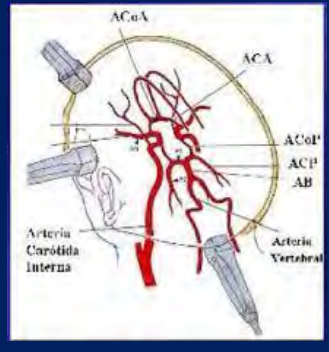
CBF: Indirect/Non-Invasive Transcranial Dopplers

- Non-invasive study using ultrasound to detect changes in the velocity of blood in the arteries of the brain
- Arteries
  - Extra-cranial ICA
  - Middle Cerebral Artery
  - Anterior Cerebral Artery
  - Posterior Cerebral Artery
  - Basilar/Vertebral Arteries



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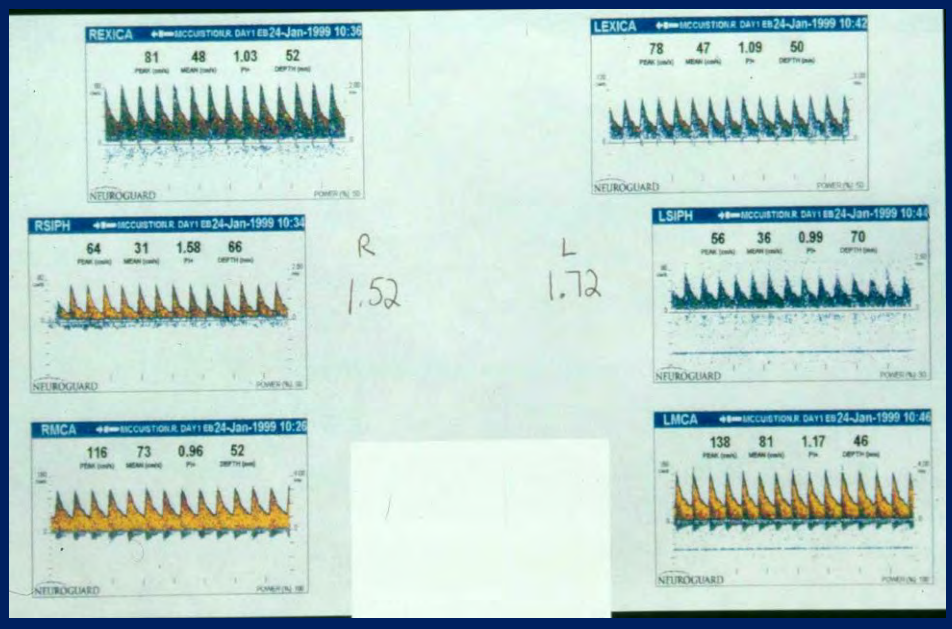

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Transcranial Dopplers

- Increased velocities correlate with vasospasm
  - Mean velocities: Norm MCA mean 55-70 ± 10cm/s
    - >200 = critical velocities
  - Lindegaard Ratio = $\frac{\text{Mean MCA}}{\text{Mean ExICA}}$
    - Normal: < 1.7
    - Moderate spasm: > 3
    - Severe spasm: > 6

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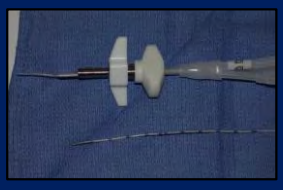
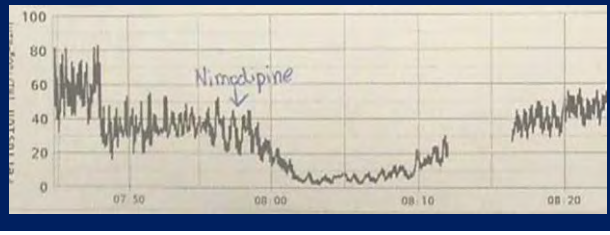
CBF: Invasive



- Thermal diffusion probe
  - Uses 2 thermisters 5mm apart/embedded on cath
  - Heats distal thermistor to measure difference in temperature between 2 sites on catheter
  - Absolute flow measurements ml/100gm/min
  - Normal CBF : > 20 ml/100gm/min



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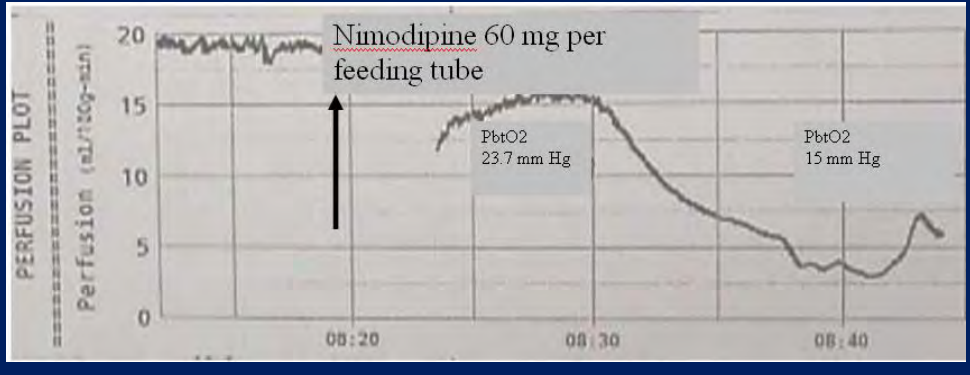
Impact of Nimodipine on PbtO2 and CBF



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Pressure - Invasive

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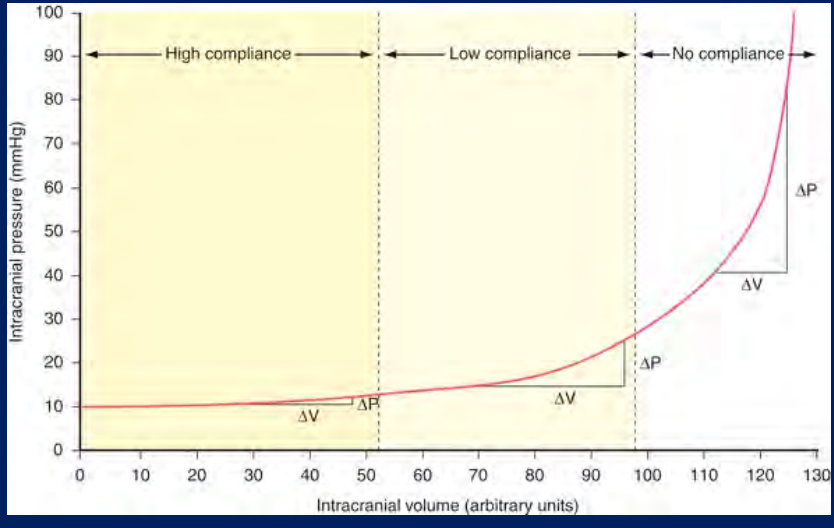
Physiologic Changes:

Intracranial Pressure

- Theories on Brain Compartment
  - 80% brain
  - 10% blood
  - 10% CSF
- If one increases the other two decrease
- Compensatory mechanisms



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Physiology
Symptoms of Increased ICP: Adults

- Early
  - Altered level of consciousness, restless, agitated, headache, nausea, and contralateral motor weakness
  - cranial nerves III and VI
- Late
  - Coma, vomiting, contralateral hemiplegia, and posturing
  - Alteration in Vital Signs
  - Impaired brainstem reflexes
    - Pupils, dysconjugate gaze

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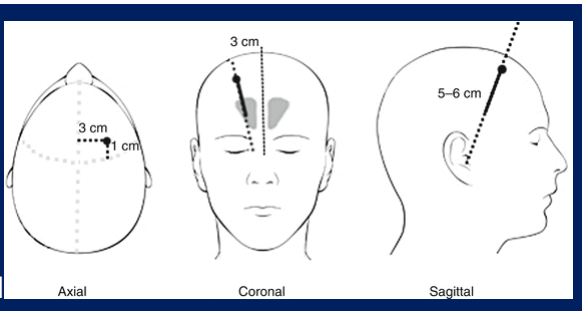
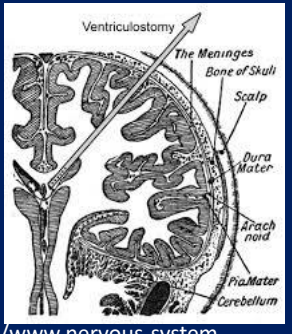
ICP Placement



- Procedure
  - Prep, cleanse scalp and drape
  - Incision right frontal made & twist d
    used to gain access
  - Dura is opened with blunt stylet/irrigate
  - EVD catheter passed into the ventricle
  - Confirm CSF flow
  - Incision is closed with suture
  - CSF system connected to drainage system



http://www.nervous-system-diseases.com/ventriculostomy.html

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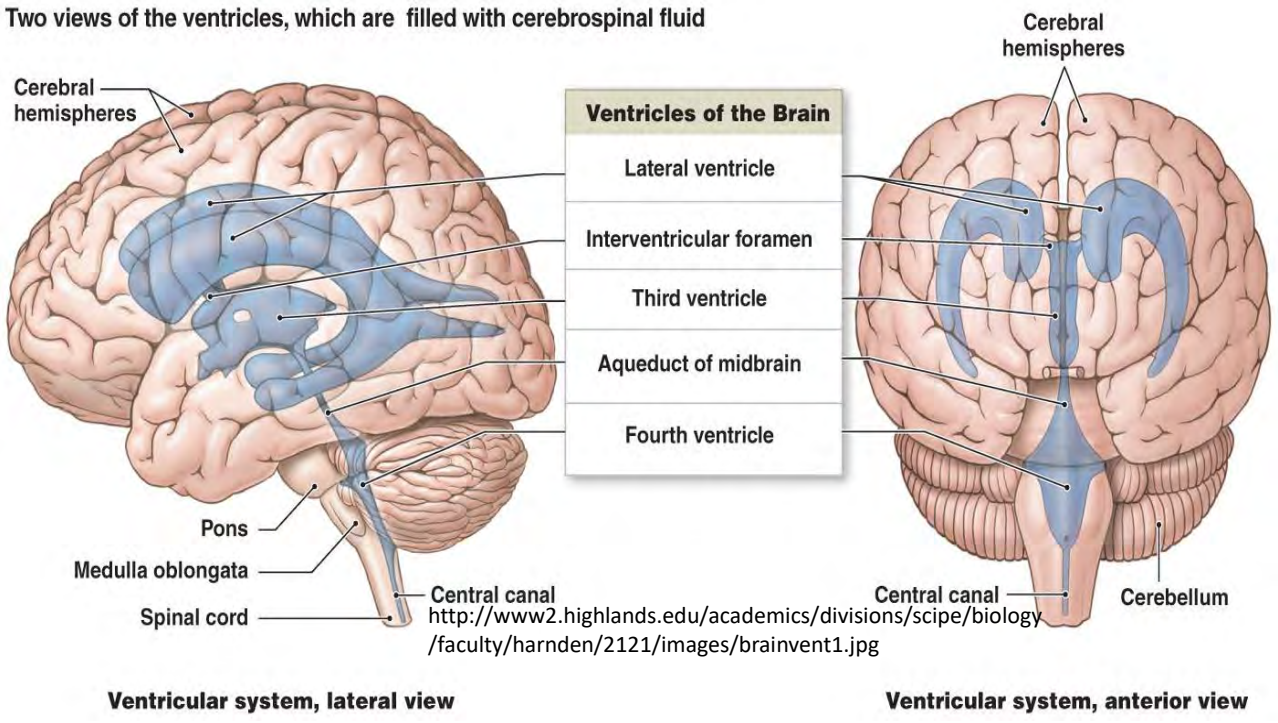

http://www2.highlands.edu/academics/divisions/scipe/biology/faculty/harnden/2121/images/brainvent1.jpg

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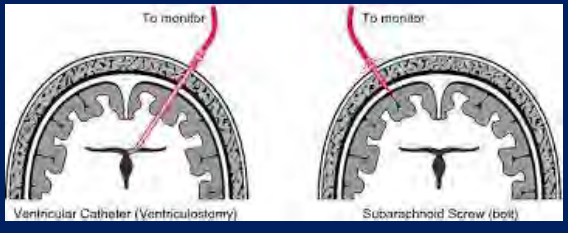
Physiology:

Intracranial Pressure

Normal range

0-15 mm Hg

Abnormal ranges **> 20 mm Hg**



Cerebral Perfusion Pressure

MAP – ICP = CPP

Optimal CPP in TBI

2016: 60-70 mm Hg

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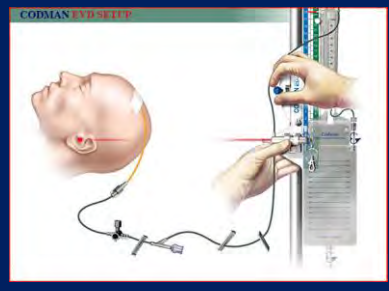
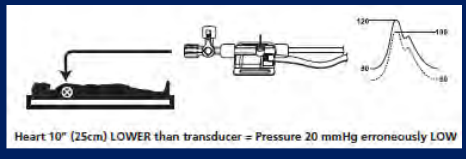
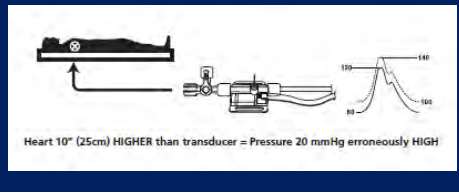
ICP: Nursing Implications CSF Drainage

- Level CSF drainage system with zero reference point
  - Pressure Transducer
    - Transducer position at phlebostatic axis (PMI -point of maximal impulse 4th ICS mid chest)
    - For every inch (2.5 cm) the heart is offset from the reference of the transducer, a 2 mm Hg of error is introduced







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Nursing Implications CSF Drainage

- Drain CSF
  - Produce ≈ 20 cc/hour
  - 125-150cc circulating at any given time
    - 20% in the lateral ventricles
- Continuous Drain
- Intermittent Drain

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Continuous Drain: How long do you wait after closing the EVD to document the ICP?

Journal of Neuroscience Nursing

Intracranial pressure (ICP) is often obtained via external ventricular drain (EVD) placement and is discussed as a key vital sign in neuroscience. Nurses are most often delegated the task of observing, adjudicating, and documenting ICP. Cerebrospinal fluid drainage requires that the transducer connected to the EVD is open to drain, prohibiting ICP monitoring. There are no recent data to support an evidence-based standard for the period an ICP waveform should be observed, after the EVD is clamped, to be able to adjudicate a value that represents the patient's status. Therefore, the purpose of this study is to determine the optimal period for which an EVD should be closed to obtain an accurate ICP value. In a sample of 30 subjects who received continuous ICP monitoring for 15 minutes, there was no universal pattern to ICP after clamping an EVD. The conditional probability of observing a patient's highest ICP if ICP is observed for 5 minutes, is 0.0181. The conditional probability increased to 0.0402 if ICP is observed for 10 minutes. There were no instances of ICP elevation requiring intervention. The results suggest that at least 5 minutes of ICP monitoring is safe and is required to provide an ICP value that reflects true ICP.

Intracranial Pressure Values Are Highly Variable After Cerebral Spinal Fluid Drainage

Michael Rogers, Sonja E. Stutzman, Folefac D. Atem, Samarpita Sengupta, Babu Welch, DaiWai M. Olson

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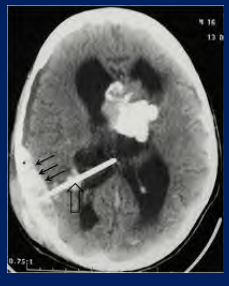
Nursing Implications CSF Drainage

- Do not over drain
  - Over-drainage
    - Sagging cerebrum
    - Pulling of bridging veins
    - Hematoma development



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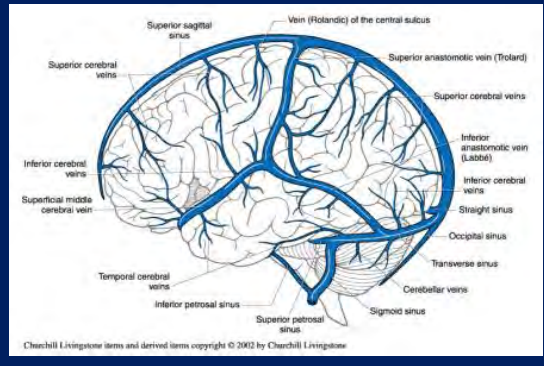

https://i.pinimg.com/originals/e3/ba/13/e3ba13dc62c1033f179bc2bab8e953d2.png

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Nursing Implications CSF Drainage

- What if CSF stops draining?
  - CSF will not drain into bag when stopcock opened or CSF drains backwards into the patient (with concurrent reading of increased ICP reading)
    - Check all stopcocks to assure they are in open and drain position
    - Check vent filter to assure filter is not wet. If wet, change out the entire tubing system using sterile technique
    - Notify neurosurgeon. There may be a clot inside the ventricle blocking the CSF outflow holes on the catheter

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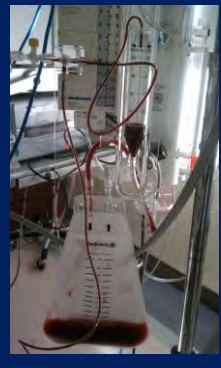
Blood in the Ventricles causing CSF system to stop draining?

- Intraventricular thrombolysis
  - CLEAR trial
  - MISTE trial
- Small doses of IT tPA
  - 1mg every 8 hours
  - Clamp EVD x 1 hour
- Monitoring
  - ICP
  - Frequent CT scans
    - Monitor clearing of blood
    - Monitor for any new hemorrhage



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Nursing Implications

- C & S every other day – change bag
  - DO NOT invade system
- Use sterile aseptic technique
  - Zero procedures
  - Changing bag/transducer
  - Irrigation done by MD

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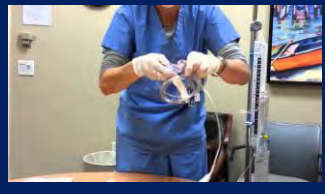
Nursing Implications CSF Drainage: Reducing Infection Risk

Setup



- Assure aseptic technique at all times when changing bag/sampling

Change drainage bag as ordered by physician. This may be done every other day in order to send CSF specimen to laboratory for analysis or when the bag is full of CSF. The technique changing the bag requires 2 people and use of aseptic, sterile technique is absolutely essential. Gather equipment and supplies for the procedure.

. Personnel must scrub hands, don masks
a. Person #1 dons sterile gloves and establishes sterile field with sterile towels
b. Person #2 opens new drainage bag setup and passes to Person #1 observing sterile technique
c. Person #2 opens and passes sterile 4 x 4's to Person #1. Person #2 opens and passes chloroprep to person #1.
d. Person #1 scrubs connection between bag and upper chamber for 3 minutes
e. Person #1 disconnects old drainage bag from tubing
f. Person #2 dons sterile gloves and secures new sterile collection bag and system
g. Cap. Label and send old drainage bag to the Laboratory for analysis (WBC, total protein, glucose, C&S, and gram stain). Send 3 labels for lab tests
h. Document date, time, procedure, and patient tolerance

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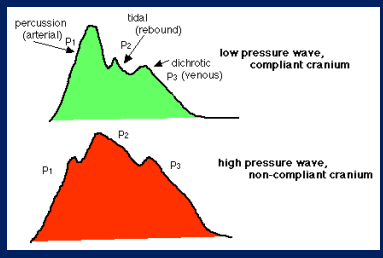
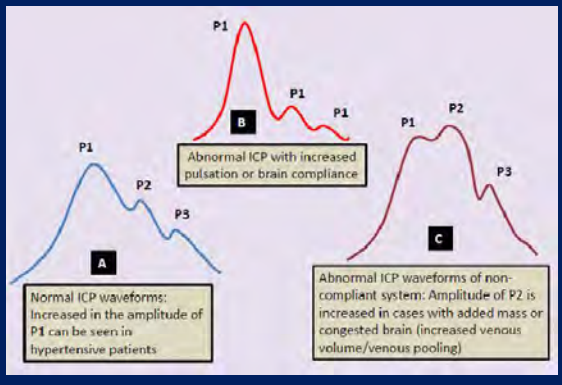
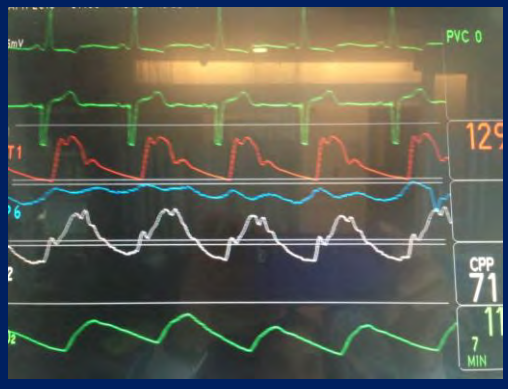
Intracranial Pressure







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Pressure - NonInvasive

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Physiology: Pupils and Pressure

Pupils: Assessing the "Beat" of the Brain

- Pupillary exam is vital to monitor potential increases in ICP
- High inter-examiner variability (up to 39%) and a severe lack of reliability is reported in:
  - *Litvan I, Saposnik G, Maurino J, Gonzales L, Saizar R, Sica REP, Bartko JJ: Pupillary diameter assessment: need for a graded scale. Neurology, 54:530-531, 2000.*
  - *Du R, Meeker M, Bacchetti P, Larson MD, Holland MC, Manley GT: Evaluation of portable infrared pupillometer. Neurosurgery, 57: 198-203, 2005.*

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neurocritical care society Neurocrit Care
DOI 10.1007/s12028-015-0182-1

ORIGINAL ARTICLE

Interrater Reliability of Pupillary Assessments

DaiWai M. Olson[1] · Sonja Stutzman[1] · Ciji Saju[1] · Margaret Wilson[1] · Weidan Zhao[1] · Venkatesh Aiyagari[1,2]

Methods This single-blinded observational study examined interrater reliability of pupil exam findings between two practitioners and between practitioners and a pupillometer.

- 1166 observations – paired subjective pupillary assessment by practitioners compared to automated pupillometer device assessments

Results From 2329 paired assessments, the interrater reliability between practitioners was only moderate for pupil size ($k = 0.54$), shape ($k = 0.62$), and reactivity ($k = 0.40$). Only 33.3 % of pupils scored as non-reactive by practitioners were scored as non-reactive by pupillometry.

50

Physiology: Pupillometer

- Taylor, Chen, Meltzer, et al J of Neurosurgery 98: 205-213 (Jan 2003)
  - –CV fell to 0.81 mm/sec when ICP trended to > 20

TABLE 3

Pupillary measurements obtained in healthy volunteers and head-injured patients

Parameter	Value
healthy volunteers (310 persons, 2432 paired measurements)	
mean maximum resting aperture (mm)	4.1 ± 0.34
mean minimum aperture (mm)	2.7 ± 0.21
mean reduction in size (%)	34
mean constriction velocity (mm/sec)	1.48 ± 0.33
mean latency duration (secs)	0.24 ± 0.4
head-injured patients w/ ICP < 20 mm Hg (26 persons, 168 paired measurements)	
mean maximum resting aperture (mm)	2.10 ± 0.16
mean minimum aperture (mm)	1.7 ± 0.1
mean reduction in size (%)	19
mean constriction velocity (mm/sec)	1.18 ± 0.18
mean latency duration (secs)	0.26 ± 0.6

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Physiology: What is the NPi™ (Neurological Pupil index™) ?

- Rates strength of pupillary reaction on scale from 0-5.
- Purpose: to quantify pupillary reactivity and remove subjectivity from assessment
- Algorithm developed by NeurOptics scientists based on >half a million pupil measurements
- Variables include size, latency, constriction velocity and dilation velocity.

52

- NPi
- MAX/MIN mm
- %CH % Constriction % or Percentage Change
- LAT Seconds
- Latency Constriction Velocity (CV)
- Maximum Constriction Velocity (MCV)

53

Bedside Nursing Use of Pupillometry

- **Head Injury**
  - **mild, moderate & severe**
- **Subarachnoid hemorrhage**
- **Intracerebral hemorrhage**
- **Ischemic stroke**
- **Craniotomy patients post-op**
- **Multisystem trauma patients with history of loss of consciousness**
- **Post Cardiac Arrest Patients**

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SICU – New Admits with Neuro Diagnoses q 1h

- 49 yr old female admitted post op following clipping of a cerebral aneurysm. Pupilometer Assessment @2000 shows normal NPI and Cons Velocity

Right Eye Pupil Reactivity	4.7
Right Eye Max Aperture	3.04 mm
Right Eye Min Aperture	2.13 mm
Right Eye Percent Change	30 %
Right Eye Constriction Velocity	1.78 mm/sec
Left Eye Pupil Reactivity	4.7
Left Eye Max Aperture	2.87 mm
Left Eye Min Aperture	2.08 mm
Left Eye Percent Change	28 %
Left Eye Constriction Velocity	1.91 mm/sec

55

Careful reassessment by our Night Shift RN reveals the following:

9/5/18 23:57	9/6/18 00:02	9/6/18 01:05
Internal	Internal	Internal
No - Ventric not draining. MD aware	No - Ventric not draining. MD aware	No - Ventric not draining. MD aware
Dampened	Dampened	Dampened
Continuous	Continuous	Continuous
4.3	4.3	3.5
2.25 mm	2.25 mm	2.80 mm
1.98 mm	1.98 mm	2.62 mm
12 %	12 %	6 %
0.60 mm/sec	0.60 mm/sec	0.31 mm/sec
4.4	4.4	4.2
2.26 mm	2.26 mm	2.21 mm
1.94 mm	1.94 mm	1.97 mm
14 %	14 %	11 %
0.86 mm/sec	0.86 mm/sec	0.36 mm/sec

56

Careful reassessment by our Night Shift RN reveals the following:

9/6/18 01:06	9/6/18 01:30	9/6/18 01:50
Internal	Internal	Internal
No - Ventric not draining. MD aware	No - Ventric not draining. MD aware	
Dampened	Dampened	Dampened
Continuous	Continuous	Continuous
3.0	3.2	
2.90 mm	2.79 mm	7 mm
2.82 mm	2.69 mm	
3 %	4 %	
0.17 mm/sec	0.17 mm/sec	
4.1	3.7	
2.31 mm	2.34 mm	2.5 mm
2.11 mm	2.20 mm	
9 %	6 %	
0.37 mm/sec	0.32 mm/sec	

The NPI changed 1 hour before the pupil blew! MD was notified 3 times with the pupilometer changes!!! Patient went to CT and OR for emergent craniectomy!

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Case May 2019

58

58 yr old female admit with

- Event: Pt complained of severe headache and dizziness and laid down in bed. Checked by significant other and found to be unconscious 15 minutes later
- Arrives – Code Stroke at 2351
  - GCS 1-3-1
  - Pupils reactive at 3 mm
  - BS BP 143/91 HR 115 R 16
  - Intubated immediately
  - TO CT within 15 minutes

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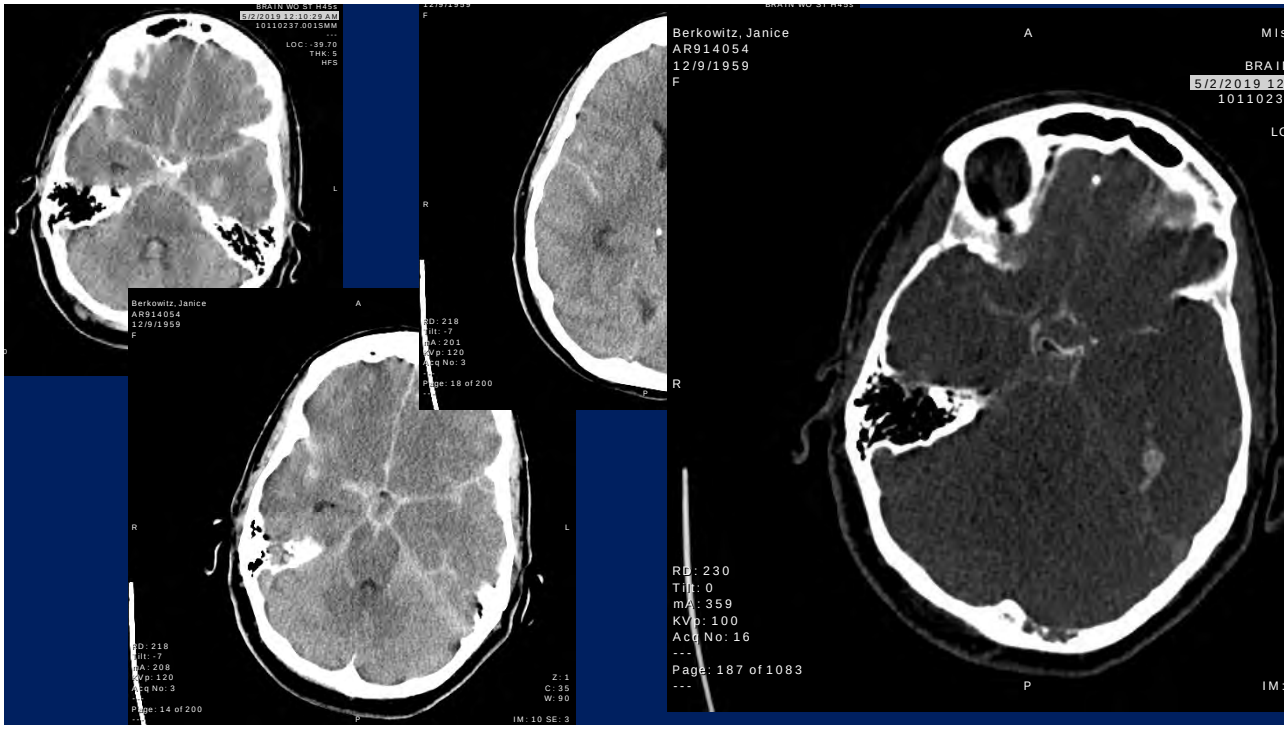


60

Day 1: OR and SICU

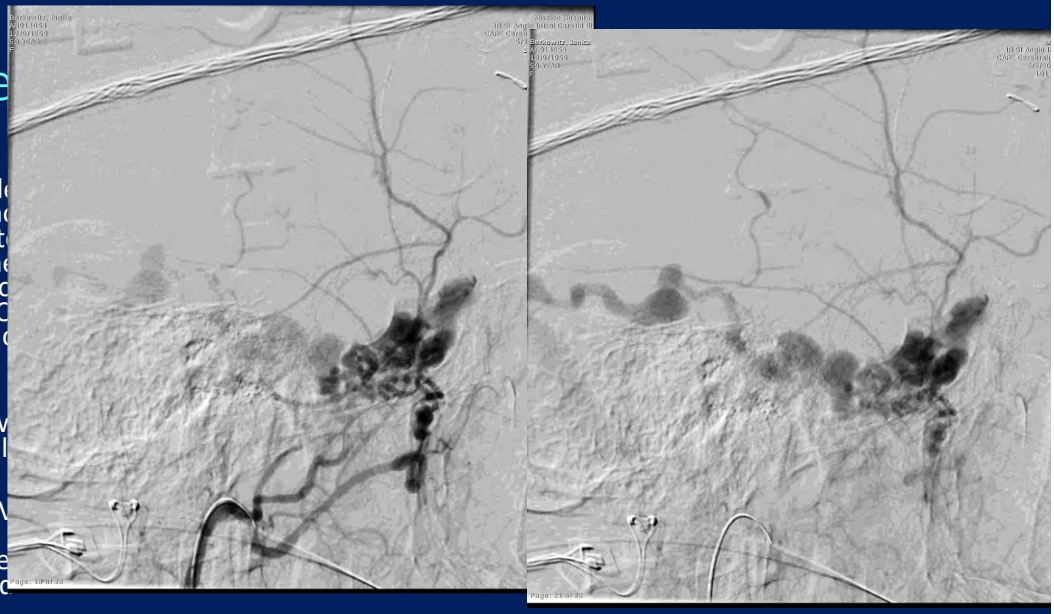
- OR: ICP and PbtO2 catheters placed
  - ICP 25 mm Hg – given 23% saline by physician
  - PbtO2 low
- SICU on admit: ICP 22 @0330
  - Pupillometry

5/2/19 03:06 thru 5/2/19 07:05	5/2/19 03:06	5/2/19 04:05	5/2/19 05:04	5/2/19 06:04	5/2/19 07:05
* Ventriculostomy / Pupillometry					
Right Eye Pupil Reactivity	4.5	4.7	4.8	4.5	4.5
Right Eye Max Aperture	3.31 mm	2.36 mm	2.13 mm	1.91 mm	1.97 mm
Right Eye Min Aperture	2.38 mm	1.88 mm	1.64 mm	1.62 mm	1.65 mm
Right Eye Percent Change	28 %	20 %	23 %	15 %	16 %
Right Eye Constriction Velocity	1.35 mm/sec	0.65 mm/sec	0.57 mm/sec	0.35 mm/sec	0.39 mm/sec
Left Eye Pupil Reactivity	4.5	4.5	4.8	4.7	4.5
Left Eye Max Aperture	3.53 mm	2.67 mm	2.03 mm	1.93 mm	1.88 mm
Left Eye Min Aperture	2.46 mm	2.10 mm	1.61 mm	1.57 mm	1.56 mm
Left Eye Percent Change	31 %	21 %	21 %	19 %	17 %
Left Eye Constriction Velocity	1.42 mm/sec	0.75 mm/sec	0.56 mm/sec	0.38 mm/sec	0.39 mm/sec

61

Ne

- Pt has complex l
  dural arteriovenc
  fistula with 3 art
  feeders from the
  left external carc
  artery and left IC
  aneurysmal pouc
- Neuro IR begins
  embolization of
  fistula complex v
  onyx glue to mul
  vessels
- Small residual AV
  fistula remains
  feeding from the
  anterior ethmoid
  artery



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Day 2: Early hours

- ICP open to drain at 15 mm Hg: checked every 15 minutes average 17 mm Hg
- Pupillometer change noted at 0111 & 0205
  - Neurosurgery called ordered 3% NaCl

5/3/19 00:04	5/3/19 01:11	5/3/19 02:05
External	External	External
Yes	Yes	Yes
Compliant	Compliant	Compliant
Continuous	Continuous	Continuous
Serosanguineous	Serosanguineous	Serosanguineous
veled And Calibrated	Leveled And Calibrated	Leveled And Calibrated
Clean/Dry (+)	Clean/Dry (+)	Clean/Dry (+)
4.5	4.5	4.4
1.96 mm	1.65 mm	1.94 mm
1.67 mm	1.67 mm	1.70 mm
15 %	14 %	12 %
0.46 mm/sec	0.63 mm/sec	0.49 mm/sec
4.1	2.9	1.0
2.42 mm	3.28 mm	4.27 mm
2.17 mm	3.06 mm	4.10 mm
10 %	7 %	4 %
0.36 mm/sec	0.29 mm/sec	0.18 mm/sec

5/3/19 03:00 thru 5/3/19 11:00	5/3/19 03:00	5/3/19 04:04	5/3/19 05:01
* Ventriculostomy / Pupillometry			
Ventriculostomy Transducer Type	External	External	External
Ventriculostomy System Patent	Yes	Yes	Yes
Ventriculostomy Waveform	Compliant	Compliant	Compliant
Ventriculostomy Drainage	Continuous	Continuous	Continuous
Ventriculostomy Drain Description	Serosanguineous	Serosanguineous	Serosanguineous
Ventriculostomy Intervention	Leveled And Calibrated	Leveled And Calibrated	Leveled And Calibrated
Drainage Insertion Site Assessment	Clean/Dry (+)	Clean/Dry (+)	Clean/Dry (+)
Right Eye Pupil Reactivity	4.4	4.8	4.5
Right Eye Max Aperture	1.97 mm	2.05 mm	2.03 mm
Right Eye Min Aperture	1.72 mm	1.57 mm	1.75 mm
Right Eye Percent Change	13 %	23 %	14 %
Right Eye Constriction Velocity	0.54 mm/sec	1.27 mm/sec	0.60 mm/sec
Left Eye Pupil Reactivity	0.9	1.1	1.3
Left Eye Max Aperture	4.48 mm	1.12 mm	4.04 mm
Left Eye Min Aperture	4.32 mm	4.02 mm	3.92 mm
Left Eye Percent Change	4 %	2 %	3 %
Left Eye Constriction Velocity	0.16 mm/sec	0.21 mm/sec	0.21 mm/sec

63

Day 2: ICP Spikes at 0930 to 28 mm Hg
3% saline and 2 hours later Mannitol 100 grams IVP.
To OR for emergent craniectomy/removal of fistula and orders hypothermia post procedural

5/3/19 06:56	5/3/19 08:04	5/3/19 08:57	5/3/19 09:56	5/3/19 11:00
External	External	External	External	External
Yes	Yes	Yes	Yes	Yes
Compliant	Compliant	Compliant	Non-Compliant	Non-Compliant
Continuous	Continuous	Continuous	Continuous	Continuous
Serosanguineous	Serosanguineous	Serosanguineous	Serosanguineous	Serosanguineous
Leveled And Calibrated	Leveled And Calibrated	Leveled And Calibrated	Leveled And Calibrated	Leveled And Calibrated
Clean/Dry (+)	Clean/Dry (+)	Clean/Dry (+)	Clean/Dry (+)	Clean/Dry (+)
3.6	3.6	2.9	3.2	3.2
2.24 mm	2.46 mm	2.86 mm	2.58 mm	2.6 mm
2.15 mm	2.37 mm	2.81 mm	2.51 mm	2.53 mm
4 %	4 %	2 %	3 %	3 %
0.20 mm/sec	0.11 mm/sec	0.12 mm/sec	0.13 mm/sec	0.06 mm/sec
0.7	0	0	0	0
4.41 mm	4.14 mm	4.4 mm	4.33 mm	4.39 mm
4.36 mm				
1 %				
0.21 mm/sec				

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Induction of Hypothermia post op

- ICP settles at 15-20 mm Hg
- PbtO2 20-25 mm Hg
- 10 hours later Left Pupil begins reacting again

5/3/19 21:00	5/3/19 22:00	5/3/19 23:00
4.0	4.0	4.2
2.15 mm	2.00 mm	2.06 mm
1.96 mm	1.86 mm	1.86 mm
9 %	7 %	10 %
0.31 mm/sec	0.22 mm/sec	0.29 mm/sec
0.0	1.3	1.5
3.99 mm	3.88 mm	3.82 mm
	3.79 mm	3.75 mm
	2 %	2 %
	0.07 mm/sec	0.05 mm/sec

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Application
Stroke Case
Basilar artery occlusion

66

Case introduction

- 78 year old female was admitted to Cardiac Telemetry Unit for Atrial fibrillation and CHF
  - 11:35am -36 hours after admit, daughter calls out for help; Patient became unresponsive with eyes looking up
  - BP 174/76 HR 60 irregular RR12
    - 02 sat 98%
    - BG 116
  - Rapid response RN to bedside and calls a Code Stroke
  - 11:38am – MD at Bedside
  - 11:47 - CT non contrast and CTA

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SICU Arrival at 1221

- Patient GCS 1-1-1 and NIHSS 23 RACE Score=6 (LVO score)
- Pupilometer Reading

Right Eye Pupil Reactivity
- 0

Right Eye Max Aperture
- 3.67 mm

Left Eye Pupil Reactivity
- 0

Left Eye Max Aperture
- 2.46 mm

- Breathing pattern changes to irregular – Pt intubated

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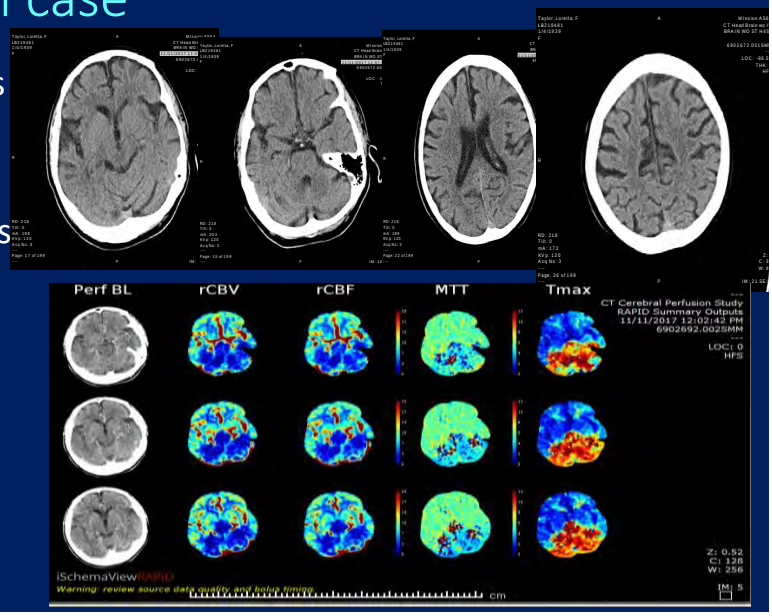
Neurologist on case

- CT Non-contrast of brain shows no edema
- CTA Cerebral Vasculature shows occlusion of basilar artery
- IV tPa is given/IR called



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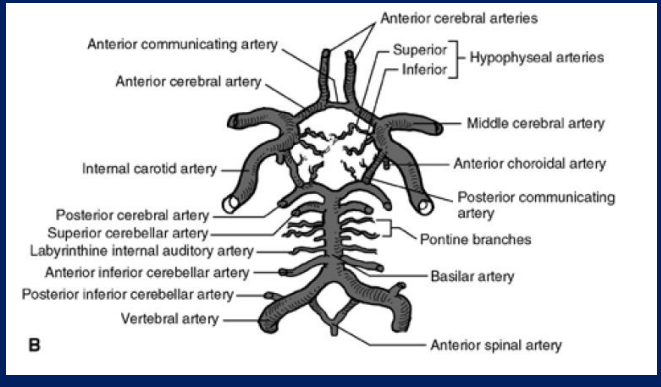
Anatomy of Case

- Basilar Artery Occlusion



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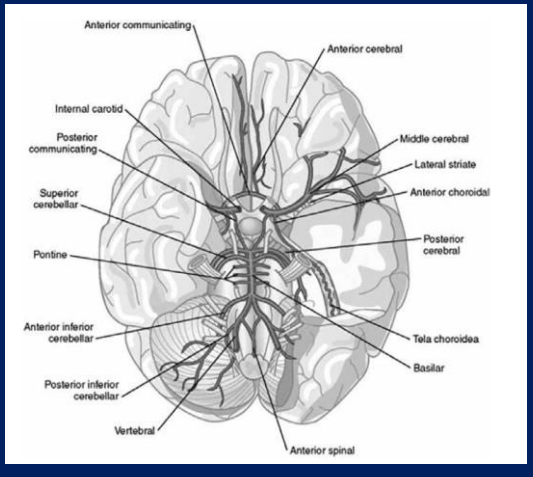
2016: Eds Bader, Littlejohns & Olson

AANN Core Curriculum for NEUROSCIENCE NURSING



Chapter 2. Anatomy of the Nervous System

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Anatomy of Case

2016: Eds Bader, Littlejohns & Olson

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- Basilar Artery feeds posterior brain (occipital lobes) brainstem, and cerebellum

Chapter 2. Anatomy of the Nervous System

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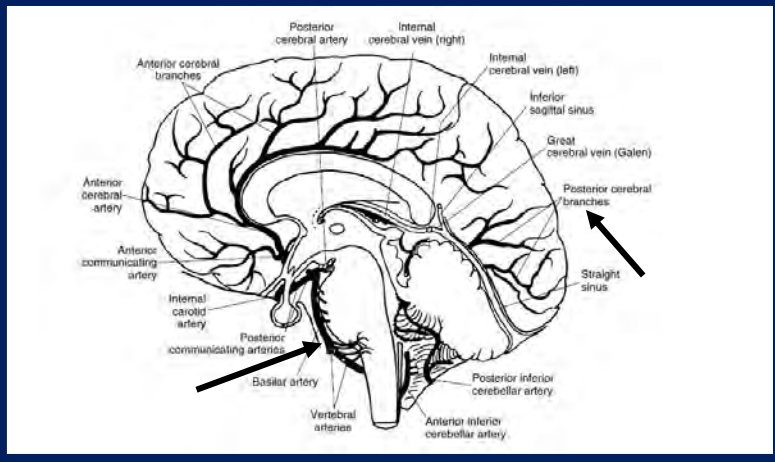

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Anatomy of Case

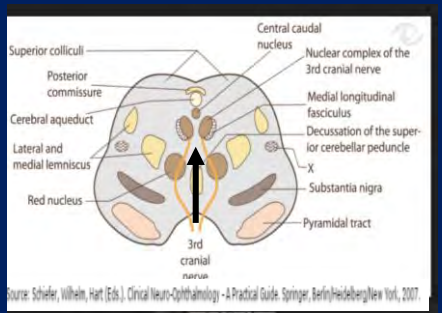
2016: Eds Bader, Littlejohns & Olson

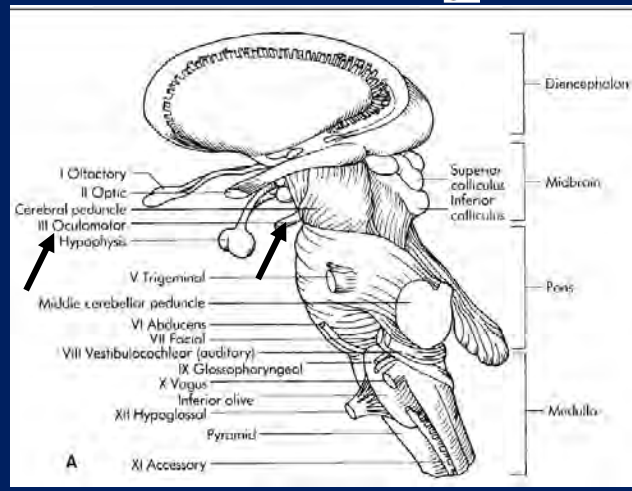
AANN Core Curriculum for NEUROSCIENCE NURSING

30

- Basilar Artery feeds posterior brain (occipital lobes) brainstem, and cerebellum

MIDBRAIN

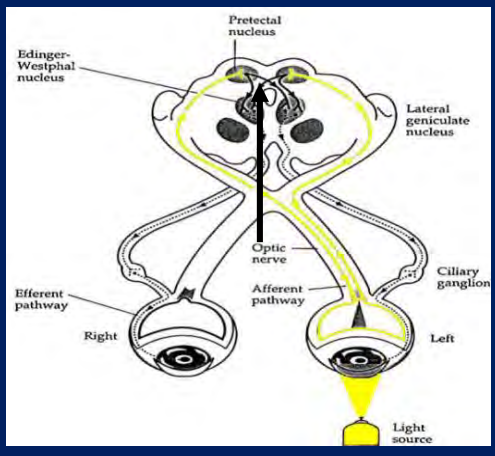




Chapter 2. Anatomy of the Nervous System

72

Anatomy of Case



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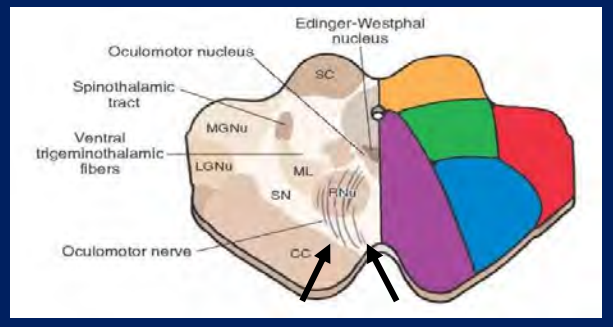

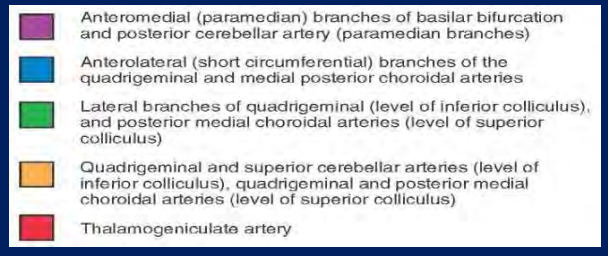

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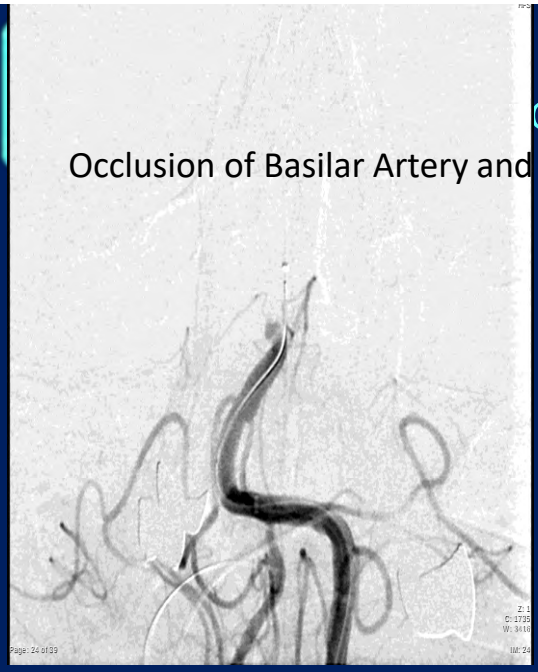
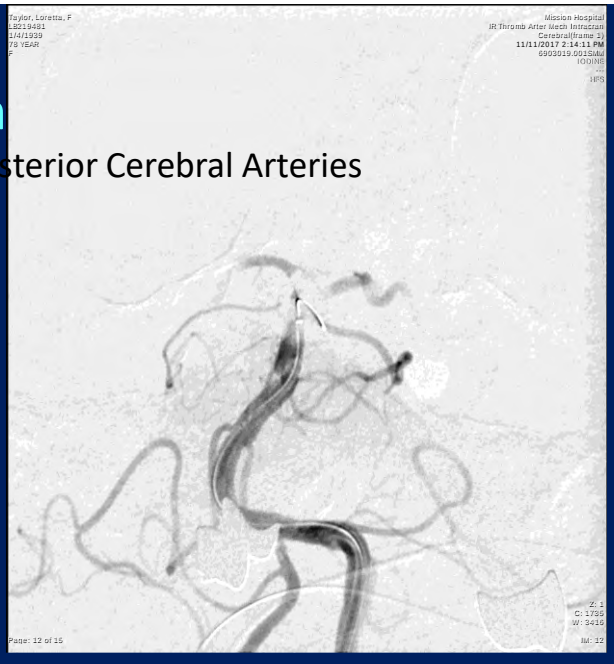
Occlusion of Basilar Artery and Posterior Cerebral Arteries





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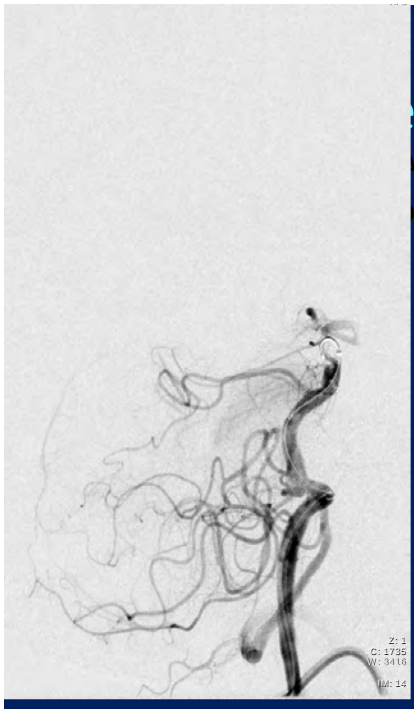

As

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To SICu Post Procedure

- Intubated on a ventilator
- Sedation changed from Propofol (intra-procedure) to Precedex (post procedure)

CODE STROKE VITAL SIGN / NEUROLOGIC CHECK DOCUMENTATION RECORD

VITAL SIGNS					NEURO CHECKS								
					NIHSS CHECKS						PUPILS		
Time q 15	BP	Pulse	Resp	O2 Sat	LOC	LOC?	LOC Comm	Motor Arm R / L	Motor Leg R / L	Best Lang	PUPILS R	PUPILS L	INTERVENTIONS/ INITIALS
1215	121/61	69	12	100	INTUBATED/PROPOFOL						4 NR	3 NR	KP
1230	121/61	71	12	100	INTUBATED/PROPOFOL						4 NR	3 NR	KP
1245	111/62	64	12	100	INTUBATED/PROPOFOL						4 NR	3 NR	KP
1400	115/58	55	12	100	intubated / Propofol						4 NA	3 NA	[illegible] assumed care / mm
1415	107/53	57	12	100	intubated / Propofol						4 NA	3 NA	NOTE: in OR Procedure in progress
1430	133/64	63	12	100	intubated / Propofol						4 NA	3 NA	/mm
1445	139/62	63	12	100	intubated / Propofol						2 NA	2 NA	/ mm
1500	154/64	65	12	100	intubated / Propofol						2 NA	2 NA	/ mm
1515	124/57	55	12	100	intubated / Propofol						2 NA	2 NA	/ mm
1518	157/57	54	12	100	intubated / Propofol						2 NA	2 NA	IN route to SICU / mm
1533	147/60	50	12	100	intubated / Propofol						2 NA	2 NA	Arrived SICU 15 5

Pre Procedure: SICU 1221

* Ventriculostomy / Pupillometry	
Right Eye Pupil Reactivity	0
Right Eye Max Aperture	3.67 mm
Right Eye Min Aperture	
Right Eye Percent Change	
Right Eye Constriction Velocity	
Left Eye Pupil Reactivity	0
Left Eye Max Aperture	2.46 mm
Left Eye Min Aperture	
Left Eye Percent Change	
Left Eye Constriction Velocity	
Ventriculostomy Pupilometry Comments	

Post Procedure: SICU 1545

3.3
1.76 mm
1.71 mm
3 %
0.2 mm/sec
4.2
1.8 mm
1.62 mm
10 %
0.55 mm/sec

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SICU Post Procedure

- Change of Shift NIHSS 20

Vital Signs

11/11/17 19:30
75 bpm (60-100)
Cardiac Monitor
Bundle Branch Block (+)
13 breaths per min (12-20)
99 % (92-100)
Ventilator
45 %
Yes
41 mm Hg (35-45)
12
Yes
ke, RT, reduced FiO2 to 45% and increased RR to 15
165/73 (94) H
94
Automatic Cuff
Right Arm
Supine
165 mm Hg (90-120) H
73 mmHg (60-90)
94 (+)

NIHSS Abbr

Critical Care
Per Protocol Post t-PA
Not Alert, Obtunded
Answers Both Incorr
Performs Both Incorr
No Effort Agnst Gravity
No Effort Agnst Gravity
Some Efft Agnst Gravity
No Effort Agnst Gravity
No Sensory Loss
Mute
Unable To Test
🗨
20

Pupilometer

4.6
3.24 mm
2.27 mm
30 %
2.38 mm/sec
4.3
3.85 mm
2.69 mm
30 %
2.68 mm/sec

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Next 24 hours

Vital Signs

11/12/17 16:00
98.8 degrees F (97.6-100.4)
Oral
89 bpm (60-100)
Cardiac Monitor
Bundle Branch Block (+)
Multifocal
26 breaths per min (12-20) H
100 % (92-100)
Ventilator
40 %
Yes
31 mm Hg (35-45) L
5
Yes
133/74 (95) H
95
Automatic Cuff
Right Arm
Semi-Fowlers
133 mm Hg (90-120) H
74 mmHg (60-90)
95 (+)

NIHSS Abbr

Critical Care
Per Protocol Post t-PA
Not Alert, Obtunded
Answers Both Incorr
Performs Both Incorr
No Effort Agnst Gravity
No Effort Agnst Gravity
Some Efft Agnst Gravity
No Effort Agnst Gravity
No Sensory Loss
Mute
Unable To Test
🗨
20

Pupilometer

4.7
3.07 mm
2.15 mm
30 %
2.37 mm/sec
4.7
3.32 mm
2.26 mm
32 %
2.49 mm/sec

78

At 1725…

Vital Signs

82 bpm (60-100)
Cardiac Monitor
Bundle Branch Block (+)
Ventilator
40 %
Yes
33 mm Hg (35-45) L
5
Yes
105/50 (72) L
72
Automatic Cuff
Right Arm
Semi-Fowlers
105 mm Hg (90-120)
50 mmHg (60-90) L
72 (+)

NIHSS Abbr

Critical Care
Per Protocol Post t-PA
Not Alert, Obtunded
Answers Both Incorr
Performs Both Incorr
No Effort Agnst Gravity
No Effort Agnst Gravity
Some Efft Agnst Gravity
No Effort Agnst Gravity
No Sensory Loss
Mute
Unable To Test
20

Pupilometer

Right Eye Pupil Reactivity	0
Right Eye Max Aperture	
Left Eye Pupil Reactivity	0
Left Eye Max Aperture	
Left Eye Min Aperture	
Left Eye Percent Change	
Left Eye Constriction Velocity	
Ventriculostomy Pupilometry Comments	

Pupil is “cat-eye” shape

Neurologist notified: Orders Stat CT scan of brain no contrast

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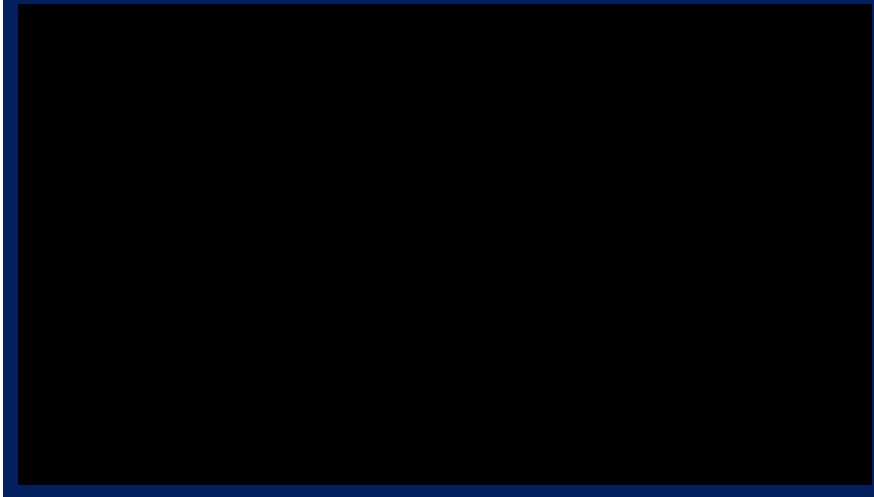
At 1725…



Pupilometer

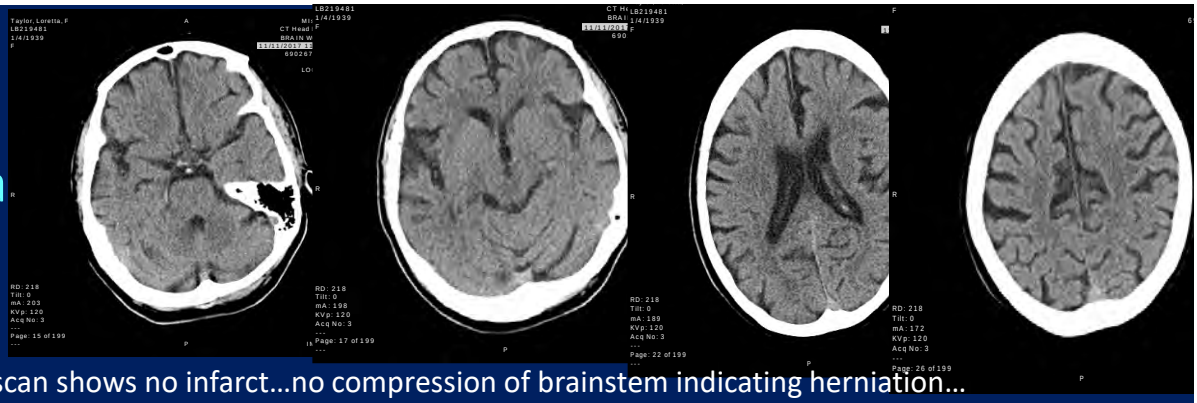
Right Eye Pupil Reactivity	0
Right Eye Max Aperture	
Left Eye Pupil Reactivity	0
Left Eye Max Aperture	
Left Eye Min Aperture	
Left Eye Percent Change	
Left Eye Constriction Velocity	
Ventriculostomy Pupilometry Comments	

Pupil is “cat-eye” shape

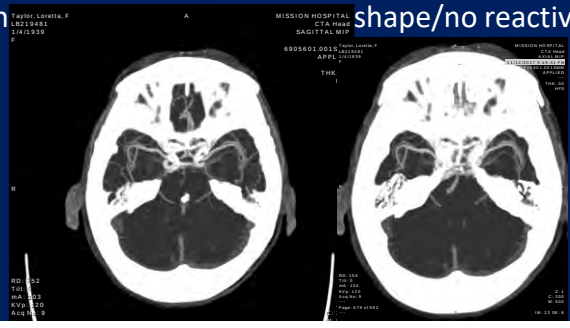
Neurologist notified: Orders Stat CT scan of brain no contrast

80

CT Sca



CT scan shows no infarct…no compression of brainstem indicating herniation…
Nurse is told to go back to SICU: Nurse challen shape/no reactivity
Neurologist: OK…we will do a CTA
Results: CTA –Reocclusion of Basilar Artery!



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Outcome

- Family declined 2nd Interventional treatment
- Patient made Comfort Care…

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Oxygen

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Systemic and Brain Oxygenation

- Maintenance of adequate oxygenation is 1º objective of critical care
  - Assessment of tissue oxygenation essential
- Hypoxia
  - Reduction of tissue oxygenation to levels insufficient to maintain cellular function and metabolism
  - May be a result of ischemia due to macro-vascular/microvascular, anemia, & hypoxemia
  - Cytopathic hypoxia: failure of cell to extract O2
  - Aggravates secondary brain damage
  - Monitor and Treatment paramount

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Oxygen: Recommendations Systemic Oxygenation/CO2

- ABG Analysis (SaO2, PaO2) and SpO2 monitoring
  - Safe and reliable
  - SpO2 and ABG analysis detect pulmonary and circulatory abnormalities
  - Use of monitors helpful in detecting desaturations which are associated with poorer outcomes
- CO2: ABG (PaCO2) Capnography (ETCO2)
  - Safe and reliable (++research on CO2 in anesthesia /critical care)
  - ETCO2 and PaCO2 correlate in healthy volunteers but ongoing comparison of both should occur in clinical setting
  - Use of monitor can detect and guide hyperventilation

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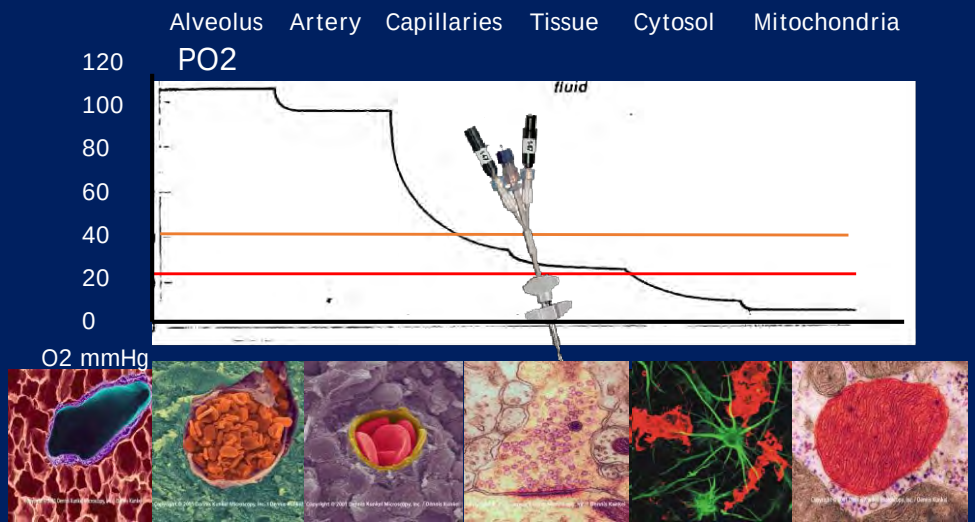
Physiology: *Oxygen flux from air to neuron*



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Physiology Oxygen Dynamics: Brain Tissue Oxygen Monitoring

- Indications for clinical use of $pbtO_2$ monitoring
  - TBI
  - SAH
  - Ischemia
  - Intraoperative monitoring to avoid ischemic complications

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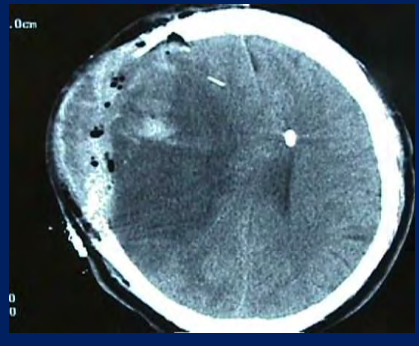
Physiology: Selecting the Site for Monitoring

- Penumbra



Regional Detection
Penumbra Area

Global

Global Measurement
Contralateral to Injury

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Physiology: Brain Tissue Oxygen (Pbt02)

- Normal: 20-40 mm Hg
- Risk of death increases
  - < 15 mm Hg for 30 minutes
  - < 10 mm Hg for 10 minutes
- PbtO2 < 5 mm Hg
  - high mortality
- PbtO2 ≤ 2mm Hg - neuronal death

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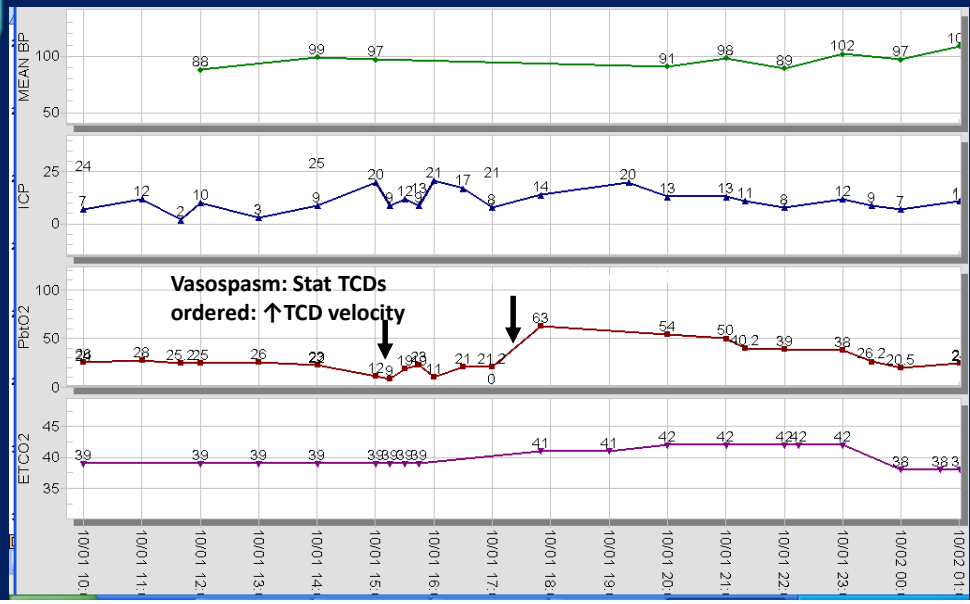
Focal Vasospasm



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Myocardial Stunning: "tako tsubo"

PbtO2	23	5.6	26.5	12.2		20.1
CBF	20	4	22	11		19
Cardiac						
HCT						30.3
PAS	29	+ 54	17	+ 50		+ 36
PAD	17	+ 30	10	+ 27		+ 18
PAM	23	+ 41	14	+ 37		+ 28
PAW		22				+ 19
CO		1.50	5.70	3.40		+ 4.2
CI		0.8	4.0	1.4		+ 2.9
SVR			1374	2374		1827
CVP	6	10		+ 8		+ 10
PVR			Start			171
SVO2			Dobut	Start Mag		
SV			@ 5	in Dobut line		42.9
LV SWI						34.5
RV SWI						8.1

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Critical Thinking Algorithms
Severe Brain Injury Population

PbtO2 >20 - 40 mm Hg
ICP > 20 mm Hg

- Drain CSF
- Normothermia
- Optimize CPP 60-80 mm Hg
  1) Use saline to optimize volume (assess SVV – Maintain < 10%). Test fluid responsiveness prior to starting pressors.
  2) Optimize MAP with norepinephrine or phenylephrine
- ✓ Analgesia/sedation:
  ↑Propofol/Midazolam
  ↑ Fentanyl prn
- ↓ CO2 to 30-35 mm Hg until ICP < 20; stop↓ when PbtO2 @ 20 mm Hg
- Give Hypertonic Saline 3% 200ml over 20 min or Mannitol 0.25-1.0 grams/kg IV
- Call MD
- CT scan if ICP doesn't remain <20mmHg

Refractory Increased ICP MD Decision

Craniectomy
Barb Coma
Mild Hypothermia 33-36 °C

PbtO2 < 20 mm Hg
ICP > 20 mm Hg

- Drain CSF
- Normothermia
- Optimize CPP* for patient: 60-80 mm Hg
  1) Use saline to optimize volume (use SVV –_Maintain < 10%).Test fluid responsiveness prior to starting pressors.
  2) Optimize MAP with norepinephrine
- ✓Analgesia/sedation:
  ↑ Propofol or Midazolam
  ↑ Fentanyl prn
- Give Hypertonic Saline 3% 200ml over 20 min or Mannitol 0.25-1.0 grams/kg IV
- Titrate PaCO2 to 35 mm Hg
- Call MD
- CT scan if ICP doesn't remain <20

Refractory Increased ICP - MD Decision

Craniectomy
Barb Coma
Mild Hypothermia 33-36 ° C

*Refer to decision tree in ICP <20 and PbtO2 < 20 for critical analysis of hemodynamic vs. pulmonary causes

PbtO2 < 20 mm Hg
ICP < 20 mm Hg

- ✓PaCO2: if low then ↑ to 40-45mm Hg as long as ICP stays within range
- Normothermia: Is patient shivering?
- If PbtO2 is low in conjunction with PaO2, place patient increased FIO2 x 5-15min while evaluating possible pulmonary issues
- ✓ SVV/SV/CI/MAP as well as lung sounds/vent setting

1) Hemodynamic Eval:
✓SVV/ SV/CI: consider Fluids if SVV >10%

✓ MAP/SVR/CI
Assess Cardiac Status
Start vasopressors as needed

2) Pulmonary Eval
✓ Consult RCP
✓ Vent settings
✓ Need for additional sedat
✓ Need for paralytic (vent)
✓ Need for Resp. treatment
✓ Change vent settings instead of high FIO2
Evaluate different modes

3) Fluid overload rt pulm. edema/volume overload
a) ✓ I/O balance b) ✓ Chest Xray
c) ✓SVV/SV d) Call MD e) Consider Lasix

4) Temp Management: Keep 37°

Revised 2017

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Critical Thinking Algorithm
Aneurysmal Subarachnoid Hemorrhage

Changes in PbtO2 (< 20 mm Hg or dramatic decrease in > 10 mm) or CBF (< 20)

ICP > 20 mm Hg	Pulmonary	Cardiac/Hemodynamic	Vasospasm
-Drain CSF -Assess PaCO2 and optimize (no lower than 35 mm Hg) -Assess MAP -Assess SVV to determine need for fluids -Evaluate sedation -Consider Mannitol or Hypertonic Saline -Notify Neurosurgeon -CT scan if unable to control ICP	-Assess lung sounds -Check ventilator settings -Check ABG -Check Chest X-ray -Assess sedation levels -Consult with RT/MD on optimal ventilator settings -Assess fluid status	- Assess hemodynamics SVV, SV, CO, CI, SVR -Assess for pulmonary edema; if present consider Lasix -Assess 12 Lead ECG for ST changes -Consider echo to determine if low EF -If SV decreased &/or low EF, consider dobutamine	-Assess clinical exam for new onset or worsening signs: LOC, motor weakness, &/or language -Assess decrease in sodium (drop 8-10) -Assess TCD trends √ Mean Velocities of each artery & Lindegaard Ratio Right and Left sides -Obtain stat TCD -Notify Neurosurgeon immediately with changes -If velocities increase, consider increasing MAP and/or Interventional procedures

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Electrophysiology and Seizures

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Electrophysiology

- Monitoring for seizure activity
- Continuous EEG (detecting non-convulsive status)

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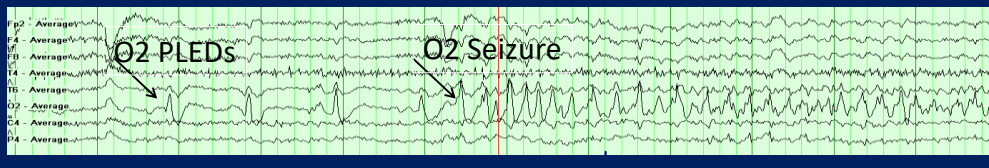
Seizure Criteria

Modified Young Criteria (Chong and Hirsch)

- Duration >10 seconds
- Either:
  - Repeating epileptiform discharges at >3Hz *or*
  - Clinical correlate + one of:
    - Rhythmic slowing >1Hz with evolution in frequency (change >1Hz), location, or morphology and involving at least 2 electrodes
    - Repeating epileptiform discharges <3 Hz + secondary criterion

Secondary criterion

- CLINICAL improvement or newly appearing NORMAL background linked to administration of an AED.



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Indications for EEG in Critically Ill Patients

Standard 30 minute EEG

- Diagnosis of Nonconvulsive Seizures, NCSE & other paroxysmal events
- Assessment of Severity of Encephalopathy and Prognostication

Continuous EEG monitoring

- Clinical paroxysmal events suspected to be seizures
- Assessment of Efficacy of Therapy for Seizures and SE
- Epileptiform abnormalities on 30 minute EEG
- Monitoring of Sedation and High-Dose Suppressive Therapy
- Identification of cerebral ischemia in patients at high risk

Modified from:
Herman et al. J Clin Neurophysiol 2015;32: 87–95)

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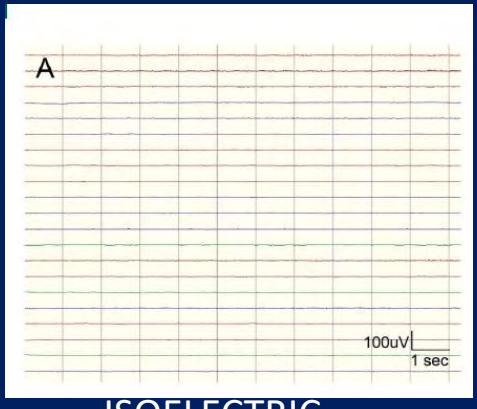
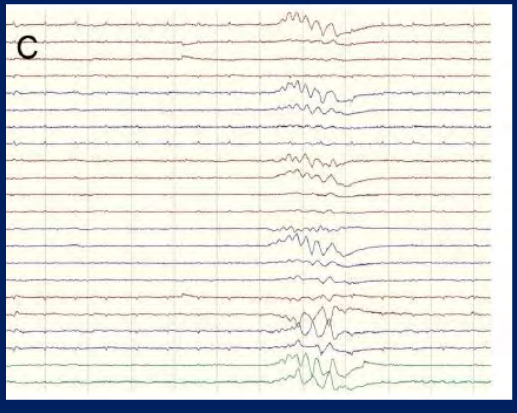
CONTINUOUS EEG



ISOELECTRIC –
”Suppressed Background



BURST SUPPRESION

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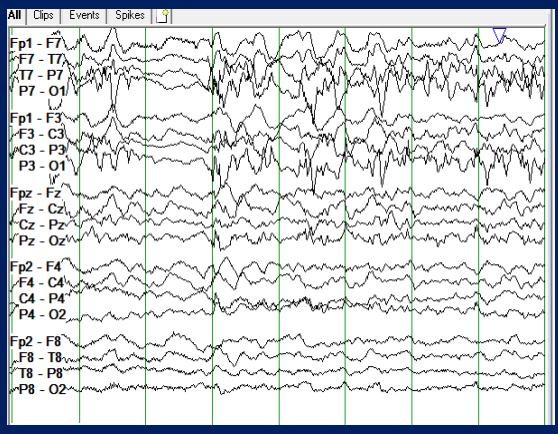
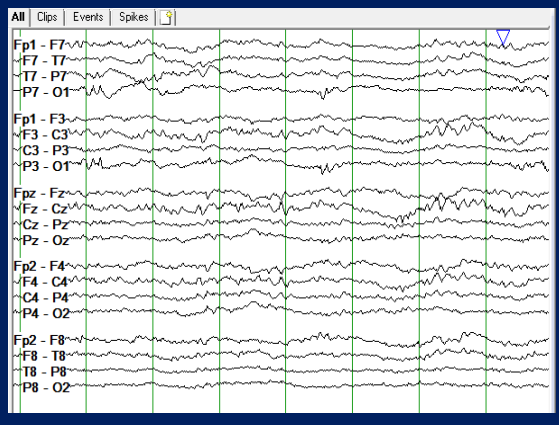
CONTINUOUS EEG



SEIZURES



SEIZURES STOPPED

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Non-convulsive Seizures (NCS) or Non-convulsive Status Epilepticus aka NCSE

- Reported to occur in 8-20% of critically ill patient populations
- Delayed diagnosis may lead to increased mortality
- 90% of recorded seizures are non-convulsive in the population for patients who have
  - Altered mental status
  - Obtunded

100

Non-convulsive Seizures (NCS) or Non-convulsive Status Epilepticus aka NCSE

- Prospective observational study/ Adult NICU
  - Pts with altered mental status
  - Data collected EEG
  - 21% of patients (36 of 170) had NCES/NCS

Fig. 2 a–d Case example 1. A 64-year-old male presented with intermittent aphasia and disorientation with a GCS of 9. **a–c** Initial EEG showed lateralized periodic discharges with a modifier fast activity (formerly called PLEDS-plus), which transitioned into ictal discharges arising from the left posterior region. **d** Brain MRI showed

Non-convulsive Status Epilepticus and Non-convulsive Seizures in Neurological ICU Patients

Ikuko Lacheo · Hasan Sonmezturk · Amar B. Bhatt · Luke Tomycz · Yaping Shi · Marianna Ringel · Gina DiCarlo · DeAngelo Harris · John Barwise · Bassel Abou-Khalil · Kevin F. Haas

neurocritical care society Neurocrit Care (2015) 22:202–211
DOI 10.1007/s12028-014-0070-0

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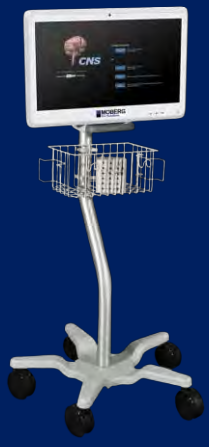
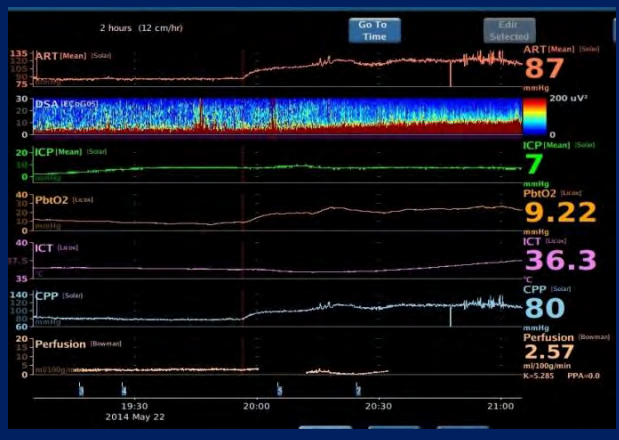
Multimodal Monitoring with the Moberg CNS Monitor





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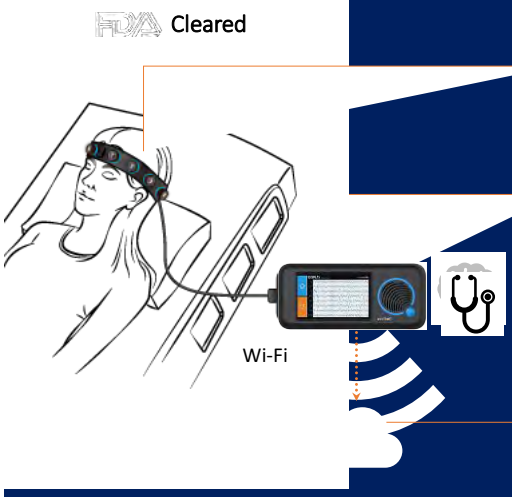
Point of Care EEG - Ceribell



1. **Ceribell EEG Headband with 10 electrodes (single-use)**
   - 6 min set up by any healthcare provider
   - No EEG technician required
2. **Ceribell EEG Recorder (Pocket size EEG recorder)**
   - Record clinical quality EEG and display on device

   Brain Stethoscope algorithm (on-device)
   - Listen to patient's brain sound
   - 96% sensitivity for EEG-untrained staff to detect seizures
3. **Ceribell EEG Portal (HIPAA compliant)**
   - Real time data streaming & remote review

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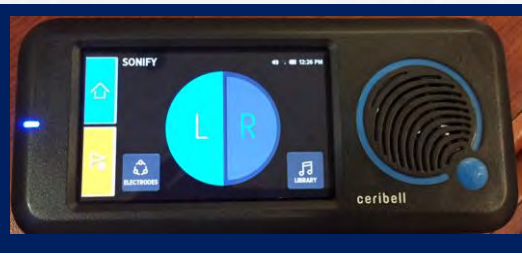
Emerging Technology: EEG with Ceribell

https://www.dropbox.com/s/82fzudq54c9j7ic/2min%20music%20only_V3.mp4?dl=0

- Ceribell EEG
  - Disposable head band with pocket size EEG recorder
  - 10 channel EEG device that records EEG and transforms EEG waves into sounds
    - White noise sounds = no seizures
    - Music/rhythmic sounds= seizures



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Portable EEG….Ceribell EEG

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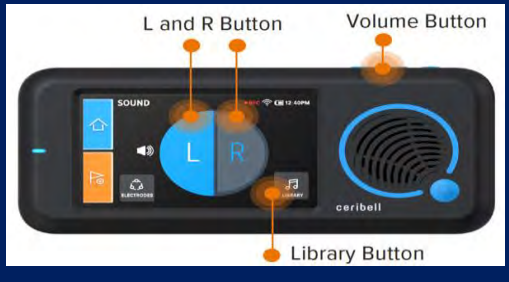
Portable EEG

- Takes 3-4 minutes to apply
- EEG can be read by Neurologist via server
- Nurse can assess for seizures using the “Seizure Sonography” button



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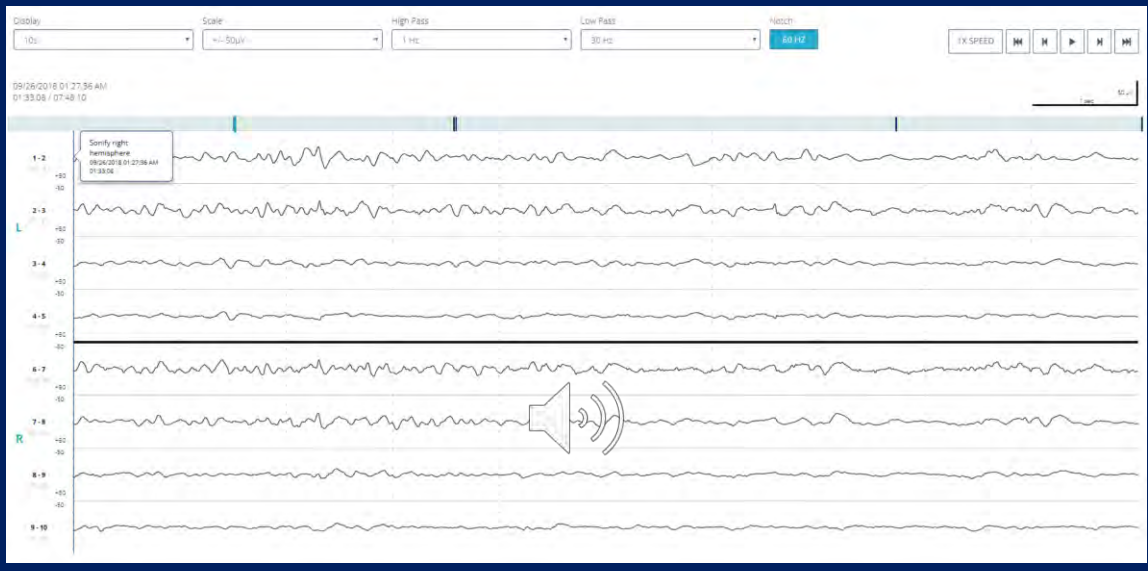
Mission – No Seizure Case



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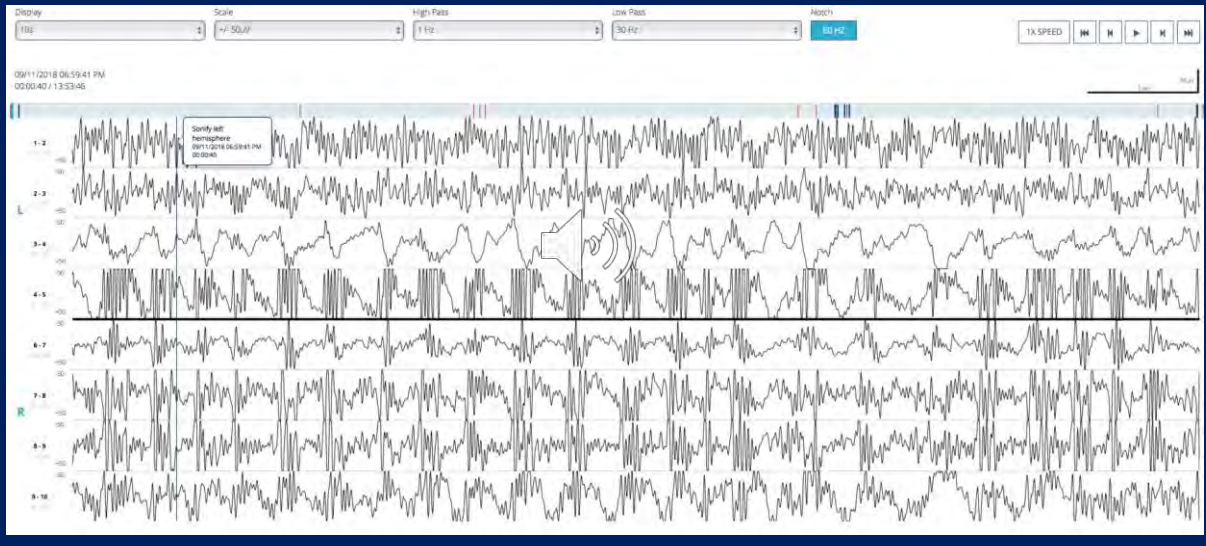
Mission – Status Case: Patient arrived in ED 0049 unresponsive. Hx of Stroke Patient intubated and Ceribell applied. Status epilepticus detected- given Ativan, Kepra & Phosphenytoin. Seizures ceased after 10 minutes



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Seizures detected overnight after subdural hematoma

SICU, during weeknight afterhours with conventional EEG available during regular hours

87 year-old female with no seizure history suffered head trauma after falling on concrete. She was diagnosed with an acute chronic subdural hematoma. She was admitted to the Surgical ICU. During the night, the patient was confused – asking repeated questions, having waxing/waning aphasia, and unaware of where she was. Head CT showed no significant interval change.

Ceribell was placed on the patient at midnight in the SICU and the recording continued for 6 hours. Brain Stethoscope was utilized several times on the left and right, which revealed abnormal EEG and suggested seizure. These findings enabled the ICU staff to request a priority review of the EEG by the neurologist, who noted several instances of seizure on the EEG portal.

IMPACT The neurologist prescribed Keppra, after which the seizures abated. The patient was transferred to the floor the next day, and subsequently discharged from the hospital.

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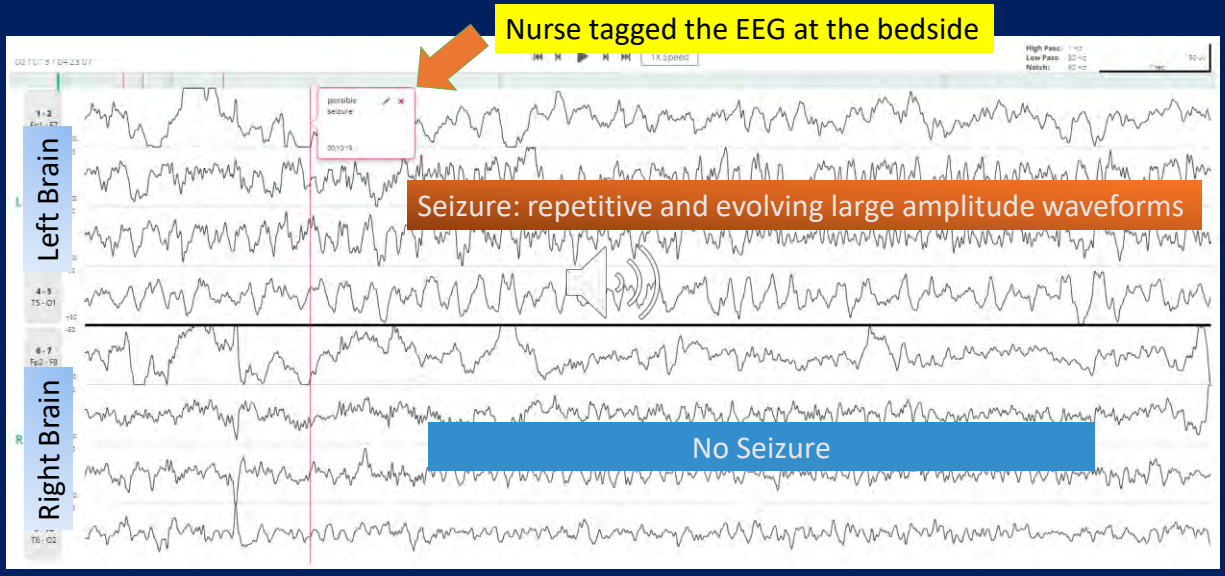
Seizure detected on portal – 10th minute of recording



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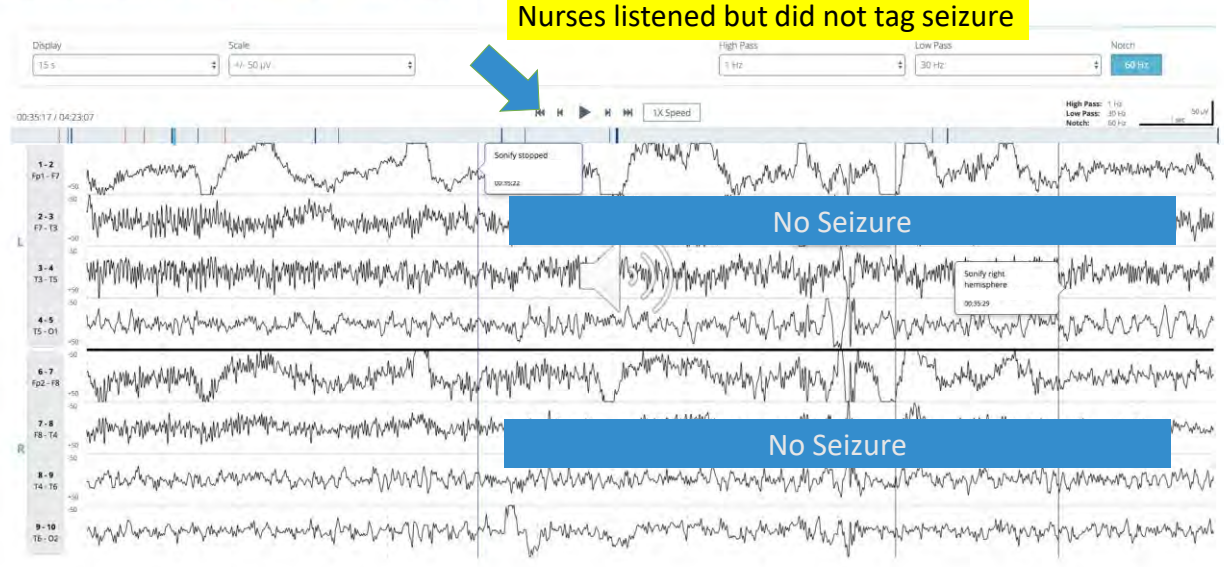
Abnormal Activity – 35th minute of recording

Nurses listened but did not tag seizure



ceribell

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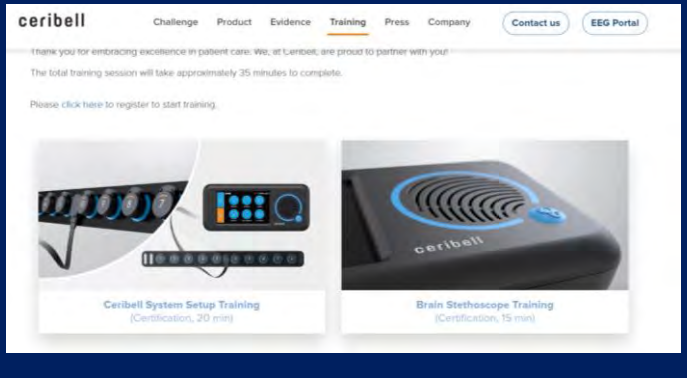
Ceribell EEG

- Go to ceribell.com
- Training
  - Brain Stethoscope Training



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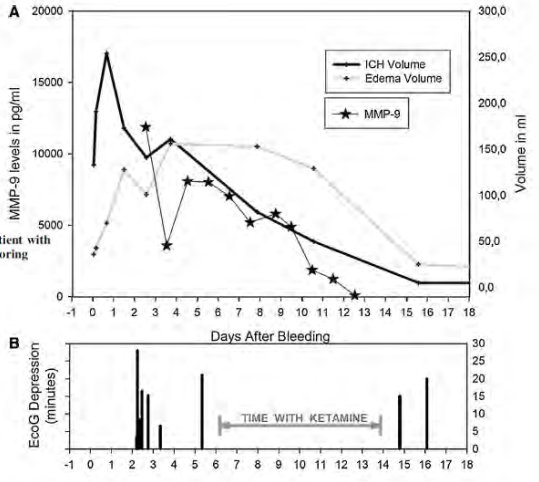
neurocritical care society Neurocrit Care (2015) 22:293–298
DOI 10.1007/s12028-014-0050-4

Spreading Depolarizations

Neurocrit Care (2015) 22:293–298 295

Fig. 2 a Radiologic parameters, matrix metalloproteinase (MMP)-9 levels, and **b** cortical spreading depolarizations (CSDs) over a period of 18 days following intracerebral hemorrhage. CSDs were observed as clusters during the onset of perihematomal edema progression



Clusters of Cortical Spreading Depolarizations in a Patient with Intracerebral Hemorrhage: A Multimodal Neuromonitoring Study

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neurocritical care society Neurocrit Care
DOI 10.1007/s12028-014-0041-5
Published online: 11 September 2014

REVIEW ARTICLE

Consensus Summary Statement of the International Multidisciplinary Consensus Conference on Multimodality Monitoring in Neurocritical Care

A statement for healthcare professionals from the Neurocritical Care Society and the European Society of Intensive Care Medicine

Monitors alone cannot save patients, but wise application of the data from monitoring the injured brain can….

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Badermk@aol.com

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