Neurologic Monitoring of the Traumatic Brain Injury Patient

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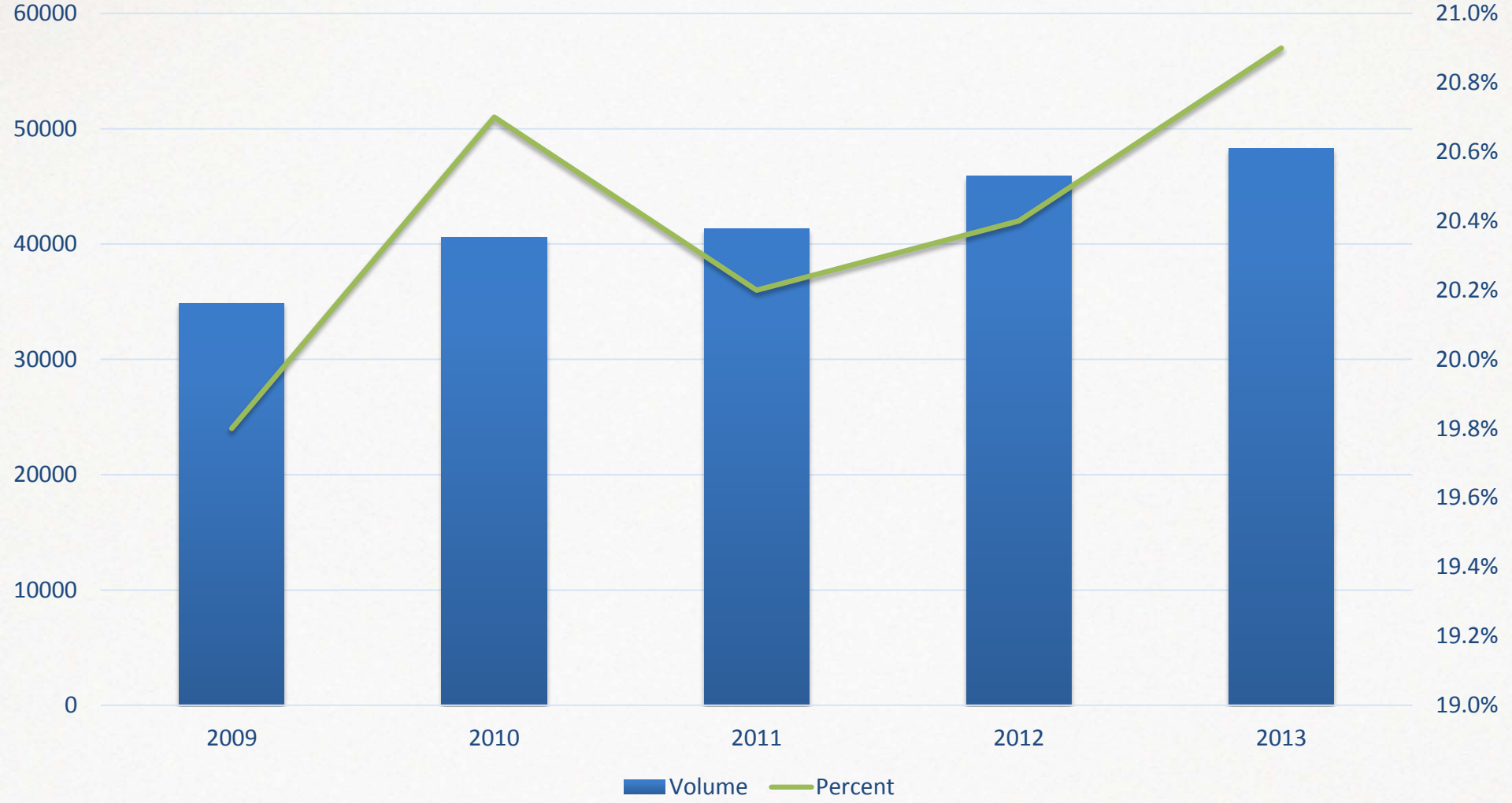
Financial Disclosures

- None to report

Objectives

- Define traumatic brain injury (TBI)
- Review key anatomy & pathophysiology
- Classify TBIs
- Identify pathology of cerebral herniation
- Identify different cerebral monitoring devices
- Relate cerebral monitoring devices to TQIP data fields

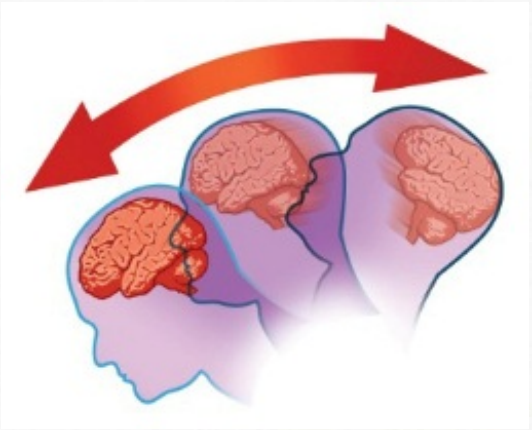
NTDB: AIS head >= 3



Traumatic Brain Injury

"Traumatic brain injury (TBI) occurs when a sudden trauma, often a blow or jolt to the head, causes damage to the brain."

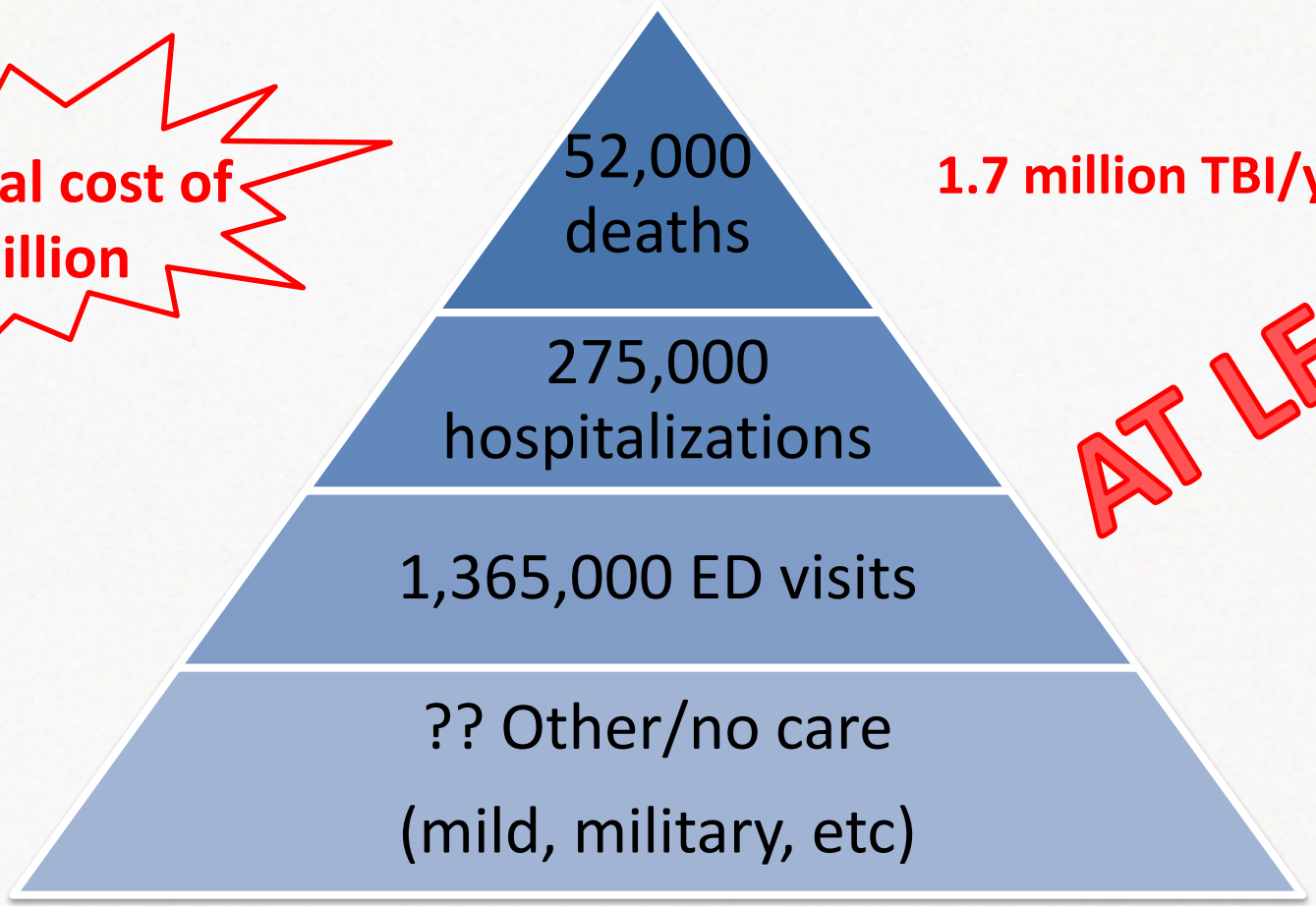
- *Brain Trauma Foundation*



https://www.braintrauma.org/tbi-faqs/

TBI Facts

Annual cost of $76 billion



1.7 million TBI/year

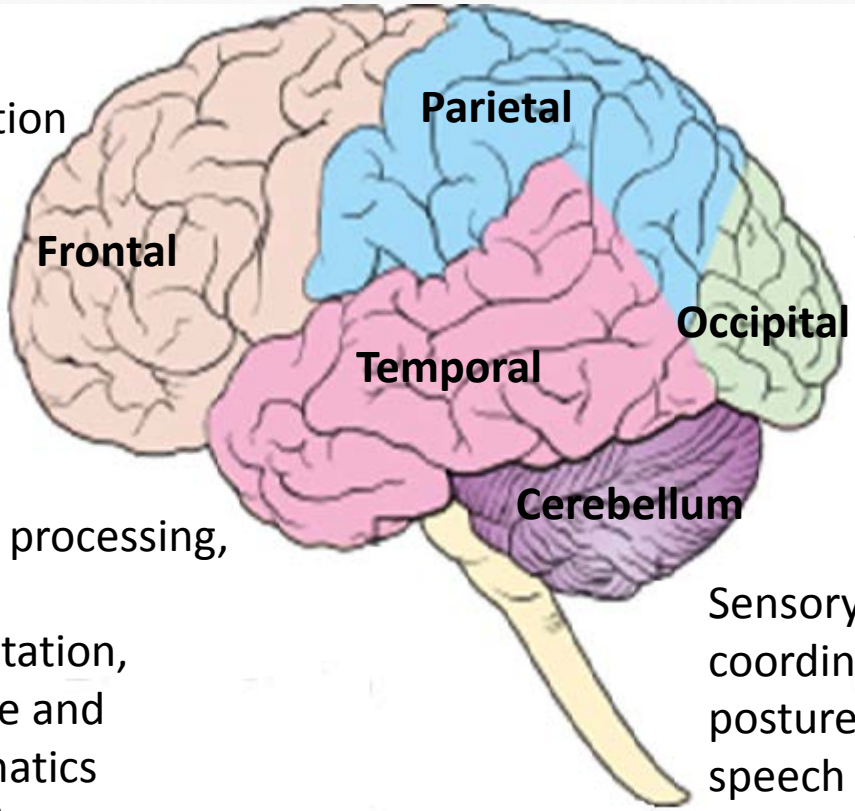
AT LEAST

CDC, 2011

NEUROANATOMY

Language mechanisms, general sensory function

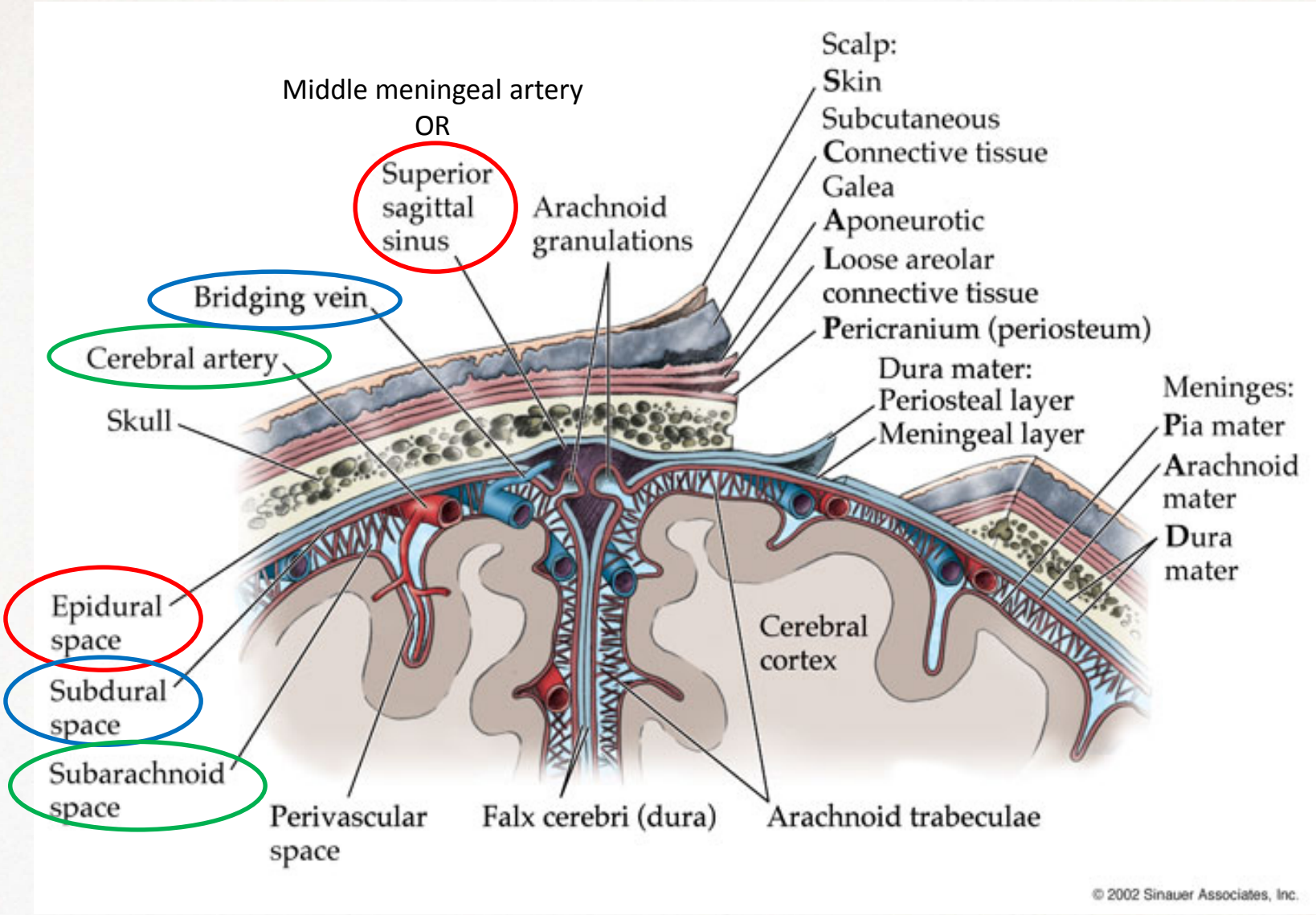
Personality, planning judgment, conceptualization



Visual processing

Sensory processing, visual interpretation, language and mathematics processing

Sensory coordination, posture, balance, speech coordination


Middle meningeal artery
OR
Superior sagittal sinus
Arachnoid granulations
Scalp:
Skin
Subcutaneous
Connective tissue
Galea
Aponeurotic
Loose areolar connective tissue
Pericranium (periosteum)
Bridging vein
Cerebral artery
Skull
Dura mater:
Periosteal layer
Meningeal layer
Meninges:
Pia mater
Arachnoid mater
Dura mater
Epidural space
Subdural space
Subarachnoid space
Cerebral cortex
Perivascular space
Falx cerebri (dura)
Arachnoid trabeculae
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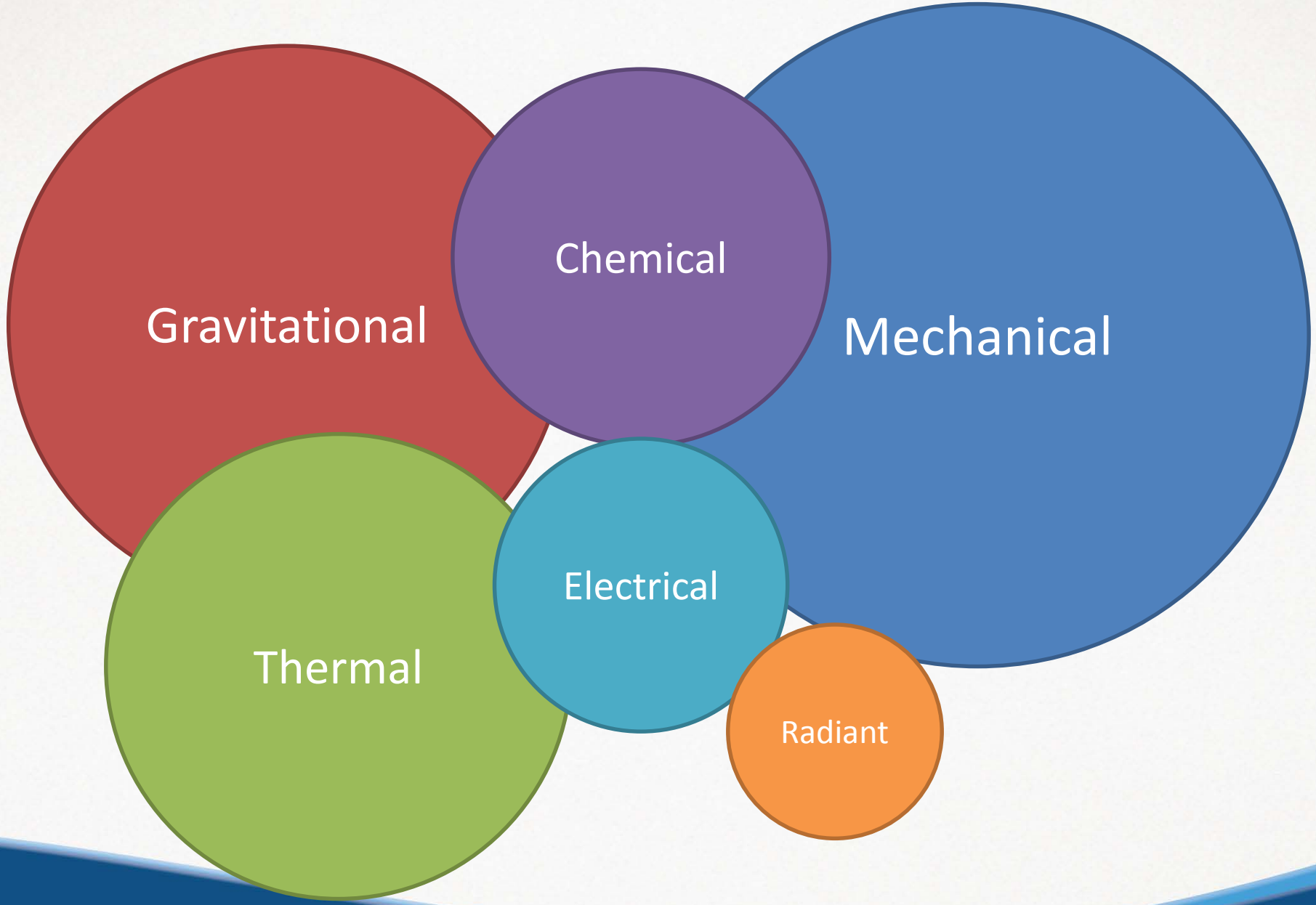
PATHOLOGY

Trauma As A Disease

- Host
  - Patient
- Vector
  - Mechanism
- Pathogen
  - Energy


Gravitational
Chemical
Mechanical
Thermal
Electrical
Radiant

Kinetic Energy

- Energy cannot be created or destroyed, only changed
- So, where did the energy (force) go?

$$KE = \frac{1}{2} \text{ mass}(\text{velocity}^2)$$

OR

$$\text{Force} = \frac{1}{2} \text{ weight}(\text{speed}^2)$$

Mechanical Energy Transfer

50 mph

70 mph

50 mph^2=
2,500 units KE

70 mph^2=
4,900 units KE

AT LEAST!

A 40% increase in speed produces an almost 100% increase in force.

CLASSIFICATION

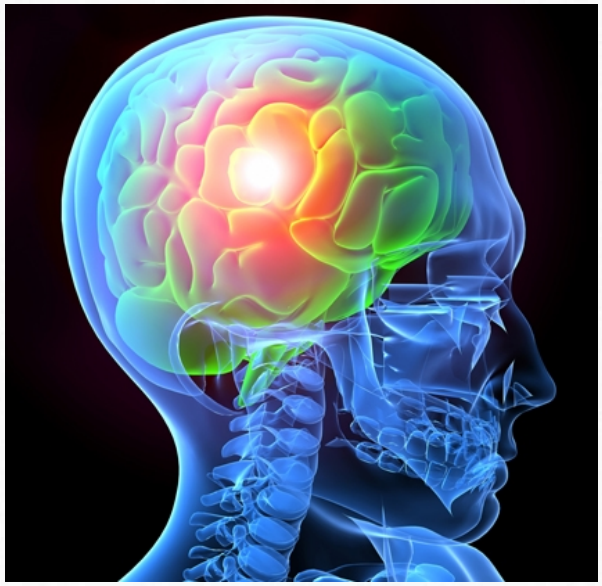
Mechanism

- Blunt
  - High or low velocity
  - Acceleration-deceleration
  - Rotation
- Penetrating
  - High velocity (gun)
  - Low velocity (knife)

McQuillan, K. A., Makic, M. B. F., & Whalen, E. (2009). *Trauma nursing : from resuscitation through rehabilitation*. St. Louis, Mo.: Saunders/Elsevier.

Severity

- Mild
  - GCS ≤ 14
    - Mild Concussion
- Moderate
  - GCS 9-13
- Severe
  - GCS ≤ 8
    - Coma



American College of Surgeons. (2008). *Advanced trauma life support for doctors, ATLS : student course manual*. Chicago, Ill: American College of Surgeons.

Primary Brain Injuries

- Contusion
  - "Bruising" that occurs as a result of mechanical force to the head
- Diffuse axonal injury (DAI)
  - Mild to severe injuries which occur when the white matter has been torn or sheared.
    - Evolves over time
    - Initial CT head may not demonstrate DAI

Baird, M. S., Keen, J. H., & Swearingen, P. L. (2005). *Manual of critical care nursing : nursing interventions and collaborative management*. St. Louis, Mo.: Elsevier Mosby.

Primary Brain Injuries

- Concussion
  - Neuroexcitatory injury, sometimes associated with DAI
    - Mild (no LOC, some confusion)
    - Moderate (brief LOC, transient focal deficits)
    - Severe (prolonged LOC or focal deficits)

Baird, M. S., Keen, J. H., & Swearingen, P. L. (2005). *Manual of critical care nursing : nursing interventions and collaborative management*. St. Louis, Mo.: Elsevier Mosby.

"Bleeds"

- Epidural hematoma
  - Common cause: linear temporal bone fracture → middle meningeal artery laceration
  - Develops rapidly
- Subdural hematoma
  - Bleeding from veins between the dura and arachnoid space
  - Acute, subacute, or chronic

Baird, M. S., Keen, J. H., & Swearingen, P. L. (2005). *Manual of critical care nursing : nursing interventions and collaborative management*. St. Louis, Mo.: Elsevier Mosby.

“Bleeds”

- Subarachnoid hemorrhage
  - Bleeding in the subarachnoid space seen over the convexities or in the basal cisterns
- Intracranial hematoma
  - Blood collection from damage to the small arteries and veins within the subcortical white matter

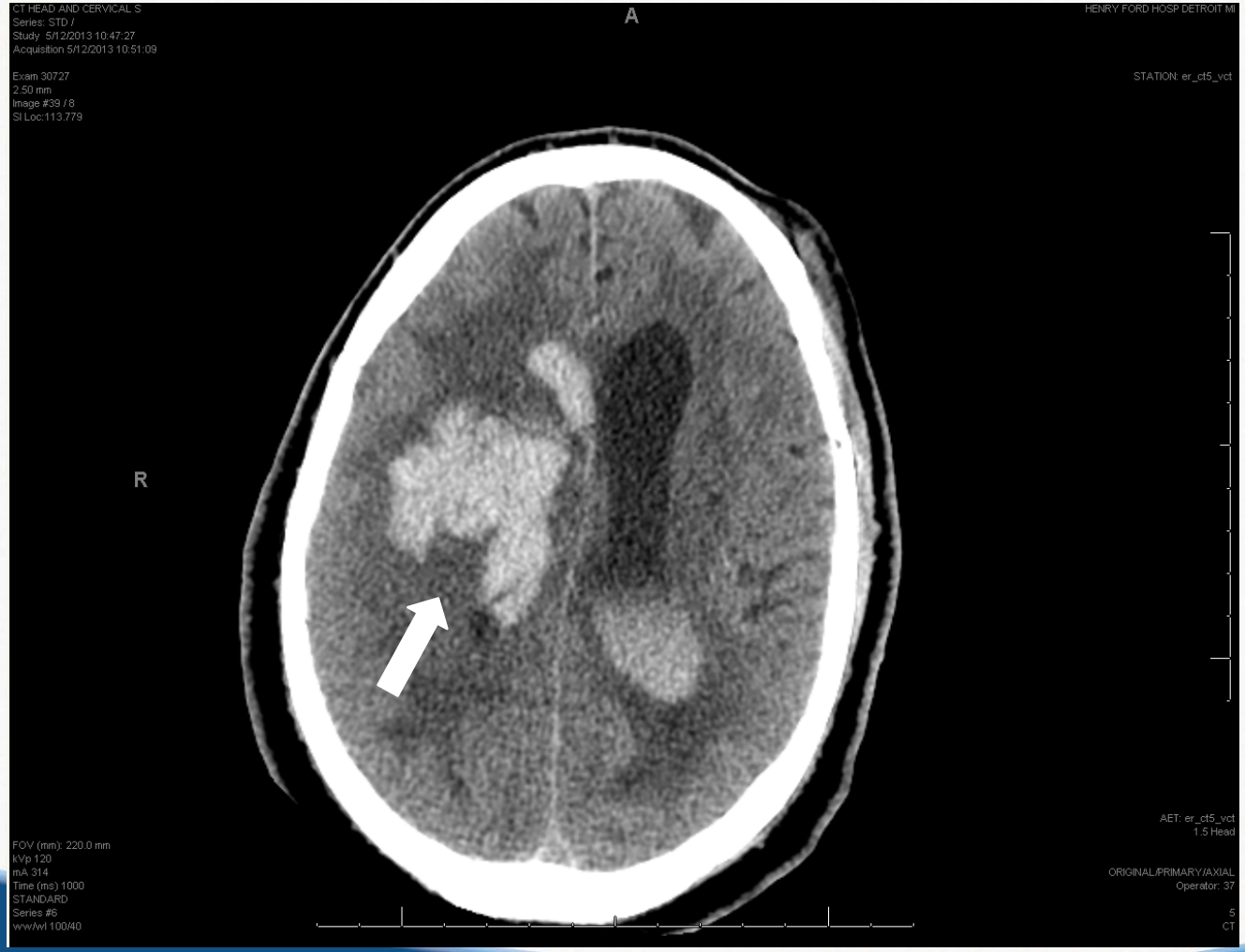
Baird, M. S., Keen, J. H., & Swearingen, P. L. (2005). *Manual of critical care nursing : nursing interventions and collaborative management*. St. Louis, Mo.: Elsevier Mosby.

Epidural Hematoma

Subdural Hematoma

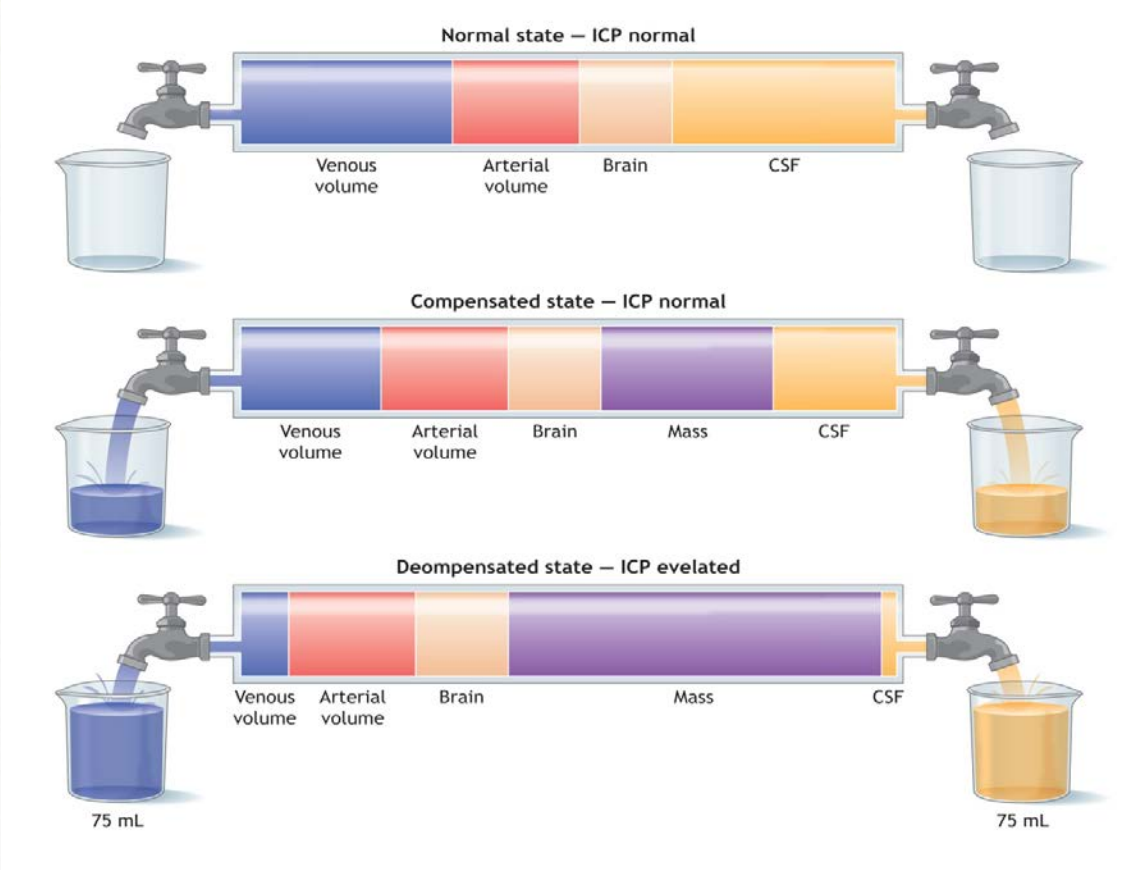
Subarachnoid Hemorrhage

Intracranial Hemorrhage



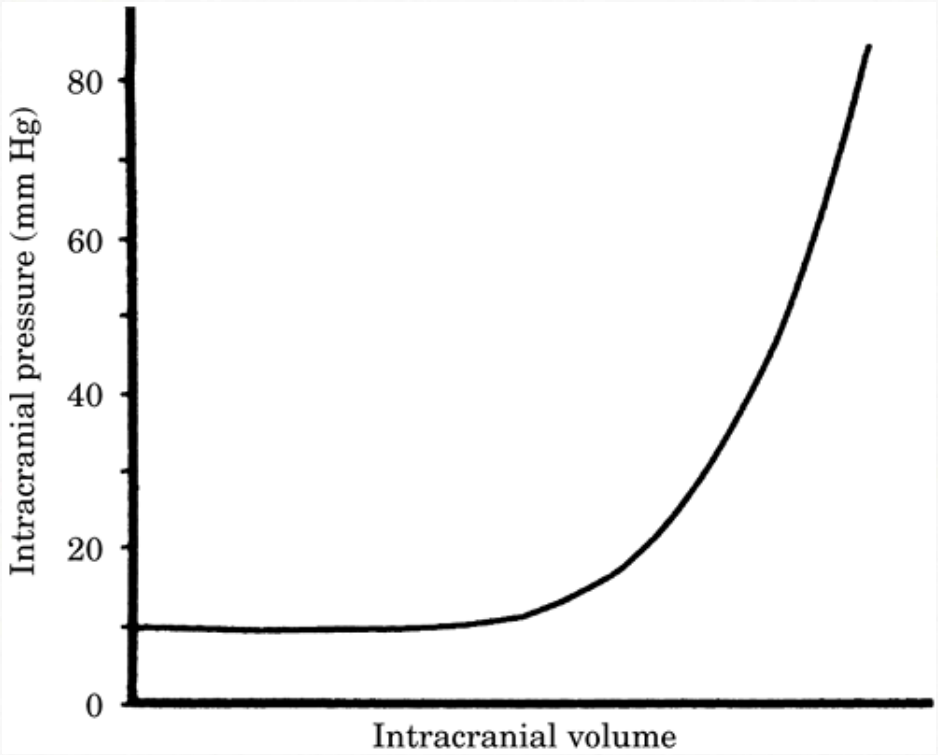
IMPLICATIONS

Monro-Kellie Doctrine



American College of Surgeons. (2008). *Advanced trauma life support for doctors, ATLS : student course manual*. Chicago, Ill: American College of Surgeons.

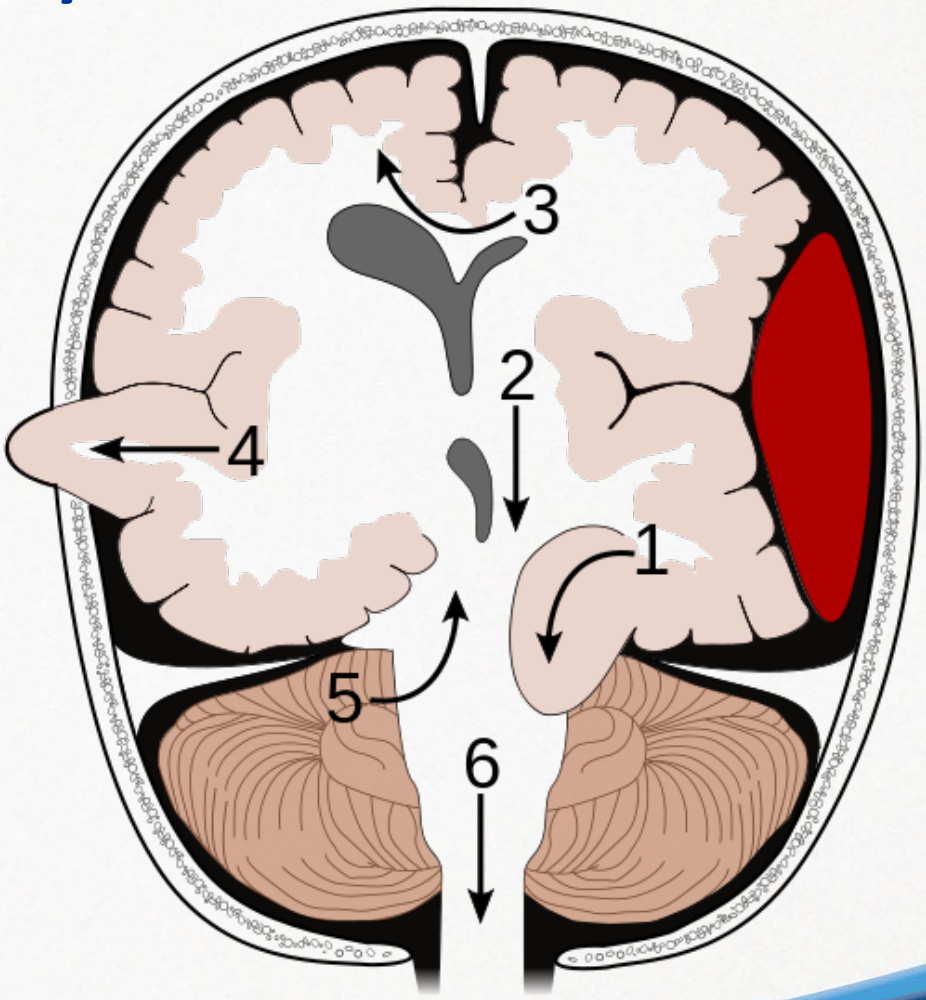
Herniation Syndromes



http://www.neuroicu.info/intracranialcomponentvolume.htm

Herniating Syndromes

1. Uncal
2. Central
3. Cingulate (subfalcine)
4. Transcalvarial
5. Upward transtentorial
6. Tonsillar

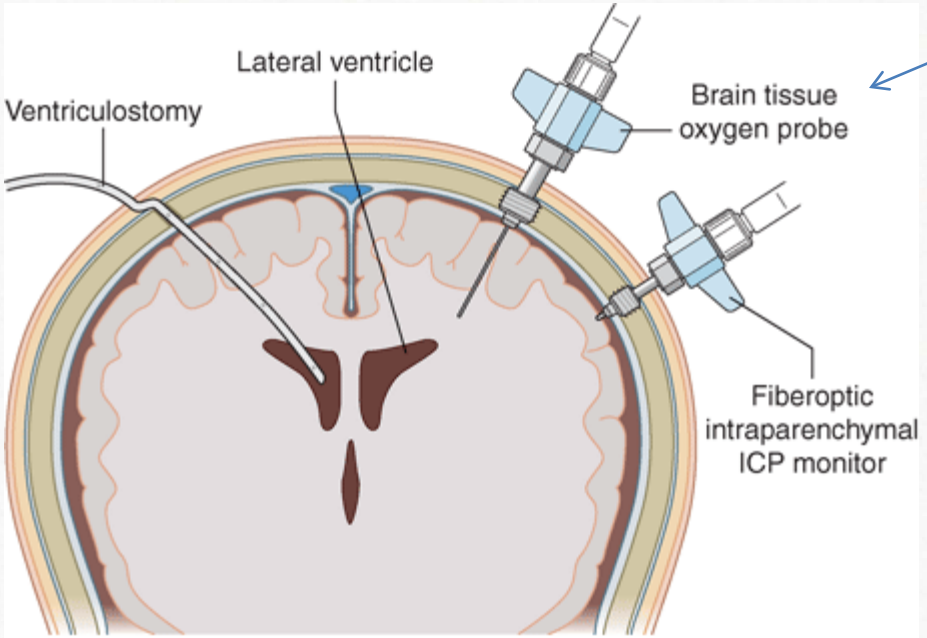


http://en.wikipedia.org/wiki/Brain_herniation

MONITORING DEVICES

Intracranial Devices

EVD



Licox

Bolt/Camino

Source: Longo DL, Fauci AS, Kasper DL, Hauser SL, Jameson JL, Loscalzo J: *Harrison's Principles of Internal Medicine, 18th Edition*: www.accessmedicine.com

Intraventricular Drain/Catheter

- Also called a ventriculostomy, ventric, or extraventricular drain (EVD)
- Used to *intermittently* monitor ICP and drain CSF

Intraventricular Drain/Catheter

- Typically placed in the lateral ventricles in patients who have, or are at risk for, hydrocephalus
- Diagnostic and therapeutic

Intraparenchymal Pressure Monitor

- Also called a bolt or Camino
- Used to continuously monitor ICP
- Typically placed in the intraparenchymal space of patients that have sustained a TBI
- Diagnostic, *not* therapeutic

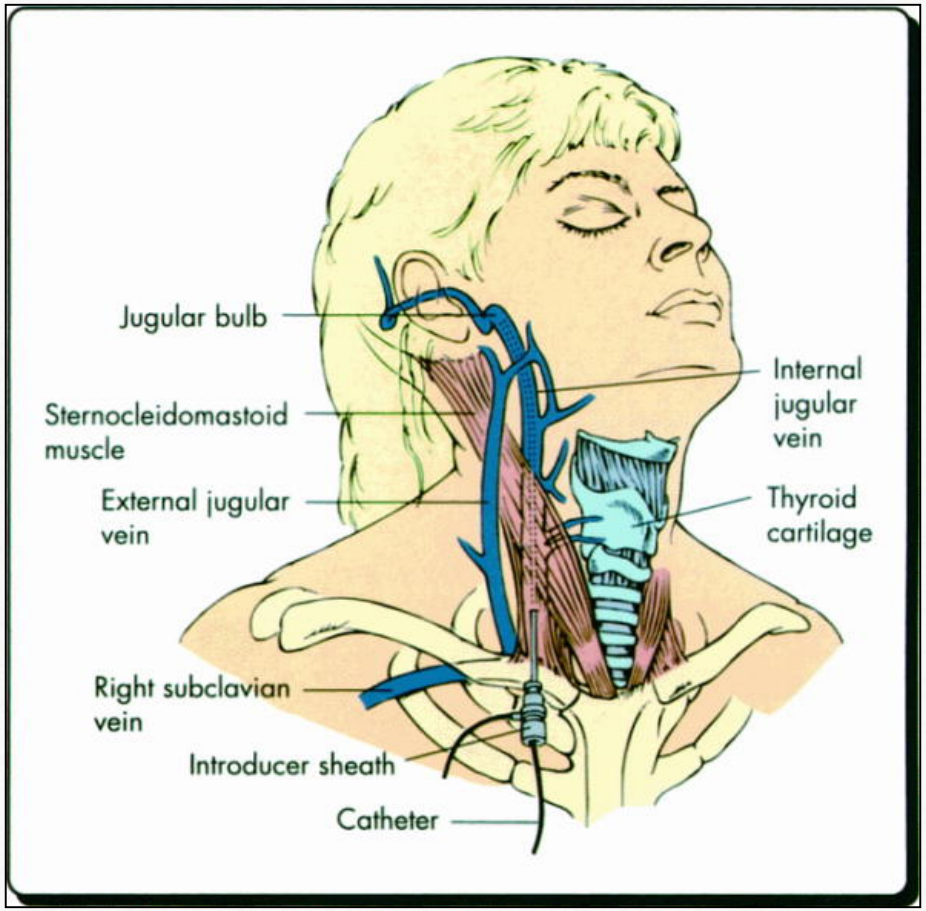
Intraparenchymal Oxygen Monitor

- Also called a Licox
- Uses one entry into cranium for pressure, oxygenation, and temperature monitors

Intraparenchymal Oxygen Monitor

- Oxygenation is reported as $PbtO_2$
  - Partial pressure of oxygen at the tissue site
- Use as a surrogate for global cerebral oxygenation
- Oximetry is limited to catheter site
- Diagnostic, *not* therapeutic

Extracranial Device



Schell RM, Cole DJ. Cerebral Monitoring: Jugular Venous Oximetry: *Anesthesia & Analgesia*. 2000;90(3):559-566. doi:10.1097/00000539-200003000-00012.

Jugular Venous Bulb Oximetry

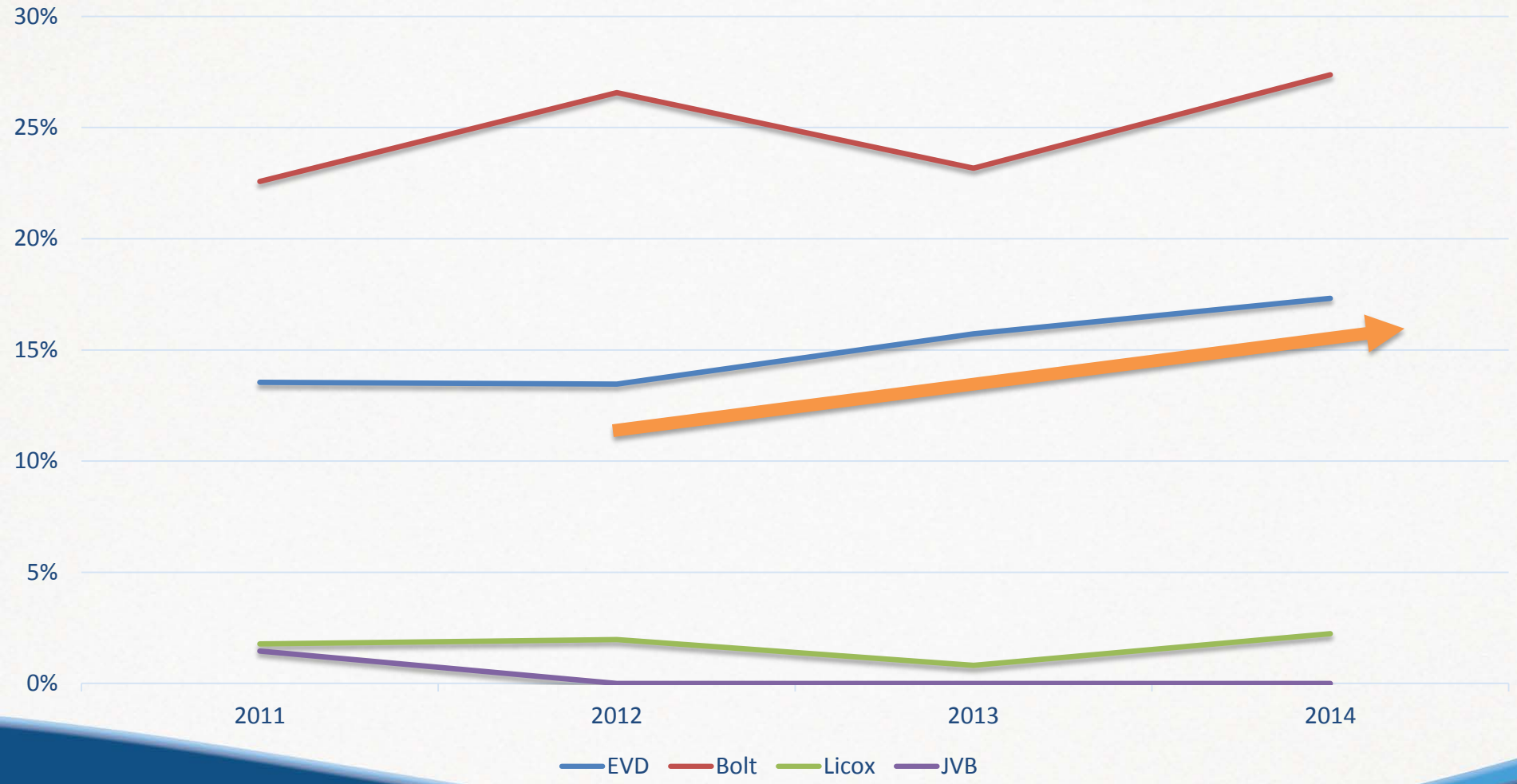
- Catheter placed in the internal jugular vein, directed upwards, terminating in the jugular venous bulb
- Blood samples checked for mixed venous oxygen saturation (SjO_2)
- Diagnostic, *not* therapeutic

RARE

Jugular Venous Bulb Catheter

- Normal range: 50-75%
- Abnormally low (< 50%), without ↓ in SaO_2
  - Imbalance between consumption/delivery
- Abnormally high (> 85%)
  - Increased cerebral blood flow or shunting

Neurologic Monitoring Device Use
All MTQIP Reporting Centers
n=1973



Henry Ford Health System

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HIGHEST GCS TOTAL

Collection Criterion: Collect on patients with at least one injury in AIS head region

Definition

Highest total GCS within 24 hours of ED/Hospital arrival.

Field Values

- Relevant value for data element

Additional Information

- Refers to highest total GCS within 24 hours after ED Hospital/Arrival to index hospital, where index hospital is the hospital abstracting the data.
- Requires review of all data sources to obtain the highest GCS total. In many cases, the highest GCS may occur after ED discharge.
- If patient is intubated then the GCS Verbal score is equal to 1.
- Best obtained when sedatives or paralytics are withheld as part of sedation holiday.
- If a patient does not have a numeric GCS recorded, but there is documentation related to their level of consciousness such as "AAOx3," "awake alert and oriented," or "patient with normal mental status," interpret this as GCS of 15 IF there is no other contradicting documentation.
- The null value "Not Applicable" is used for patients that do not meet collection criteria.

Data Source Hierarchy

1. Neuro Assessment Flow Sheet
2. Triage/Trauma/ICU Flow Sheet
3. Nursing Notes/Flow Sheet
4. Progress Notes

PM_02

HIGHEST GCS MOTOR

Collection Criterion: Collect on patients with at least one injury in AIS head region

Definition

Highest motor GCS within 24 hours of ED/Hospital arrival.

Field Values

Pediatric (≤ 2 years):

1. No motor response
2. Extension to pain
3. Flexion to pain
4. Withdrawal from pain
5. Localizing pain
6. Appropriate response to stimulation

Adult

1. No motor response
2. Extension to pain
3. Flexion to pain
4. Withdrawal from pain
5. Localizing pain
6. Obeys commands

Additional Information

- Refers to highest GCS motor score within 24 hours after arrival to index hospital, where index hospital is the hospital abstracting the data.
- The null value "Not Applicable" is used for patients that do not meet the collection criterion.
- Requires review of all data sources to obtain the highest GCS motor score. In many cases, the highest GCS motor score might occur after ED discharge.
- Best obtained when sedatives or paralytics are withheld as part of sedation holiday.
- If a patient does not have a numeric GCS score recorded, but written documentation closely (or directly) relates to verbiage describing a specific level of functioning within the GCS scale, the appropriate numeric score may be listed. E.g. the chart indicates: "patient withdraws from a painful stimulus," a Motor GCS of 4 may be recorded, IF there is no other contradicting documentation.

PM_03

GCS ASSESSMENT QUALIFIER COMPONENT OF HIGHEST GCS TOTAL

Collection Criterion: Collect on patients with at least one injury in AIS head region

Definition

Documentation of factors potentially affecting the highest GCS within 24 hours of ED/hospital arrival.

Field Values

1. Patient chemically sedated or paralyzed
2. Obstruction to the patient's eye
3. Patient intubated
4. Valid GCS: patient was not sedated, not intubated, and did not have obstruction to the eye

Additional Information

- Refers to highest GCS assessment qualifier score after arrival to index hospital, where index hospital is the hospital abstracting the data.
- The null value "Not Applicable" is used for patients that do not meet the collection criterion.
- Requires review of all data sources to obtain the highest GCS motor score which might occur after the ED phase of care.
- Identifies medical treatments given to the patient that may affect the best assessment of GCS. This field does not apply to self-medication the patient may have administered (i.e. ETOH, prescriptions, etc.).
- Must be the assessment qualifier for the Highest GCS Total.
- If an intubated patient has recently received an agent that results in neuromuscular blockade such that a motor or eye response is not possible, then the patient should be considered to have an exam that is not reflective of their neurologic status and the chemical sedation modifier should be selected.
- Neuromuscular blockade is typically induced following the administration of agent like succinylcholine, mivacurium, rocuronium, (cis)atracurium, vecuronium, or pancuronium. While these are the most common agents, please review what might be typically used in your center so it can be identified in the medical record.
- Each of these agents has a slightly different duration of action, so their effect on the GCS depends on when they were given. For example, succinylcholine's effects last for only 5-10minutes.
- Check all that apply.

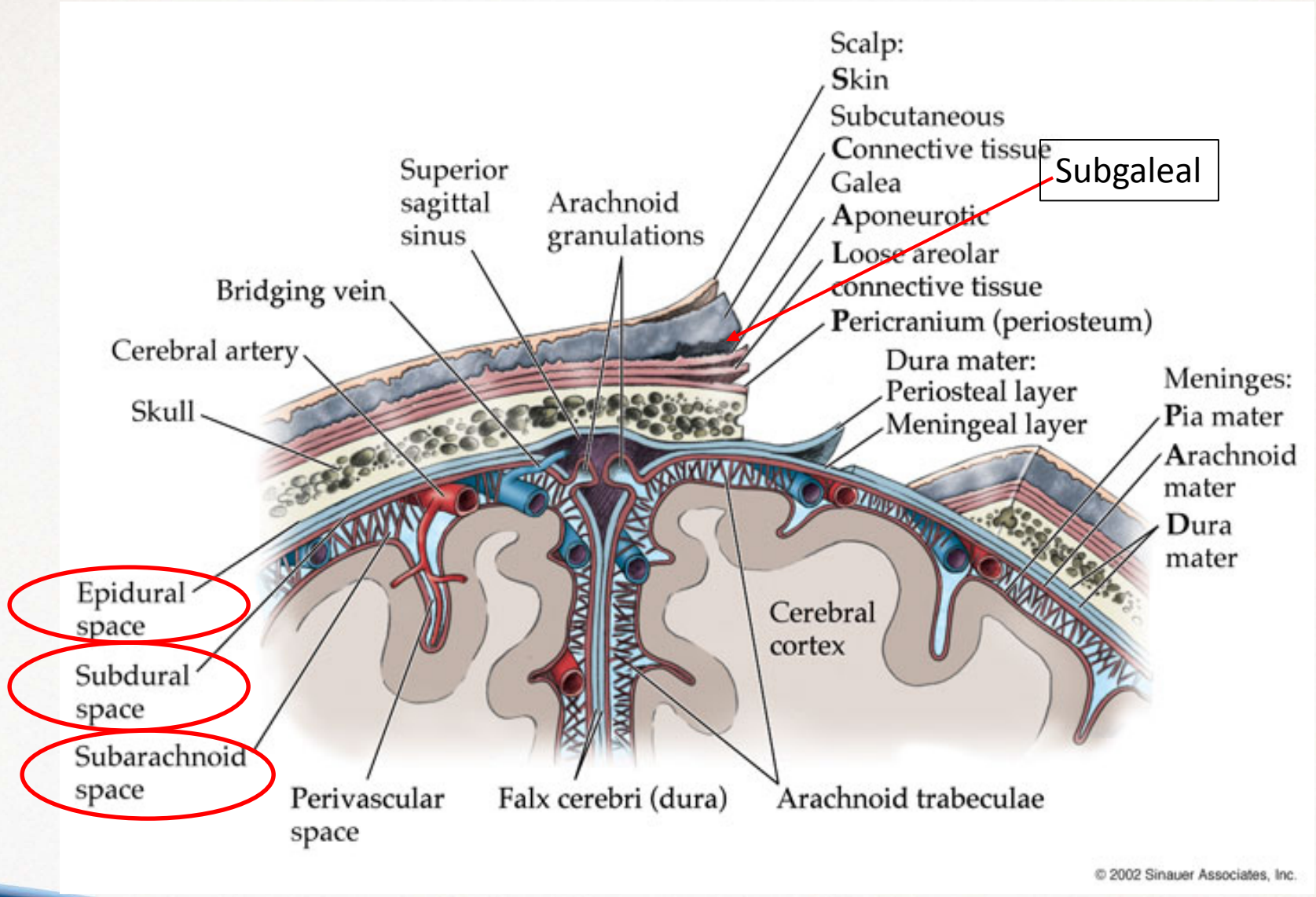
Neuromuscular Blocking Agents

AGENT	ONSET (seconds)	DURATION (minutes)
Cisatracurium (Nimbex)	90	60-80
Vecuronium (Norcuron)	60	30-40
Rocuronium (Zemuron)	75	45-70
Pancuronium (Pavulon)	90	180+
Succinylcholine (Anectine or Sux)	30	3-10

http://www.clinicalpharmacology-ip.com/

Other Drains

- Used as surgical drains, not for monitoring
- May use the same device as an extraventricular drain
- When in doubt, check the OR report


Scalp:
Skin
Subcutaneous
Connective tissue
Galea
Aponeurotic
Loose areolar
connective tissue
Pericranium (periosteum)
Subgaleal
Superior
sagittal
sinus
Arachnoid
granulations
Bridging vein
Cerebral artery
Skull
Dura mater:
Periosteal layer
Meningeal layer
Meninges:
Pia mater
Arachnoid
mater
Dura
mater
Epidural
space
Subdural
space
Subarachnoid
space
Cerebral
cortex
Perivascular
space
Falx cerebri (dura)
Arachnoid trabeculae
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Guidelines

ACS TQIP
BEST PRACTICES IN THE MANAGEMENT OF TRAUMATIC BRAIN INJURY

Guidelines for the Management of Severe Traumatic Brain Injury
3rd Edition
Brain Trauma Foundation
Improving the Outcome of Brain Trauma Patients Worldwide

Institutional

Evaluation and management of mild traumatic brain injury: An Eastern Association for the Surgery of Trauma practice management guideline

Thank You

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