2019 MID-ATLANTIC
CONFERENCE

9th ANNUAL CURRENT CONCEPTS IN

VASCULAR THERAPIES

2019

Hilton Virginia Beach Oceanfront
Virginia Beach, Virginia

MAY 2-4

CRITICAL CARE MANAGEMENT OF THE STROKE PATIENT

-Shola Aluko, Neurocritical and Critical Stroke Care, SNGH.

May 4, 2019.

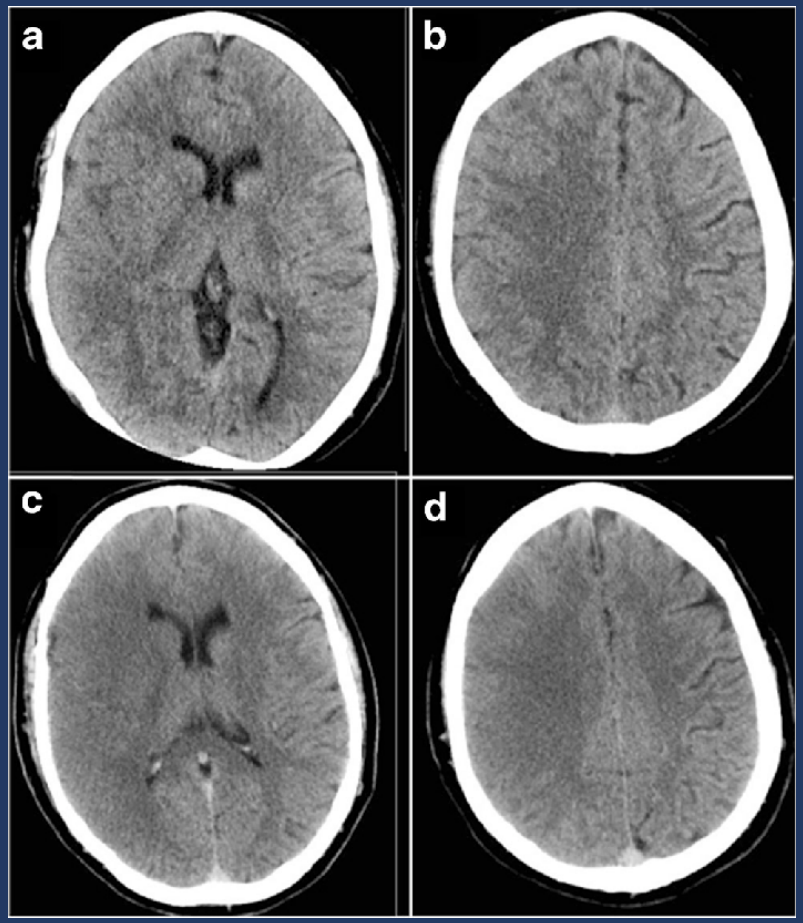
Learning

- What is stroke?
- Identify the subset of stroke patients that require critical care.
- Basic theories of cerebral perfusion.
- What is primary cerebral injury.
- What is secondary injury.
- Principles of management.
- Prevention and treatment of complications.
- Prognostication after stroke.

Stroke

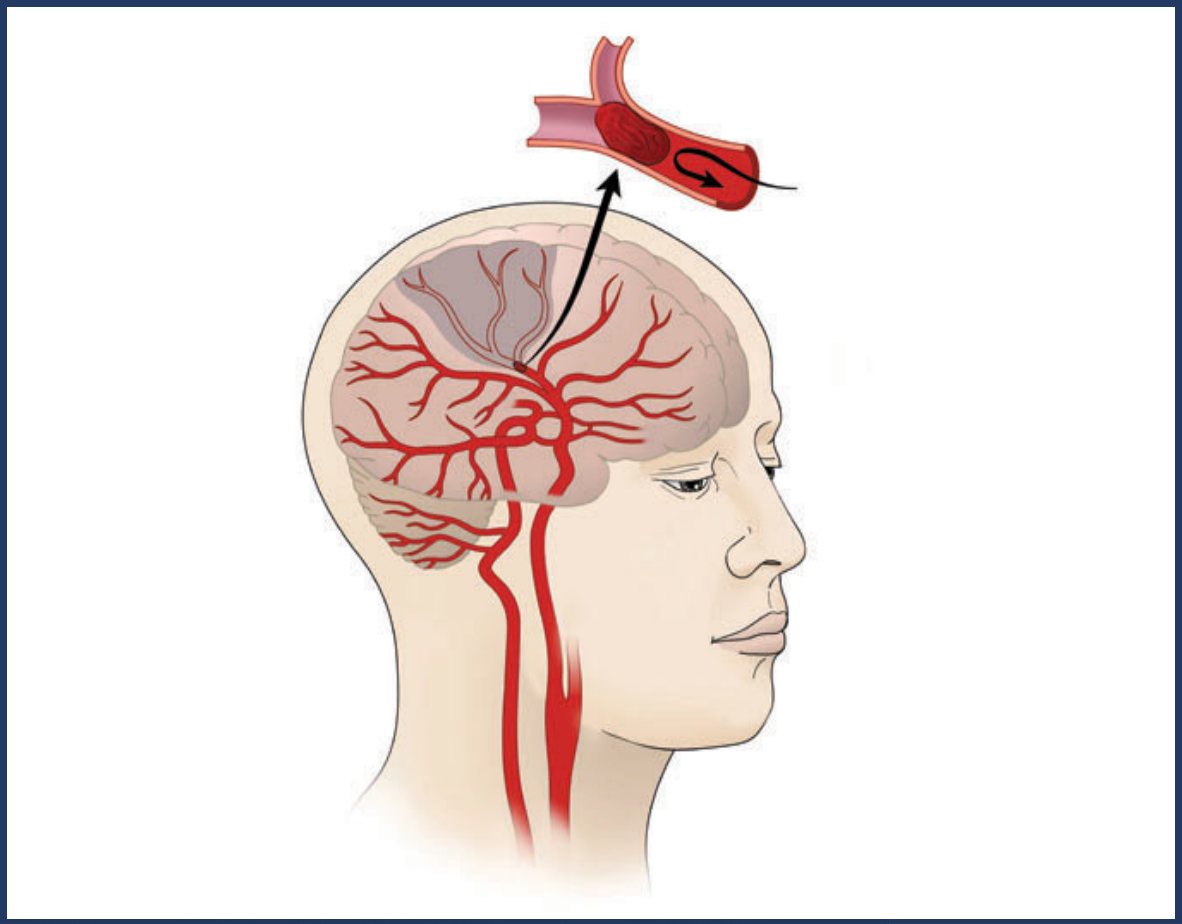
- Acute neurological dysfunction>24hours.
- Acute neurological dysfunction with radiological evidence of infarction or hemorrhage.
- Subarachnoid Hemorrhage (SAH)
- Cerebral arterial air embolism
- CRAO
- Pure intraventricular hemorrhage (IVH)
- *Stroke 2013 July;44(7)2004.*

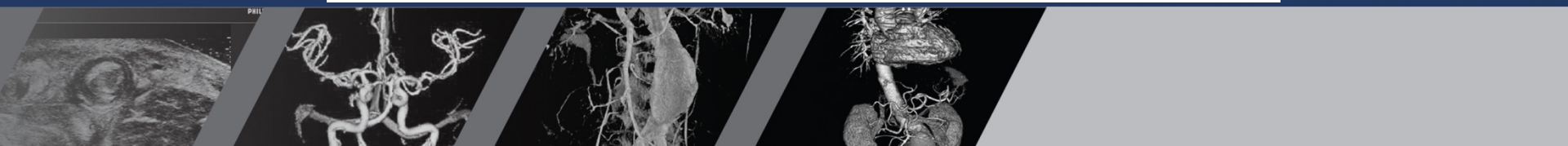
Large right MCA stroke



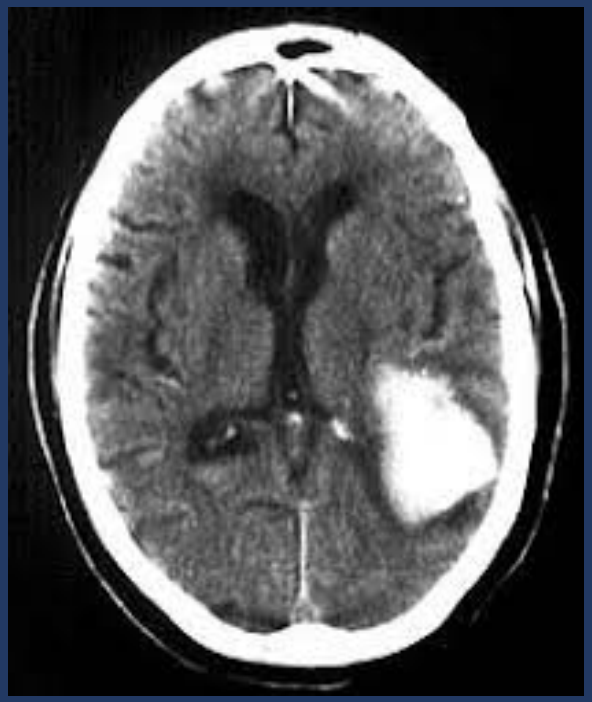
Schematic: arterial occlusion

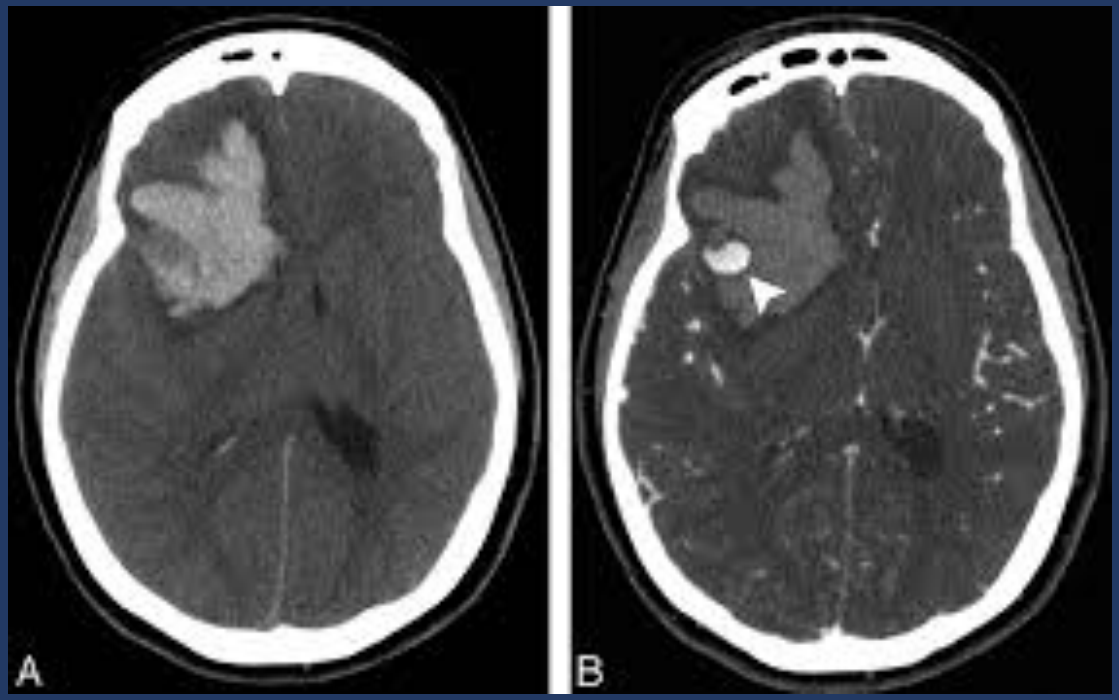
ninds.nih.gov



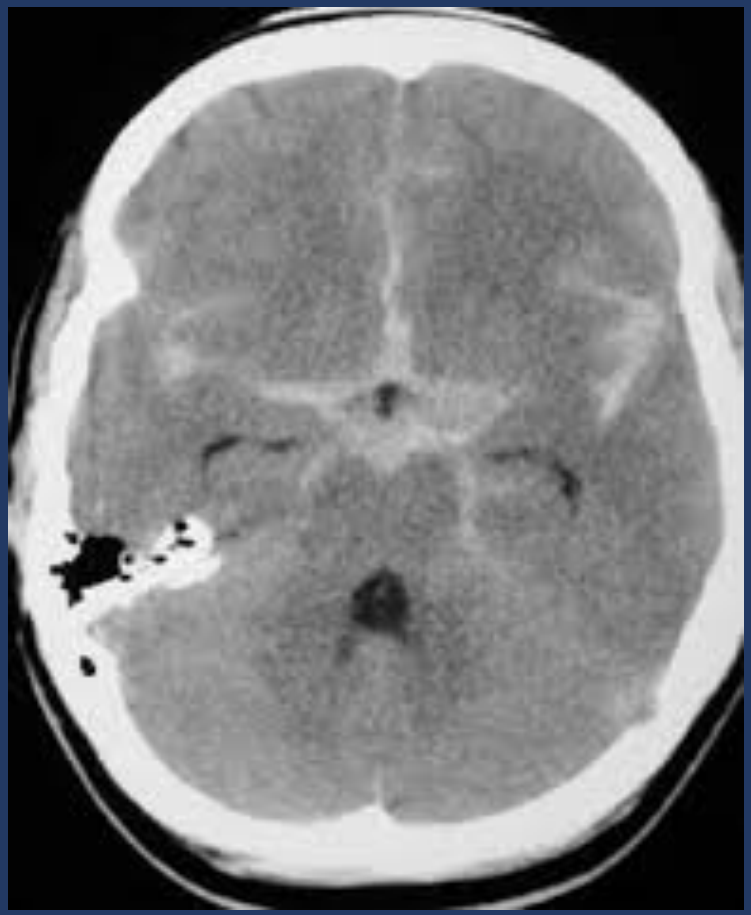


Intraparenchymal hemorrhage



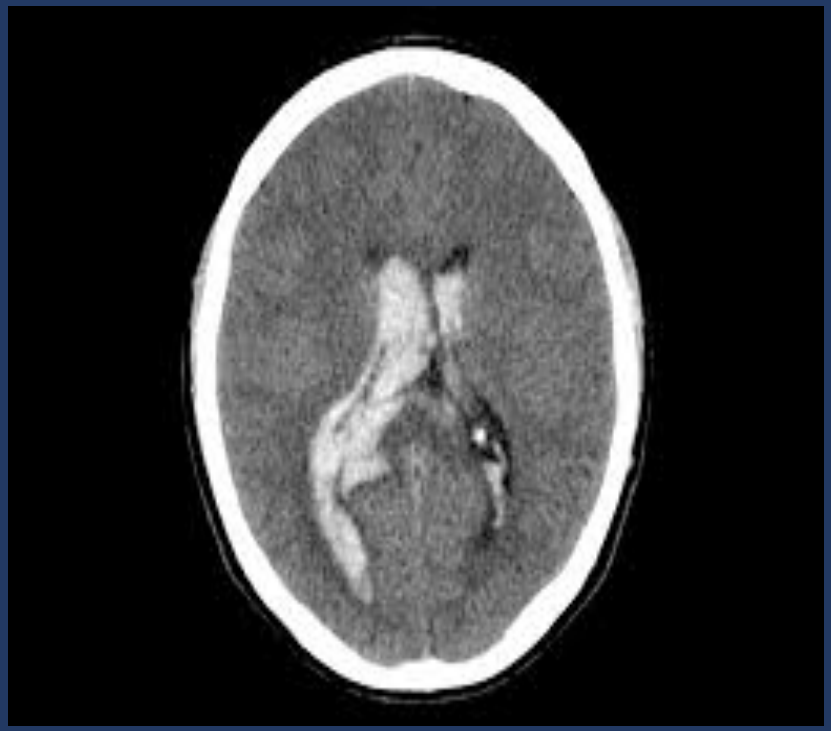


Acute SAH

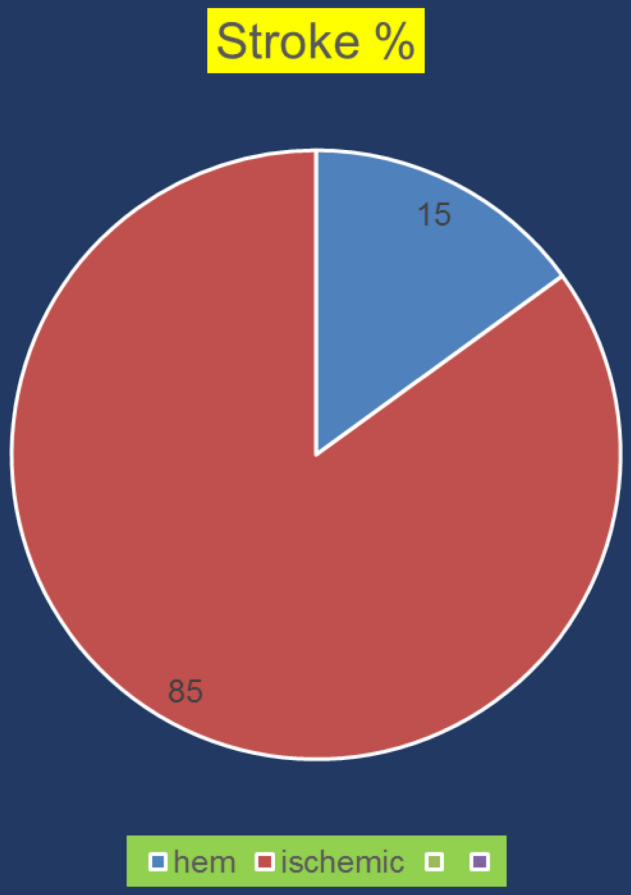


Pure IVH

medscape



Epidemiology



EPID.

- 217-281 per 100,000 person years globally.
- US incidence new or recurrent stroke 800,000/yr
- Of these, 610,000 are first strokes.

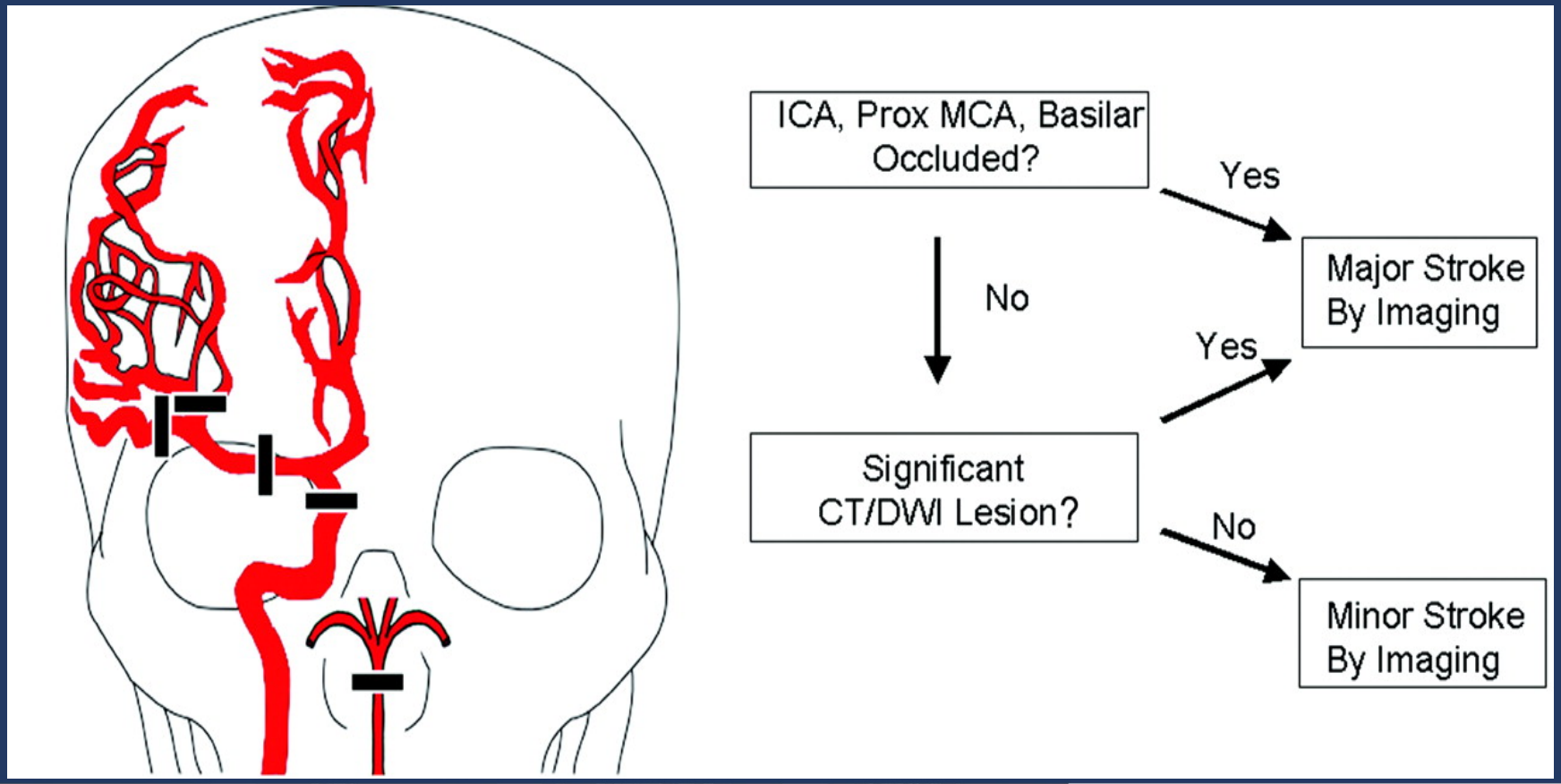
Indications for ICU admission

- Intracerebral hemorrhage >30mls vol.
- All intracerebral hemorrhage on anticoag.
- All post TPA acute ischemic stroke.
- All post thrombectomy acute ischemic stroke.
- Acute isch. stroke with vol >30% of the hemisphere.
- All vertebrobasilar insufficiency with post circ stroke.
- All SAH.

ICU admission…

- All IVH
- All stroke patients with GCS <9
- All stroke patients on mechanical ventilation.
- All flow-dependent perfusion insufficiency, with or without infarction.

Large vessel occlusion



Cerebral Perfusion

- Mean arterial pressure(MAP)
- Intracranial pressure ICP (<20)
- Cerebral perfusion pressure CPP (55-75mmhg)
- Cerebral blood flow CBF (25-100ml/100g)
- Cerebral vascular resistance(CVR)

- CPP=MAP-ICP
- CBF=CPP/CVR

Primary Cerebral Injury

- Infarction caused by occlusion or prolonged diminution of flow.
- Primary Neuronal and axonal injury caused by hemorrhage.
- Cerebral infarction caused by local hemorrhage.
- “Neuron burnout”- status
- Cerebral perfusion arrest → Neuronal necrosis

Secondary Injury

- Occur as a consequence of the primary: usually lead to further cerebral ischemia, infarction and raised ICP.
- Etiology:

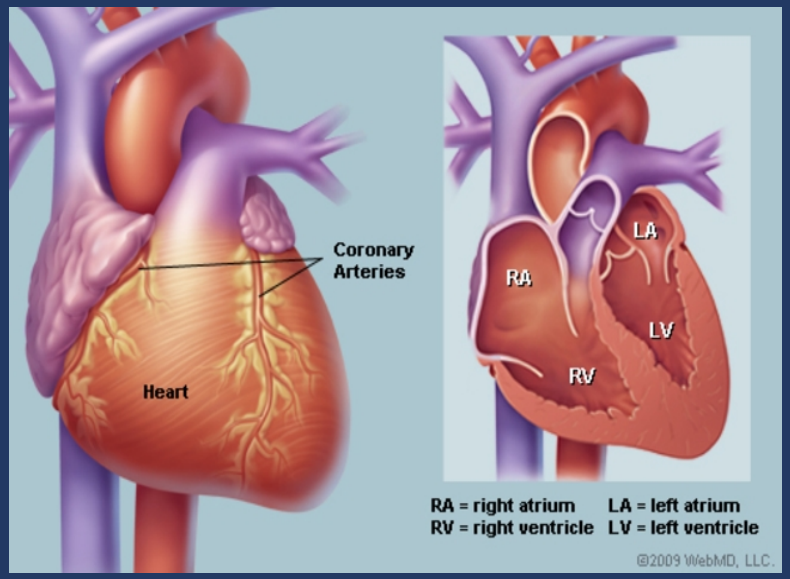
-*Vascular:* vasospasm, reperfusion injury.

-*Mechanical:* cerebral edema, hydrocephal.

-*Toxic/Metabolic:* release of vasoactive, pro-inflammatory subst, free radicals, products of blood/cell breakdown, PMN activity.

Complications

- *Intracranial*: Secondary injury.
- *Extracranial:* Cardiac



-cardiac arrhythmias

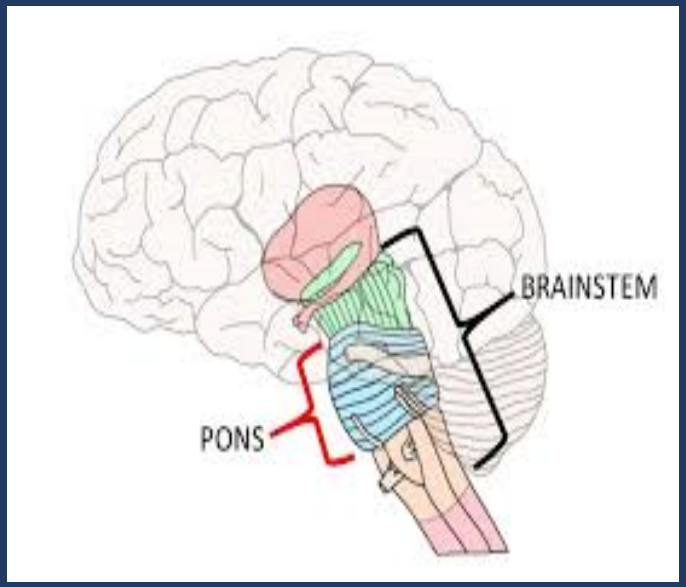
-stress cardiomyopathy

-autonomic dysfunction

-acute MI and acute heart failure

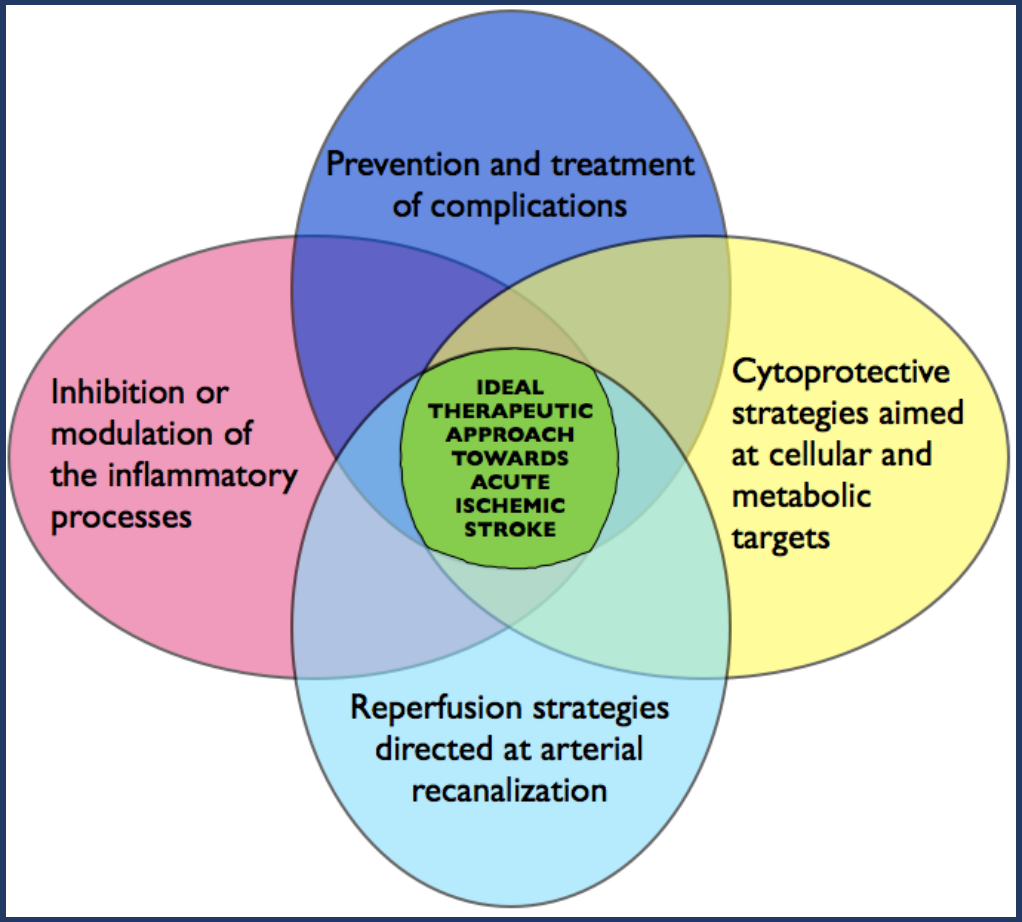
Complications

- *Acute resp failure:*



- - ↓ consciousness.
  -brainstem injury.
  -acute pulm edema.
  -acute obstr. hydroceph.
  -seizures.
  -oropharyngeal dysmotility.
-

Approach to stroke care



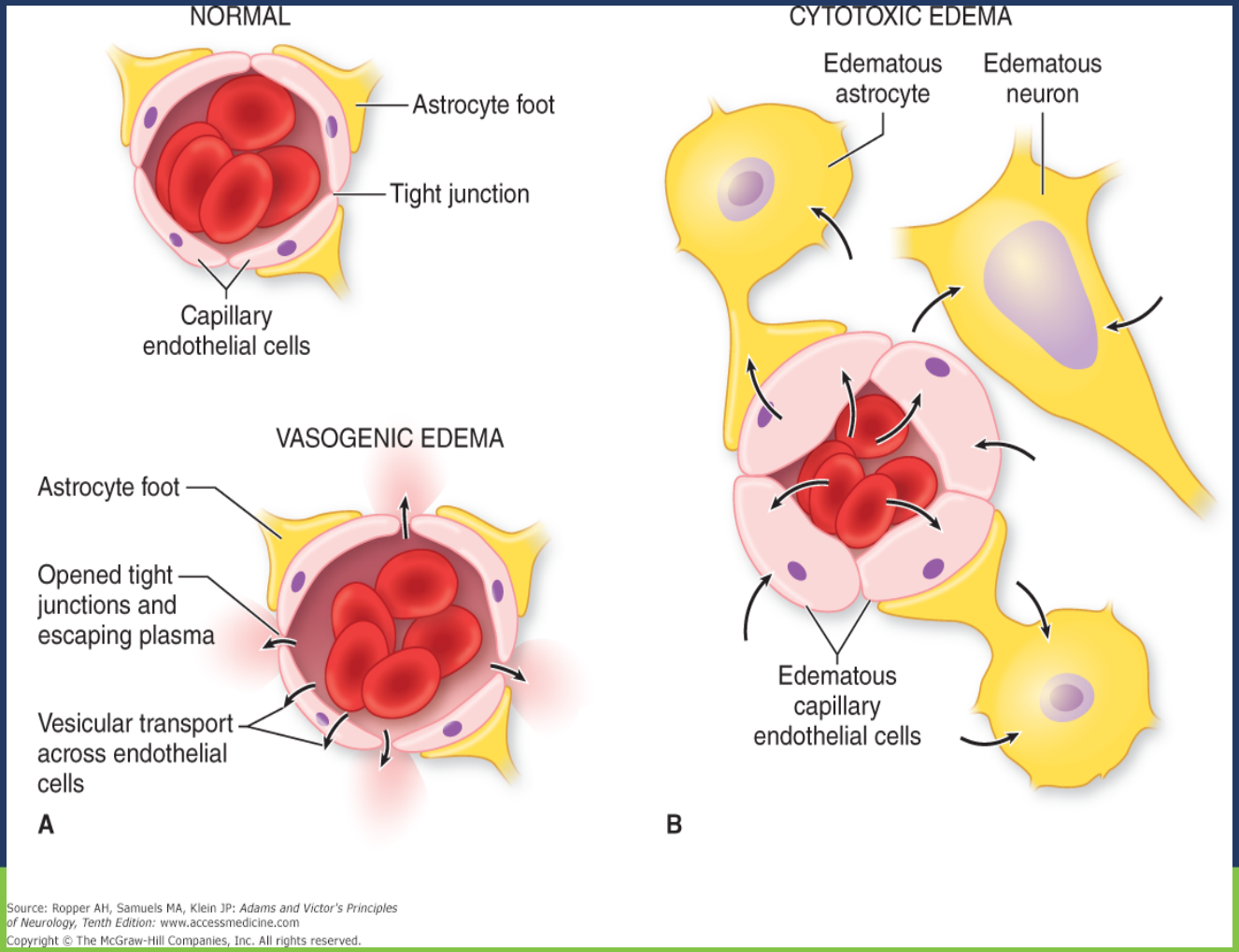
Principles of Management

- A.B.C.
- Airway and oxygenation (hypoxia, hypercapnia worsens stroke outcome across the board)
- Circulation and maintenance of cerebral perfusion.
- Prevention and treatment of raised ICP.
- Blood pressure maintenance.
- Invasive Bp monitoring.
- Treatment of complications.
- Multimodality monitoring

Cerebral Edema

- Can occur as sequela of primary injury.
- Secondary injury.
- Usually cytotoxic in the setting of AIS.
- Can be vasogenic in ICH.
- End result is raised ICP and cerebral herniation syndromes.

Cerebral edema



Cytotoxic cerebral edema

- Aim to decrease edema and optimize cerebral perfusion.
- Tiered approach *(NeuroCritical care soc).*
- Hypertonic therapy(2%/3%/23.4% saline).
- Hyperosmolar therapy (mannitol).
- Decompressive craniectomy.
- Medical coma(pentobarb,phenobarb,enflurane, ketamine).

Cytotoxic cerebral…

- Medical coma : (pentobarb,phenobarb,enflurane, ketamine)
- Therapeutic Hypothermia.

Vasogenic edema

- Brain tumors, ICH
- Aim: same as above
- Intravenous steroids, treatment of primary cause.
- In ICH, cytotoxic edema usually surpasses vasogenic, therefore treat as cytotoxic.
- Steroids worsen outcome in stroke *(level IIIb AHA,stroke guidelines 2018)*

Raised ICP

- NCC tier 0-3 approach:
- Aim to optimize cerebral perfusion pressure(CPP)
- Decrease ICP
- Increase MAP: bp augmentation.
- Note: ICP lowering measures are superior to bp augmentation *(Neurocritical care soc guidelines 2017.)*

DI,CSWS,SIADH

- Central DI could be rapidly fatal.
- Hypernatremia, aquauresis, low urine SG, high serum osm, circulatory collapse.
- Aim of treatment in DI:

  -maintain serum volume, correct Na

  -hypotonic fluids(0.45,D5)

  -Intravenous DDAVP

  **rate of sodium change not >0.5meq/hr*

CSWS

- Hyponatremia, natriuresis, circulatory collapse, seizures.
- Aim: volume repletion, correction of hyponatremia.
- Treat with isotonic fluid normal saline, hypertonic saline, V2 receptor antagonists(Tolvaptan, Conivaptan)

SIADH

- Hyponatremia, high urine SG.
- Increased water reabsorption due to too much ADH.
- Aim: decrease plasma volume, correct hyponatremia.
- *Water restriction, salt pills, hypertonic saline, aquauretics(Tolvaptan, Conivaptan) **care to be taken in stroke patients.*

Intracerebral Hemorrhage

- Goals:

  -To decrease risk of ongoing bleeding.

  - Bp control (systolic <140) *Interact-II;Attach-I*
  - Reversal of hypocoagulation: (FFP, K-centra, Recombinant factor 7, Profilnine, cryoprecipitate, Vit k, Platelets, Tranexamic acid) *STROKE 2016*

    -DO NOT give platelets to ICH patients on antiplat (PATCH study DBRCC)

ICH…

-To decrease intracranial pressure:

-craniectomy and evacuation.

-tier 0-3 ICP treatment alg.

-Treatment of acute hydroceph (EVD)

-Prevention and treatment of seizures

(Status, NORSE, super-refractory status, NCSE, EPC)

Acute Reperfusion Injury

- Commonly occurs in the setting of carotid revascularization (CEA, CAS)
- Commoner in patients with extra/intracranial atherosclerosis with poor collateral circulation.
- Post thrombectomy (intracranial LVO).
- Following treatment for SAH-related vasospasm.
- Can occur with normotension

Acute Reperfusion Injury: pathoph.

- Chronic hypoperfusion
- Maximal dilatation of the arteriolar bed.
- Impaired autoregulation(impaired vasoconstriction foll. flow restoration)
- Headache, visual changes, agitation, seizures, ICH, coma, death.
- Aim: Prevention. Strict normotension, or systolic 10mmHg less than normal.

Multimodality monitoring

- Has not been shown to be clearly superior to traditional care.
- EVDs have the added benefit of direct intervention.
- Challenges with data acquisition and expertise.

Common indices

- ICP <20
- CPP as a surrogate of MAP and ICP. Cannot be directly measured (>65)
- PTBO2 (25-35mmHg) usually <5 in dead brain.
- Svjo2 (55-75%), <55% indicates hypoperfusion, >75% hyperemia.
- OEF
- Brain lactate/pyruvate (<20)
- brain glucose (<0.66mmol/L assoc with poor outcome)

Common indices

- Brain temperature(<38c)
- NIRS: near infrared spectroscopy: measures rSO2(regional cerebral oxygen sat)

-measures diff btw spectral absorption of deoxy and oxyhem. Optimal value <60% (not validated by studies)

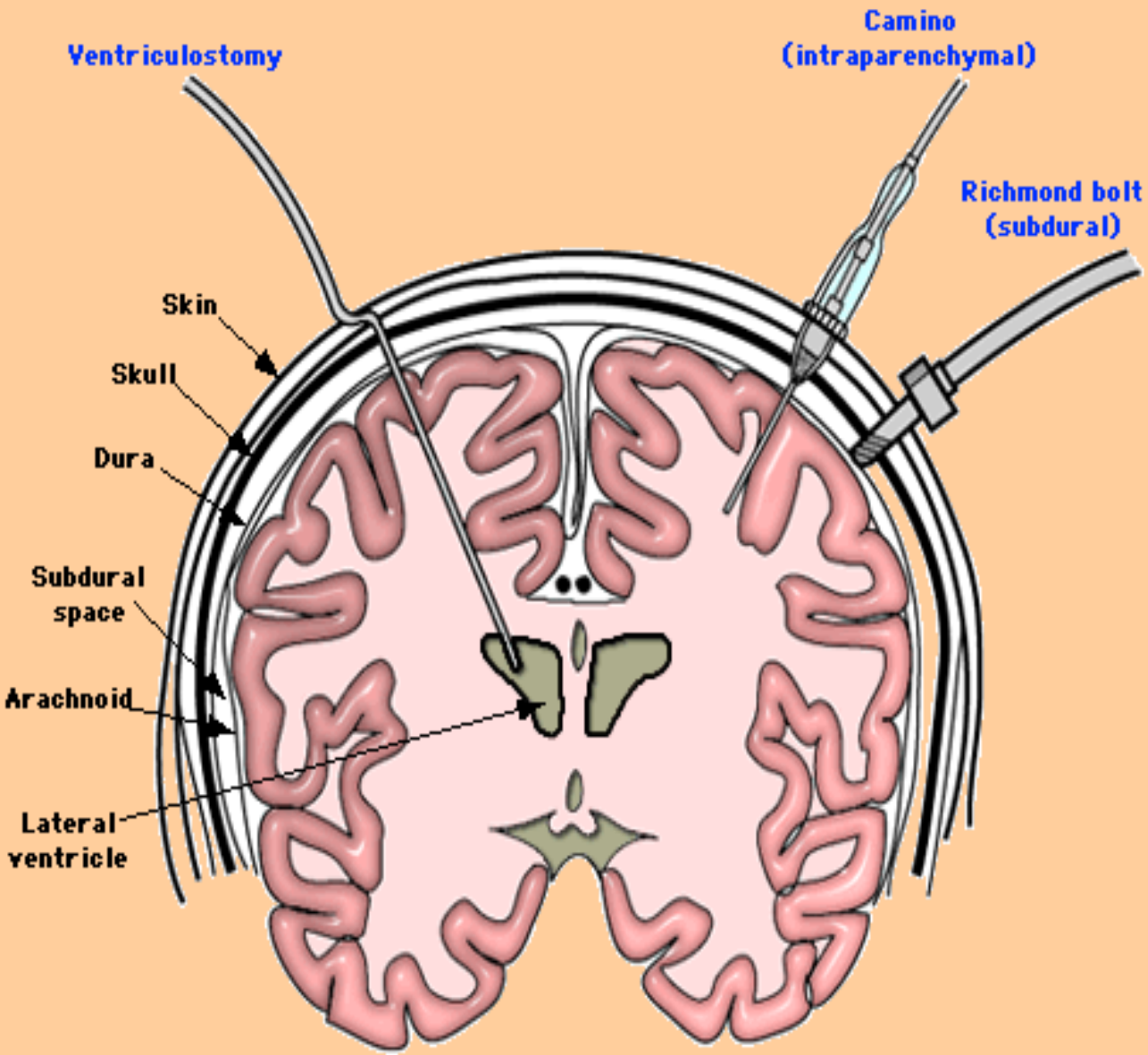
Indications for ICP monitoring

- GCS ≤ 8

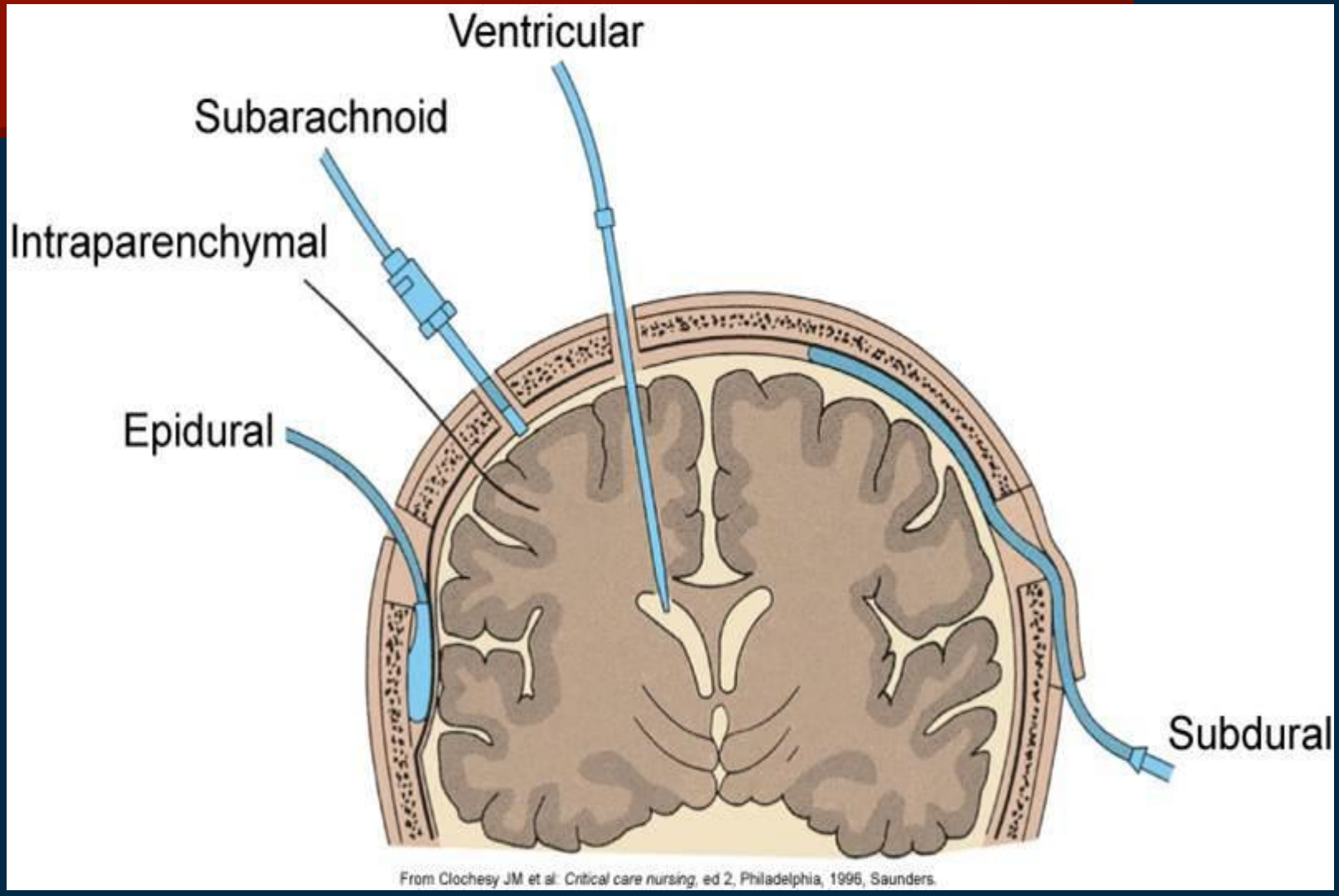
- Cisterns compressed or absent
- Midline shift > 5mm
- Post surgical removal of intracranial hematoma
- Less severe brain injury in a setting that requires deep sedation or anesthesia

ICP Monitoring Devices

Location	Product
Ventricular	catheter with drainage
Parenchymal	Codman, Camino
Subarachnoid	Bolt system
Subdural	Codman, Camino
Epidural	



Intracranial pressure monitors Ventriculostomy allows both ICP monitoring and therapeutic drainage of cerebrospinal fluid (CSF). Subdural and intraparenchymal monitors cannot be used to drain CSF.



From Clochesy JM et al: *Critical care nursing*, ed 2, Philadelphia, 1996, Saunders.

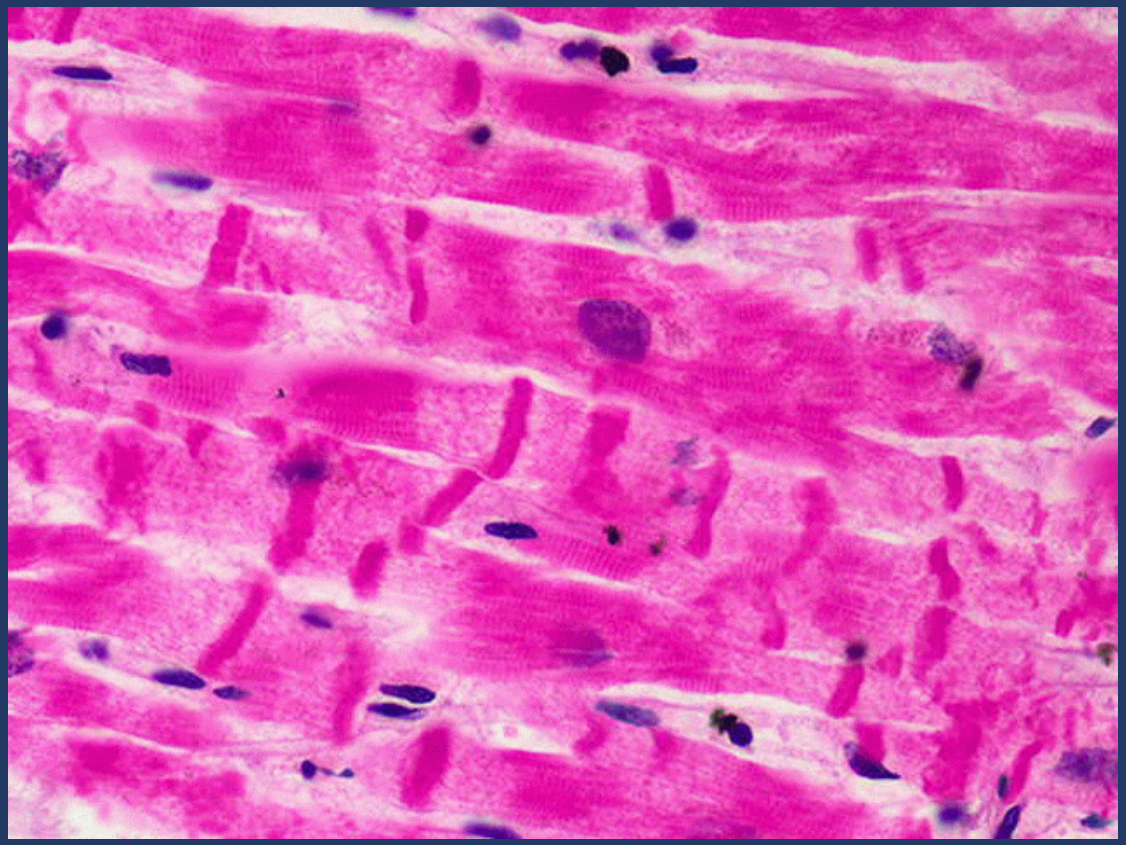
Extracranial complications

- Acute respiratory failure
- Acute pulmonary edema
- Stress cardiomyopathy: contraction band necrosis. (as against liquefactive seen in acute MI)
- Acute systolic heart failure
- Central dys-autonomia syndrome

Extracranial complications

- Acute DVT
- Acute pulmonary embolus
- Pneumonia
- Sepsis
- Depression (not limited to CNS)

Contraction band necrosis



Prognosis after stroke

- Strokes reccur in 6-20% of patients within 1st 12 mo.
- Mortality: 22.8%/100,000
- Second leading cause of death worldwide.
- Approx 6 million deaths worldwide.
- Predictors of mortality: age, race, sex, fever, initial stroke severity, htn, afib, heart failure.

Tiered ICP treatment

ENLS guidelines for ICP management.

- **Tier 0:**
- HOB > 30 degrees
- Ensure adequate sedation
- Correct hyponatremia
- Treat hyperthermia (fever).
- Treat vasogenic edema
- Treat seizures.
- ***normonatremia, normothermia, normovolemia***

ENLS guidelines for ICP management.

- **Tier 1:**

- Ensure adequate airway (endotracheally intubate or use tracheostomy if present).
- Short-term hyperventilation may be instituted either with manual bag-mask technique or mechanically.
- Mannitol 0.5-1 g/kg IV bolus
- CSF drainage: If acute obstructive hydrocephalus is contributing to clinical deterioration, place EVD emergently. If external ventricular drainage system is in place, drain 5-10 ml of CSF.
- Begin 3% IV saline to keep serum sodium between 140 and 150 meq/L. Check serum electrolytes Q 4-6 hours.
- If ICP is controlled and/or clinical signs of herniation resolve with Tier One interventions, obtain head imaging studies.

ENLS guidelines for ICP management.

- **Tier 2:**
- Hypertonic saline and sedation
- 30mls of 23.4% saline bolus. Evidence supports rapid infusion of hypertonic saline bolus to reverse transtentorial herniation or decrease ICP.
- Infusions of lower concentrations (3%- 7%) are typically used to maintain serum sodium during cerebral salt wasting and are typically not used in bolus form.
- The goal is to keep serum sodium between 140 and 150 meq/l.
- Hypertonic saline with concentrations > 3% should be given through a central venous catheter.
- If ICP is not responsive to sodium infusion, consider a sedative agent, such as propofol 1-3 mg/kg to reduce CMRO2, CBF, and ICP. Administration of propofol may be associated with circulatory depression that should be corrected with IV fluids or a vasopressor infusion to maintain CPP goal. Propofol may be continued as an infusion 200 mcg/kg/min.
- If ICP is responsive to Tier Two therapies, and the patient has not been imaged yet, obtain brain imaging.

- If the patient is unresponsive to Tier One and Tier Two interventions, consider rescue surgery(evacuation of mass lesions or decompressive crani. in the absence of mass lesions).
- If the patient is not a candidate for surgery proceed to Tier Three.

ENLS guidelines for ICP management.

- **Tier 3:**
- No longer a surgical candidate
- Tier 3 measures represent the most aggressive level of medical management and carry the highest risk of adverse effects.
- Pentobarbital coma dosing: bolus 10 mg/kg IV over 30 min, then 5 mg/kg/hour for 3 hours.
- Maintenance 1 - 4 mg/kg/hour, titrated to ICP goal with assistance of continuous EEG. Infusion is continued for 24 - 96 hours while underlying process driving ICP is treated or begins to resolve. Treatment is associated with respiratory depression, circulatory instability, immune suppression, and paralytic ileus.
- Moderate hypothermia (target core temperature, 32 - 34 degrees C) is induced with external cooling devices or with intravenous infusion of cooled fluids. Treatment is associated with shivering, cardiac arrhythmia, sepsis, coagulopathy, and electrolyte disturbances.

ENLS guidelines for ICP management.

- **Tier 3 cont'd:**
- Hyperventilation to moderate hypocapnia ($PaCO_2$ 25-35 mm Hg) may be considered in selected patients who have failed Tiers One and Two.
- Hyperventilation should be accomplished in conjunction with a cerebral oxygenation monitor (jugular venous oximetry, brain tissue oxygen probe), in order to minimize the risk of cerebral ischemia.
- Prolonging hyperventilation for > 6 hours is unlikely to be beneficial and may cause harm.
- CPP manipulation: raise MAP with fluid and vasopressors.

Does Reducing ICP's Improve Outcomes?

- Chambers et. al. 2001
  - 291 patients. Used all ICPmax and CPPmin data.
  - Measured Outcomes GOS at 6 months
  - Average age 36 and Ave 50 H of ICP/CPP
  - ICPmax of 35 mmhg with CPP min of 55 mmhg was found to have best predictive value to predict a good outcome (independent or moderately disabled) vs sev disability/veg state or dead.
  - No one with CPP below 40 for one hour at any point during their hospital course survived.

Craniectomy -- Evidence

- MCA Ischemia – DECIMAL, DESTINY, HAMLET
  - Young Age < 50 Yrs.
  - DC within 48 hours.
  - 2/3rd of territory involved.

Rx Group	mRS at 12 m ≤3	Still alive at 12
DC	43%	78%
Medical Management	29%	29%

Craniectomy - Evidence

- TBI
  - ↑ICP --- Most reliable of mortality in TBI.
  - RESCUEicp results pending.
  - DECRA Results

Rx Group	ICP	Interventions	ICU stay	Ex. GOS & Unfavorable Outcome	Morality at 6 months
DC vs MM	0.001	0.002	0.001		19%
MM vs DC				0.03 /0.02	18%

  -

Hypertonic Saline in Rx of ICP

Trial	Study Design	Regimen	ICP Rx point	Outcome
Kerwin et al	Retros. Single Ctr. N=22	23.4% 30ml over 30 min	>20	↓ICP>Mannitol
Huang et al	Prosp. Single Ctr. N=18	3%, 300 ml over 20 min.	>20	↓ICP
Ware et al	Retros. Single. N=13	23%, 30ml over 20 min	>20	↓ICP~Mannitol
Vialet et al	Prosp. Rand. Singl C. N=20	7.5%, 2ml/kg over 20 min.	>25	↓ICP, # of ICP elevations
Munar et al	Prosp. NR Single C =15	7.2%, 1.5ml/kg over 15 min	>15	↓ICP

Hypertonic Saline

- Burkhard, S et al. 1998 Crit. Care Med.
  - 35 Pediatric Patients GCS of < 8
  - randomized to NS vs Ringers lactate.
  - MAP and ICP monitored.
  - ICP and Na were inversely related (p 0.001)
  - CPP improved in NS group after 8 hours.
  - Recurrent ICP elevation in RL group.

Mannitol

- Muizelaar et al 1984
  - 0.66/kg of Mannitol reduces ICP by 27%.
- Vries et al. 1972
  - 18 patients Rxed with mannitol reduced ICP by 10 % on average.
  - High mortality in patients with high serum Osmolality.

Mannitol

- Cruz et al 2001
  - 178 adults with pupillary changes
  - HDM vs No Mannitol

Rx Group	Pup. Change	Post op ICP	Post oP O2 extraction	Outcomes at 6 M
HDM	0.0001 in fav.	0.01 in Fav	Better in HDM	0.01 in Fav
Control				

Barbiturate Coma

- Decreases CMR by 50%. *(Fuestel 1981Stroke)*
- Barbiturates are recommended for resistant to treat ICP and not as a first choice.
  - Trauma Guidelines 2000
  - Cochrane Review, Roberts et. al.
- Usually used when everything else has failed. So we are not comparing apples to apples. (*Except in Ward et. al. 1985 JNS*)

Hypothermia

- Reduces ICPs *(NABISH by 30mmgh)*
- *Jian et. al. 2000 J NS*
  - *43 pts in Rx group, 44 patient in control group*
  - *33-35 C for 14 days vs 37-38.*

Rx Group	Mortality at 1 year	Fav Outcome at 1y.
Hypothermia Group	11/43 (25%)	20/43 (46%)
Normothermia Group	20/44 (46%)	12/44 (27%)

Self assessment questions

- What antihypertensive agents to use in blood pressure maintenance in acute ischemic stroke?
- What inotropes to use?
- Anticoagulation and antiplatelet therapy in acute stroke.

Abbr.

- AIS: acute ischemic stroke.
- TIA: transient ischemic attack.
- ICP: intracranial pressure.
- CPP: cerebral perfusion pressure.
- ICH: intracerebral hemorrhage.
- IVH: intraventricular hemorrhage.
- NORSE: new onset refractory status epilepticus.
- NCSE: non convulsive status epilepticus.
- CMR: cerebral metabolic rate of oxygen.

Abbr..

- EVD: external ventricular drain.
- ADH: antidiuretic hormone.
- DI: diabetes insipidus central.
- SIADH: syndrome of inappropriate ADH secretion.
- CSWS: cerebral salt wasting syndrome.
- EPC: Epilepsia partialis continua.
- PTBo2: brain tissue oxygen partial pressure.
- OEF: brain oxygen extraction fraction.

Abbr…

- CEA: carotid endarterectomy.
- CAS: carotid artery stenosis.
- LVO: large vessel occlusion.
- CRAO: central retinal artery occlusion.

Final Note

- Microplastic Toxicity: *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6132564/*

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THANK YOU.