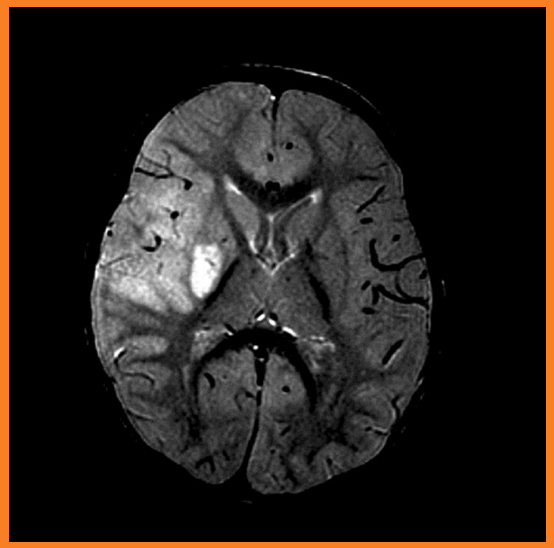

Advances in Pediatric Stroke Management

Heather J. Fullerton, MD, MAS

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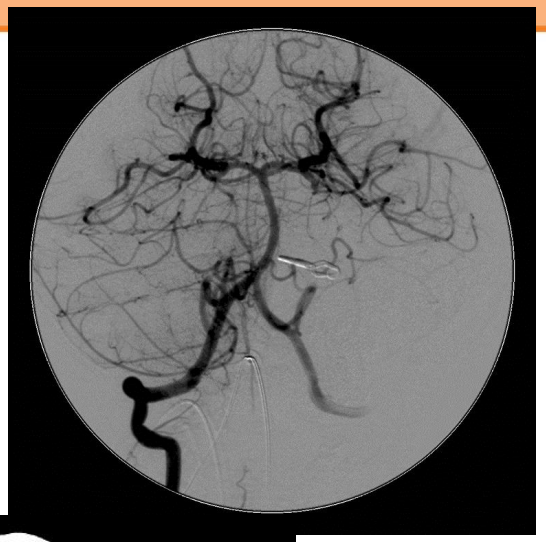
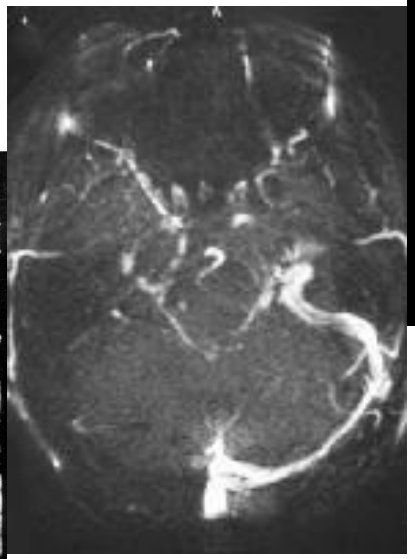
Director, Pediatric Brain Center

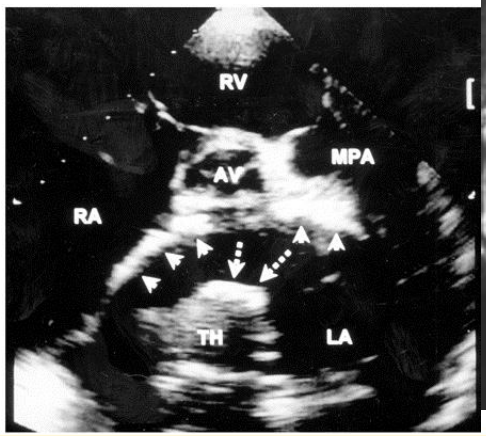
UCSF Benioff Children's Hospital
San Francisco

Outline: Pediatric Stroke

- **Presentation**
- **Diagnosis**
- **Management**
  - *Ischemic Stroke*
  - *Hemorrhagic Stroke*







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Stroke in Children: How often does that happen?

- **Incidence:**
  - *4.6 per 100,000 children/year in US*
  - *About 5,000 US kids/year*
  - *1 per 3,500 neonates*

Agrawal, *Stroke*, 2009

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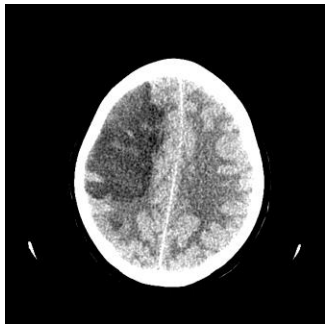
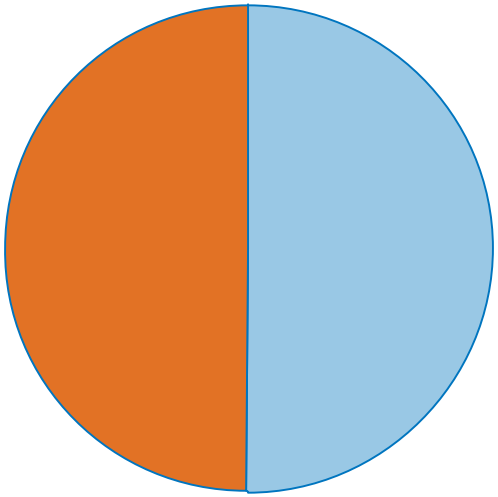
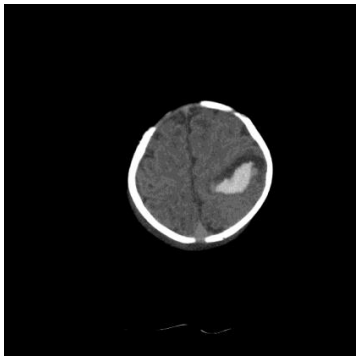
Stroke Subtype



Ischemic

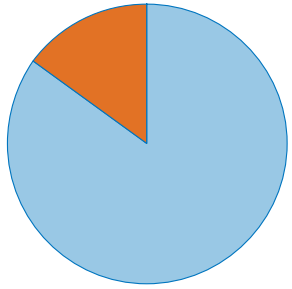




Hemorrhagic

Children

Hemorrhagic



Adults

Ischemic

Broderick, *J Child Neuro,* 1993

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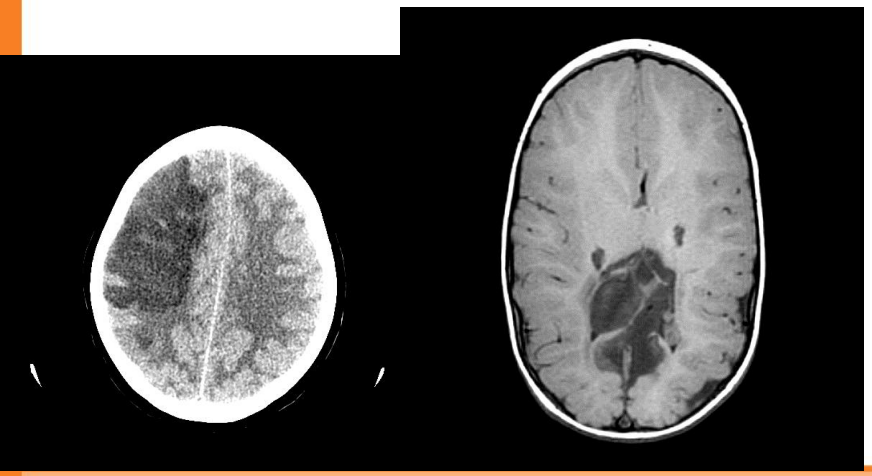
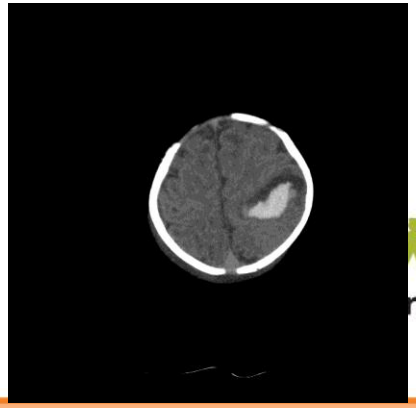
Types of stroke

- **Ischemic**
  - ***Arterial Ischemic***
    - **Large vessel**
    - **Small vessel**
  - ***Venous Sinus Thrombosis***
- **Hemorrhagic**
  - ***ICH (intracerebral hemorrhage)***
  - ***SAH (subarachnoid hemorrhage)***





Clinical Presentation: Arterial Ischemic Stroke

- **Most common presenting feature:**
  - *Hemiparesis 45-100%*

Mancini, J Child Neurol 1997;
Abram J Child Neurol 1996

- **Onset of deficit (n=47, ischemic):**
  - *Abrupt 51%*
  - *Progressive over hours 36%*
  - *Waxing/waning 13%*

Dusser, J Child Neurol 1986

- **Seizures as presenting feature: 26%**

Dusser, J Child Neurol 1986

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Clinical Presentation in Children

Venous Sinus Thrombosis

- Headache: subacute
- Encephalopathy
- Seizures
- Focal deficits (less often)
- Pseudotumor cerebri

Hemorrhagic Stroke

- Headache: thunderclap
- Syncope
- Seizures
- Focal deficits
- Hypertension

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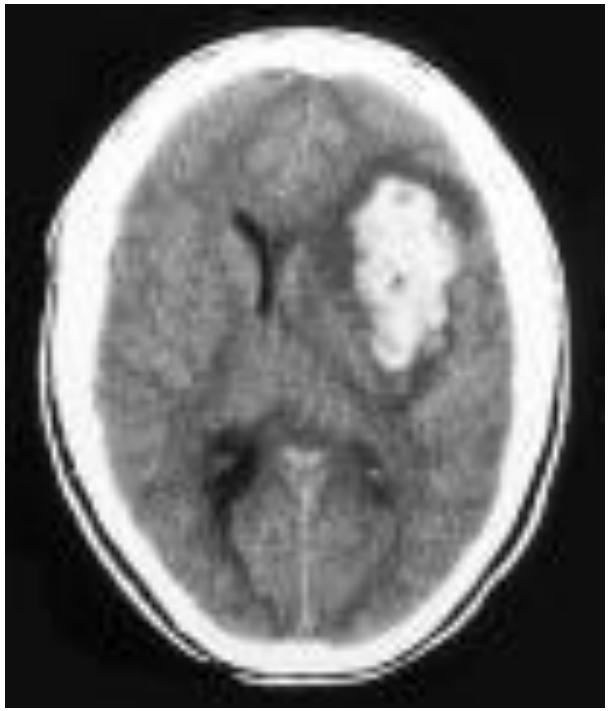
Diagnosis: CT sensitive for intracerebral hemorrhage



White (bright) on CT:

- Blood
- Contrast
- Calcium
- Metal

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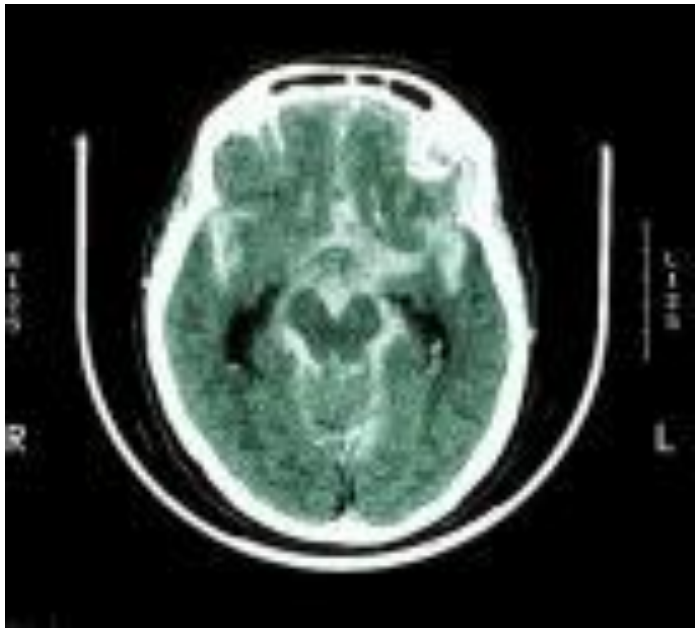
Diagnosis: CT also sensitive for subarachnoid hemorrhage

- But gold standard is LP
- Consider when convincing story



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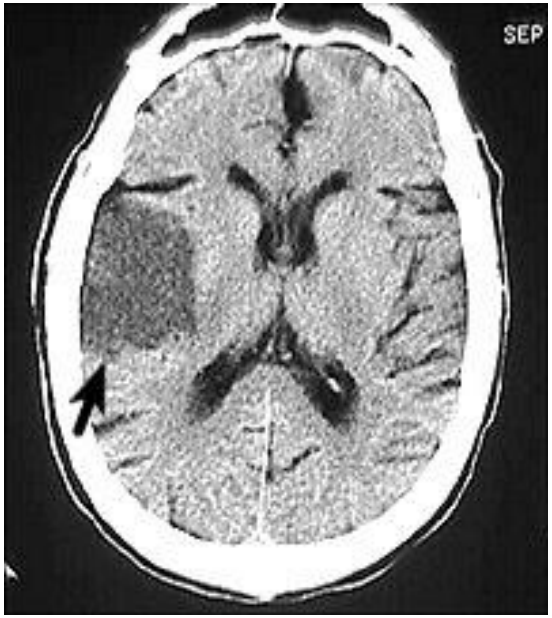
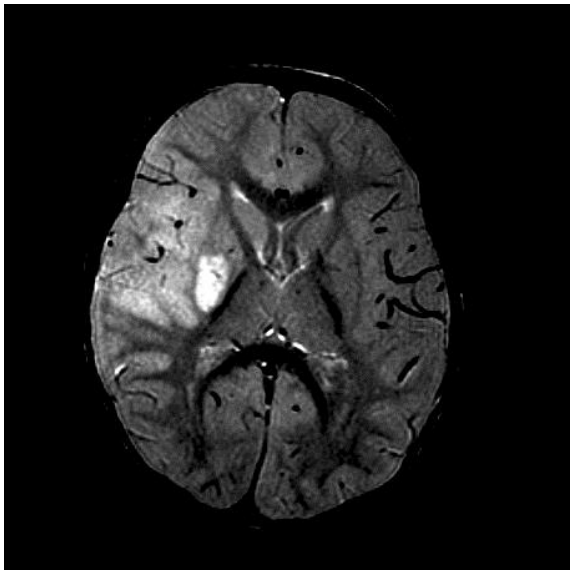
Diagnosis: Ischemic Stroke

- CT insensitive in first 6-12 hours



- MRI highly sensitive
  - DWI positive w/in minutes, up to approx 10 days



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Ischemic Stroke Management

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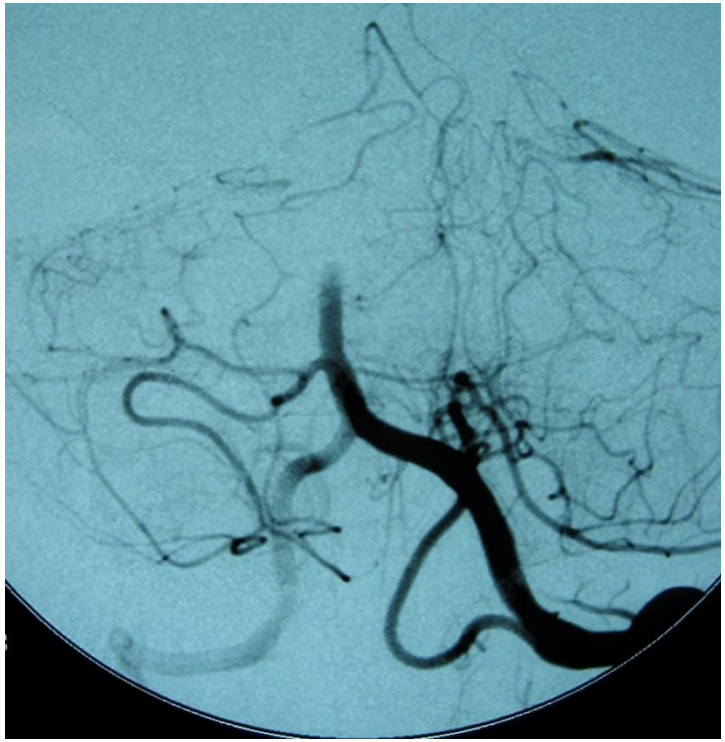
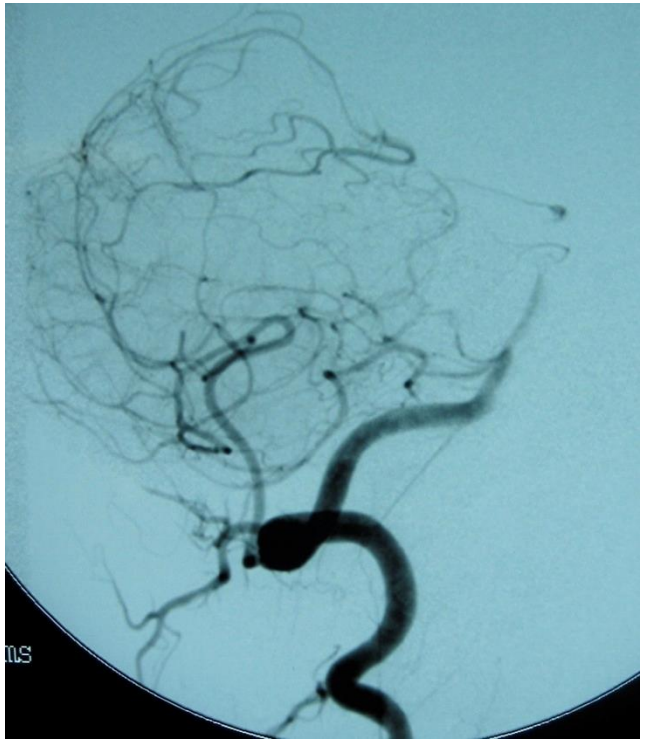
Hyperacute Managment





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Courtesy of Van Halbach, MD

ICU Mgmt: Ischemic Stroke

- **Goal #1: *Reperfuse brain by removing clot***
  - ***Only case reports in kids***
  - ***IV tPA (tissue plasminogen activator)***
    - **Time window: w/in 4.5 hrs fr last seen normal**
  - ***IA tPA***
    - **Time window: w/in 6 hrs for anterior circulation, 12 hrs for posterior circulation**
  - ***Clot retrieval***
    - **8 hrs for ant circ; no real time limit for basilar artery thrombosis**

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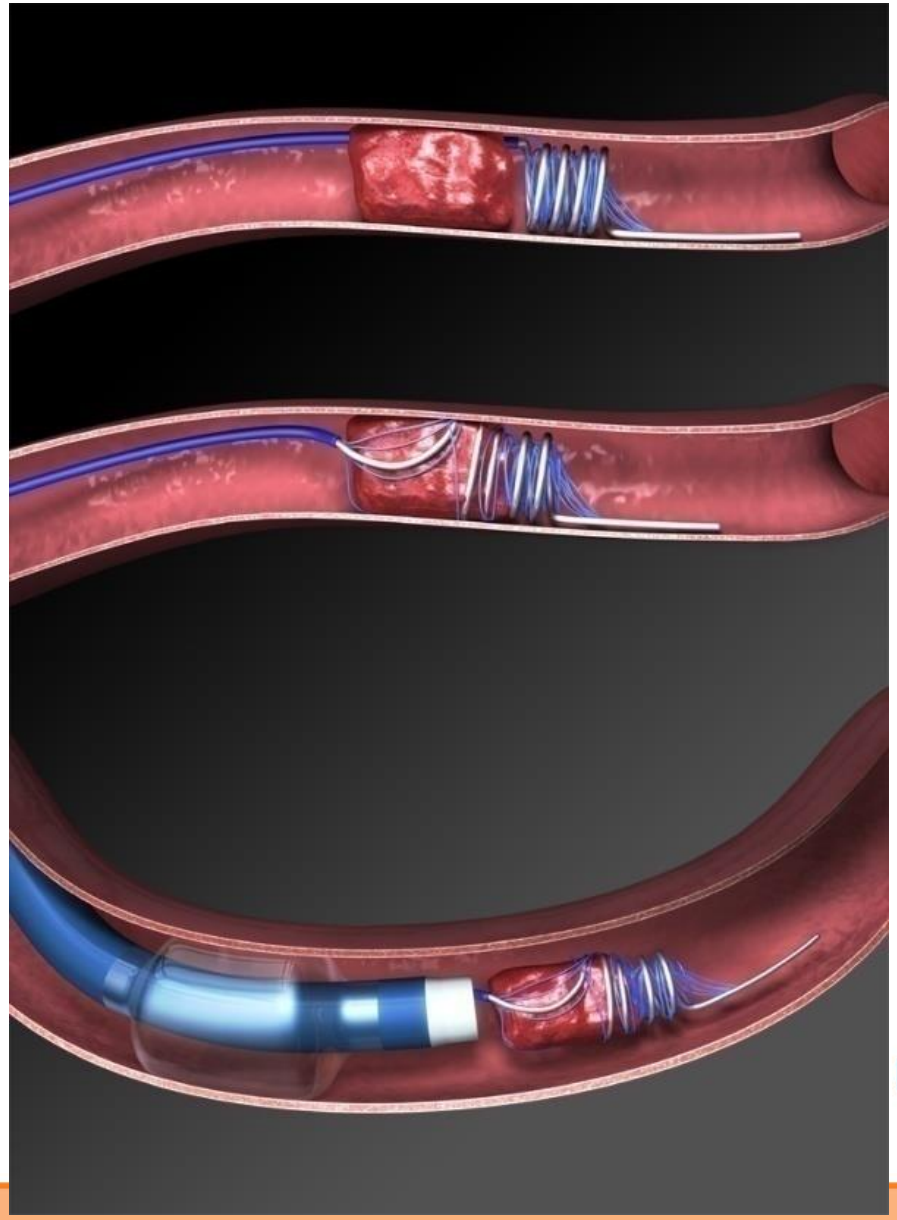
Thrombectomy: Merci retriever



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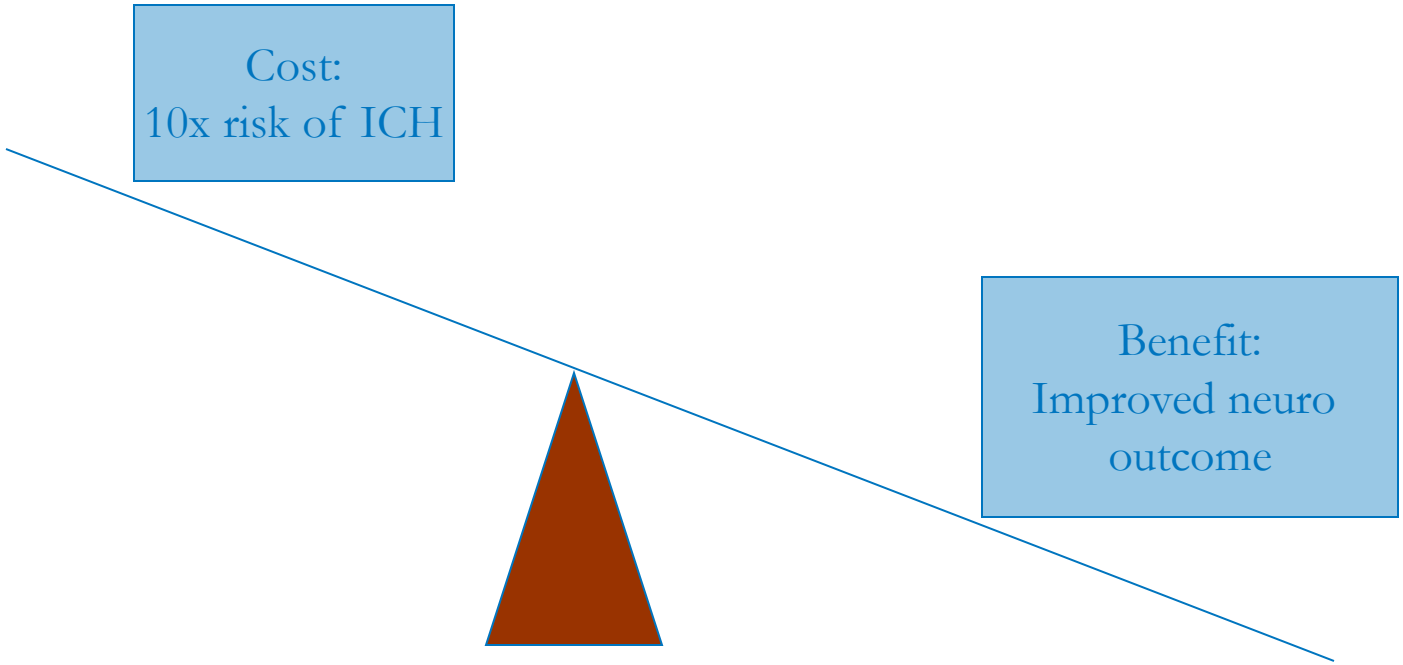
IV tPA: Cost/Benefit Ratio

- **Adults:**



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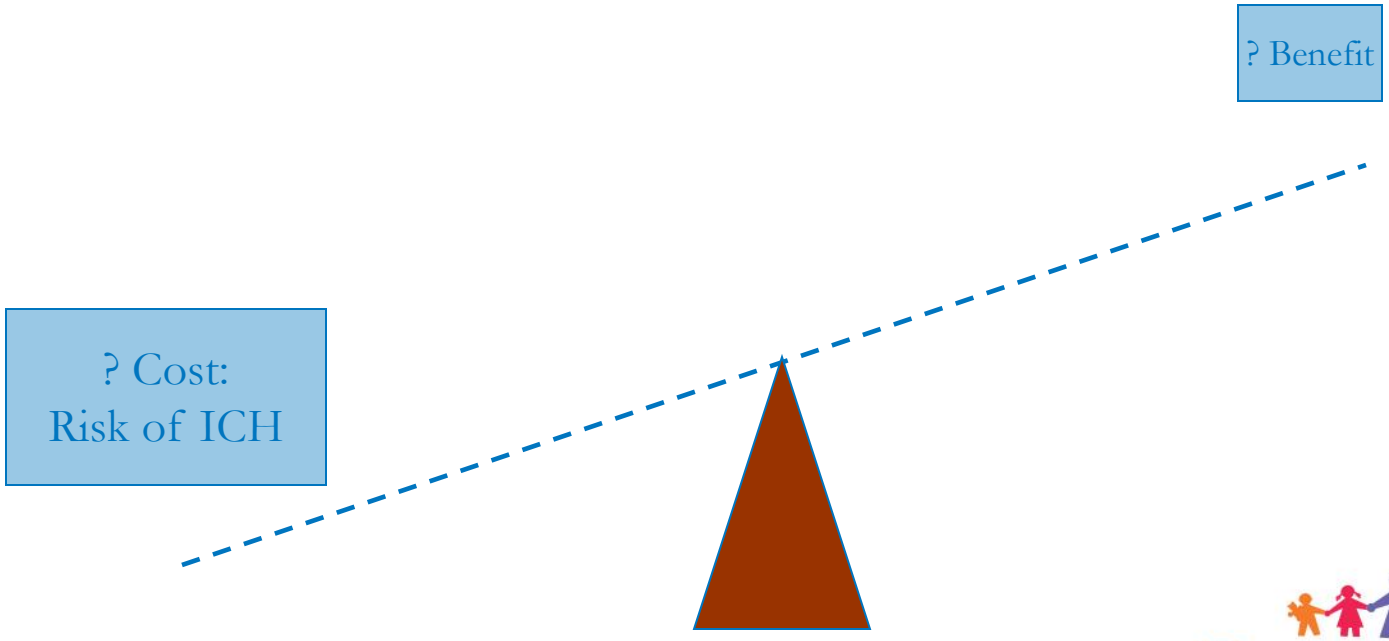
IV tPA: Cost/Benefit Ratio

- **Kids?:**



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Special Considerations in Children

- Acute hemiparesis more likely to be non-stroke (migraine, seizure)
- Delayed stroke diagnosis
- Predominantly large vessel stroke
- Immature coagulation system--? tPA dosing

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When We Consider Hyperacute Tx

- **Older teenagers**
- **Basilar artery thrombosis**
- **Dominant MCA strokes**

- ***But only with full disclosure to family of limited data in children, potential risks***

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ICU Mgmt: Ischemic Stroke

- **Goal #2: *Minimize the injury***
- **Protect the ischemic penumbra**
  - ***"permissive HTN"***
    - **At least keep normotensive**
    - **2X maintenance fluids**
    - **Pressors if necessary (esp if sedated for ICP mgmt)**
  - ***Avoid significant HTN→risk of hemorrhage***
- **Avoid hyperglycemia & hyperthermia**

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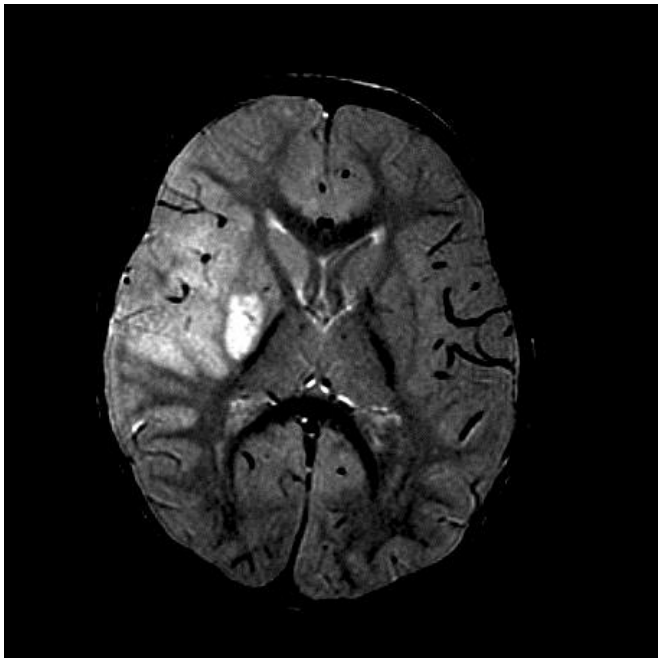
ICU Mgmt: Ischemic Stroke

- **Goal #3: *observe for neurologic decompensation***
- **Mass effect/herniation:**
  - ***max at 3-4 days***
  - ***Hemorrhagic transformation***
- **Subfalcine herniation**
  - ***ACA strokes***
- **Uncal herniation**



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ICU Mgmt: High Intracranial Pressure

- **Osmotherapy**
- **Hyperventilation (short term benefit)**
- **Sedation/Coma**
- **Decompressive surgery**
  - *Cerebellar stroke*
  - *Malignant MCA*
    - hemicraniectomy

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ICU Mgmt: Ischemic Stroke

- **Goal #3: Prevent recurrent stroke**
- **2 main predictors:**
  - ***Age: non-neonatal***
  - ***Etiology: arteriopathy***

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Etiologies of Childhood Stroke: The Typical Laundry List

- **Cardiac**
  - *Congenital ht dz*
  - *Bacterial endocarditis*
  - *Rheumatic ht dz*
  - *Arrythmias*
- **Vascular disease**
  - *Transient Cerebral Arteriopathy*
  - *Moyamoya*
  - *Arterial dissection*
  - *FMD*
- **Hematologic**
  - *Sickle cell dz*
  - *Leukemia*
  - *Polycythemia*
- **Hypercoaguable state**
  - *Aquired: sepsis, nephrotic syndrome, liver failure, SLE, anti-phospholipid syndrome, cancer*
  - *Inherited: protein c/s deficiency, AT III deficiency, Factor V Leiden, MTHFR, prothrombin 20210*

- **Infection**
  - *Meningitis/encephalitis*
  - *Chicken pox*
- **Drugs**
  - *Cocaine*
  - *OCP's*
  - *Chemotx (L-asp)*
- **Metabolic/Genetic**
  - *Homocystinuria*
  - *Fabry's*
  - *Organic acidemias*
  - *Majewski's Osteopdysplastic Primordial Dwarfism, type II*
  - *Collagen vascular (e.g., Ehlers-Danlos)*
- **Neurocutaneous d/o's:** NF1, TS

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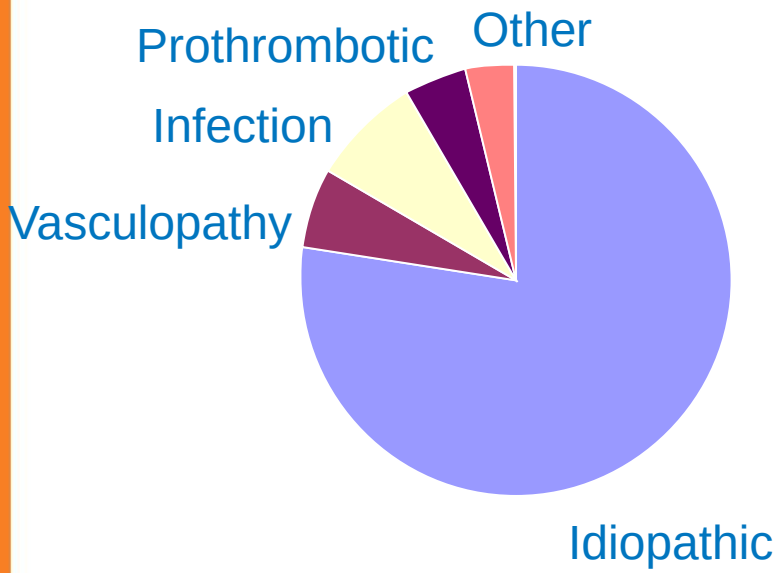
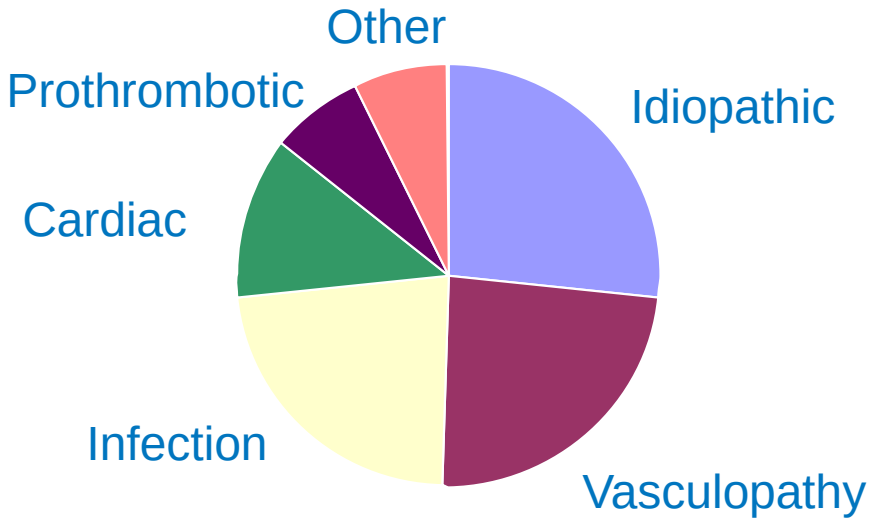
Kaiser Pediatric Stroke Study: Etiologies in a Population of Children



Neonatal



Later Childhood

Fullerton, *Pediatrics*, 2007

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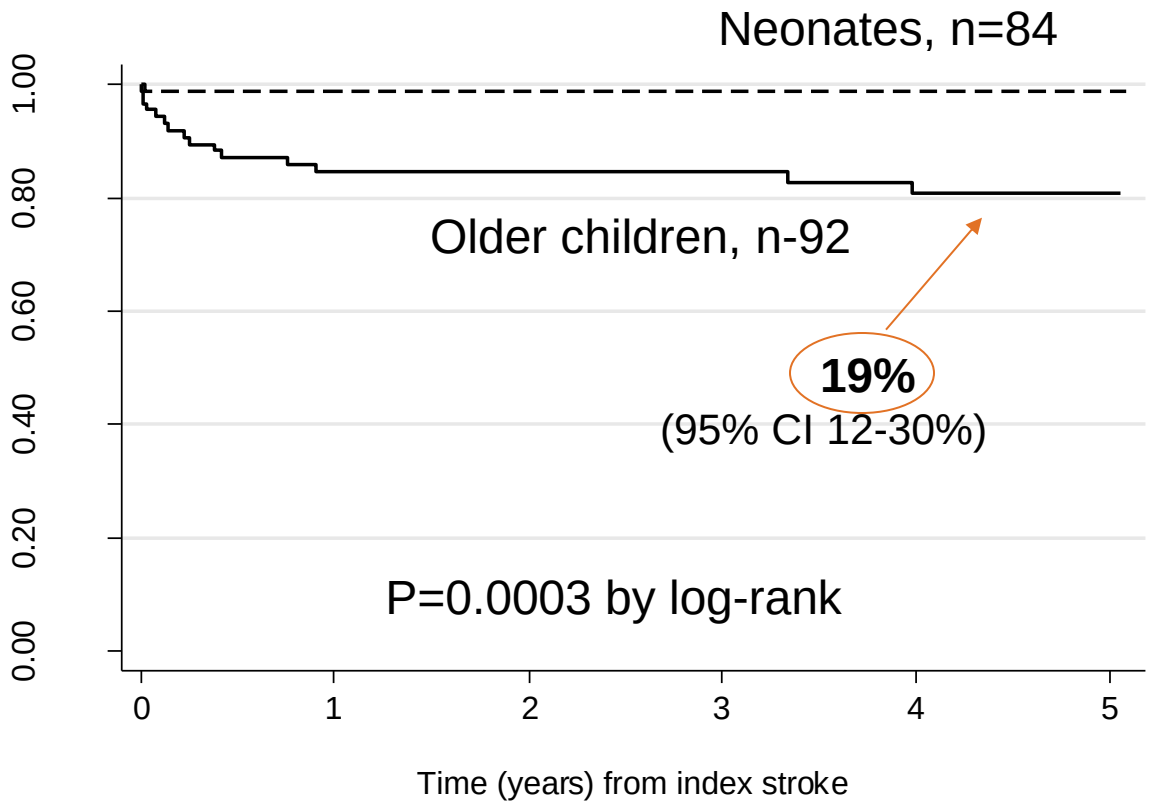
Recurrence: rare in babies, but occurs in up to 20% of older kids with stroke



Fullerton, *Pediatrics*, 2007

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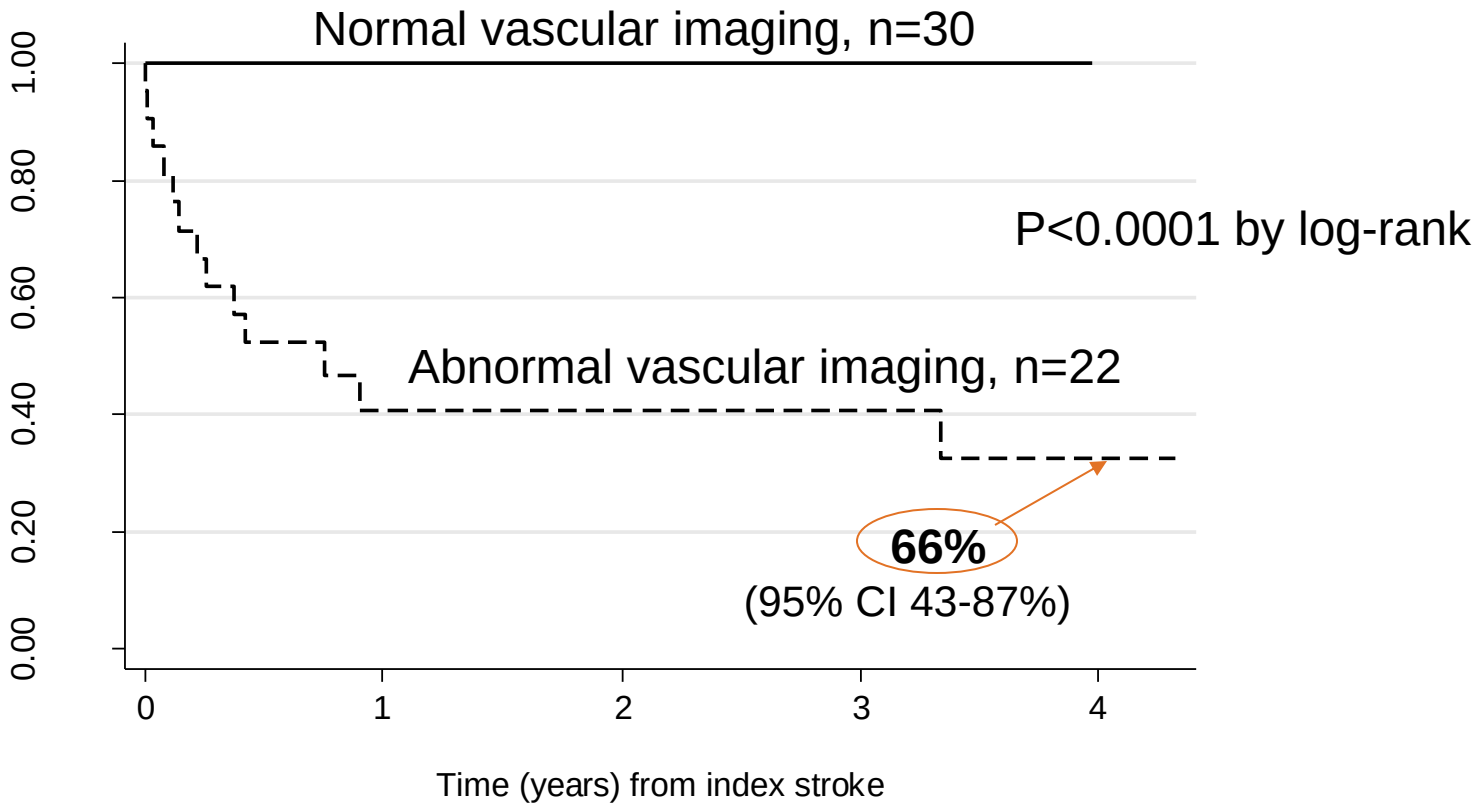
Kids with diseased blood vessels to the brain are at higher risk of recurrence



Fullerton, *Pediatrics*, 2007

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Treatment to prevent recurrent stroke depends on the cause of the first stroke

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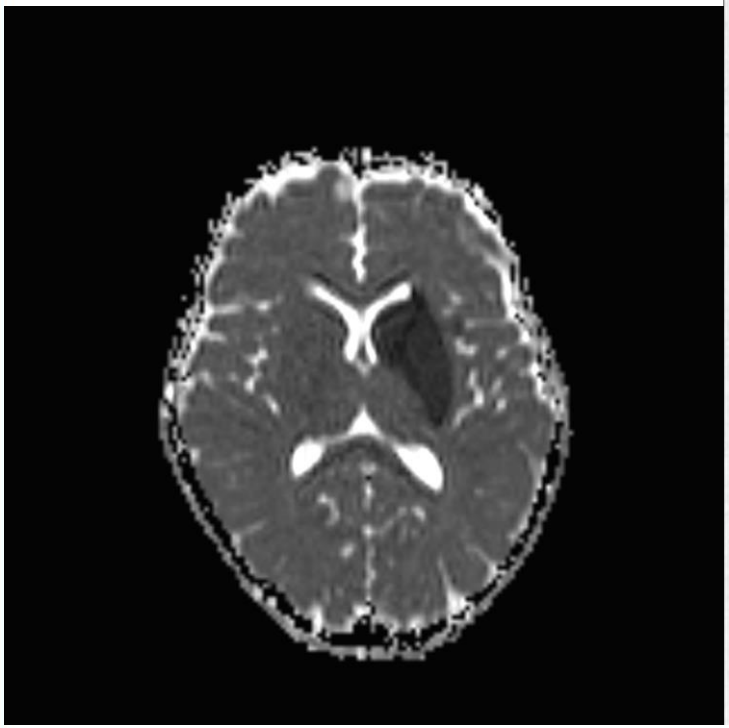
7 y.o. girl, previously healthy, R HP & aphasia



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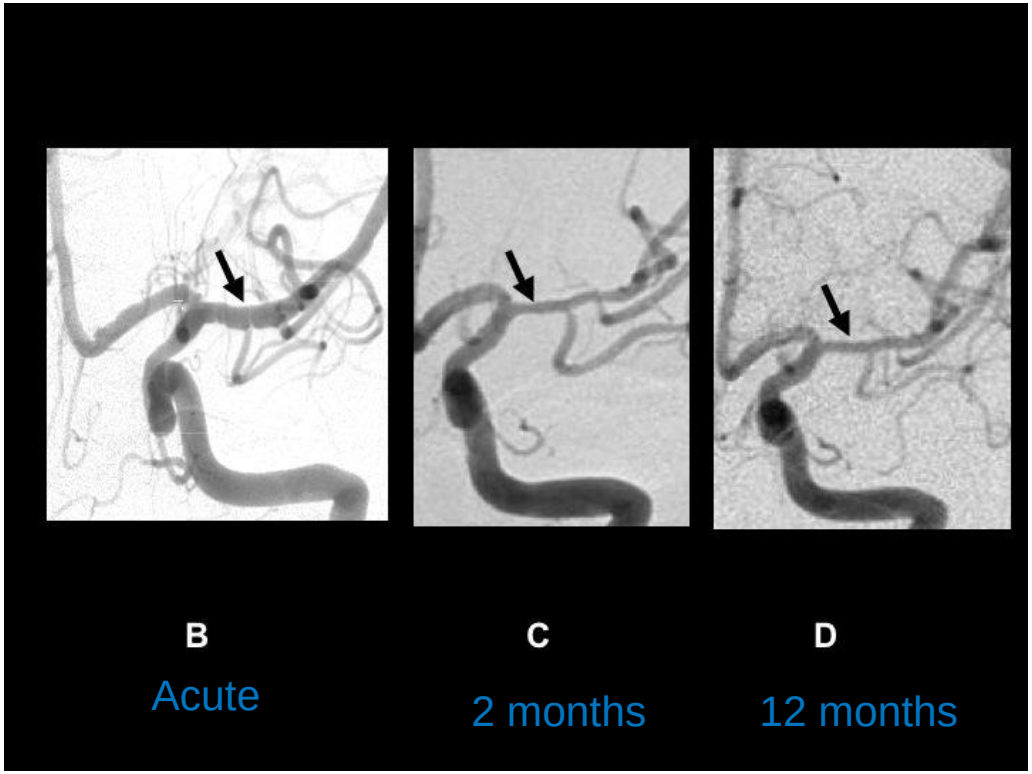
“Transient” Cerebral Arteriopathy (TCA)

- **Natural history:**
  - *Monophasic disease*
  - *Initial progression (2-6 months)*
  - *Nonprogression after 6 months*
  - *Improvement or stabilization; rarely normalization*
  - *Chabrier & Sebire, J Child Neurol 1998; Danchaivijitr, Ann Neurol 2006*
- **Tx: aspirin**



Courtesy of G. DeVeber

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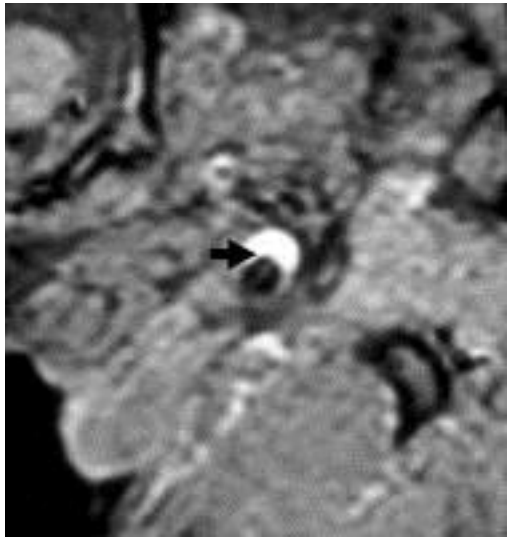
Arterial Dissection



- Tear in the wall of a blood vessel to the brain
- Caused by trauma, or spontaneous
- Tx: Anticoagulation (or aspirin)

- Fullerton, *Neurology*, 2001

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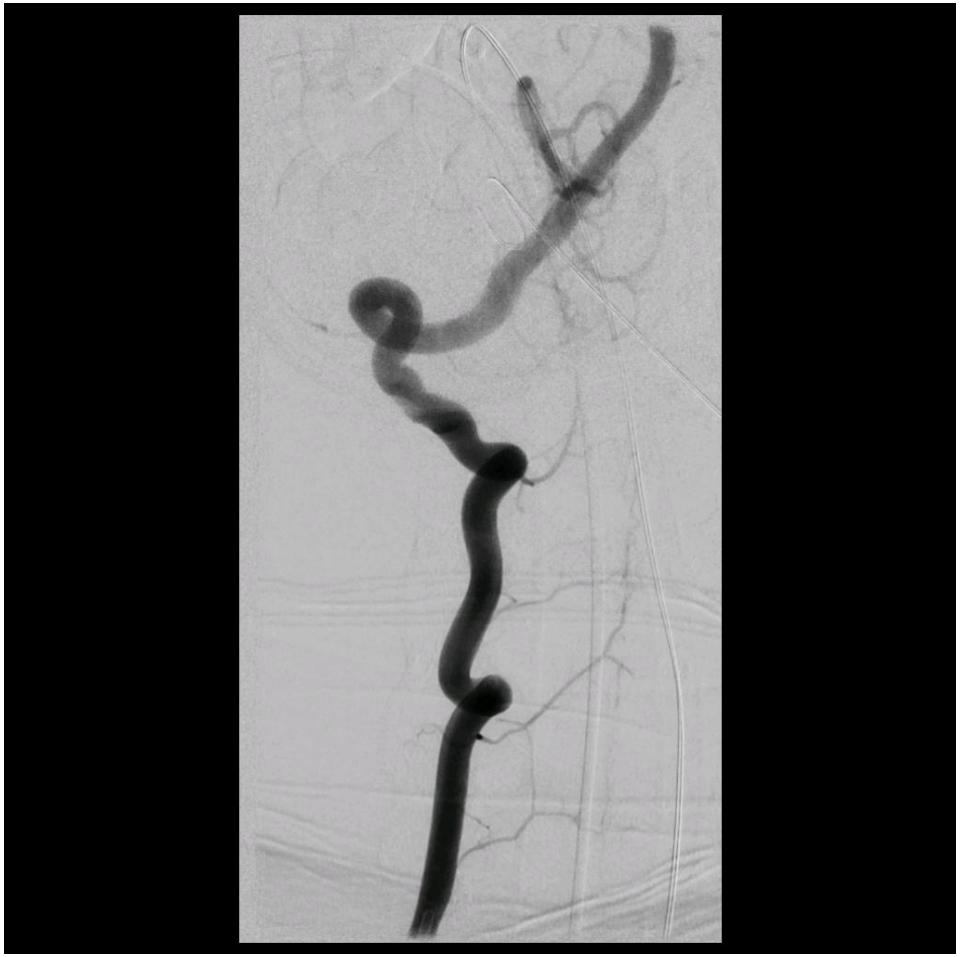
6 y.o. boy with recurrent posterior circulation ischemic strokes



R vertebral, Neutral

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Right Vertebral

Head turned 45 degrees, left

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Right Vertebral

Head turned 60 degrees, left

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“Vertebral Artery CRIMP” Syndrome

- **Cervical**
- **Rotational**
- **Injury**
- **eMbolism**
- **Posterior circulation**

- Stout C, et al, under review

- **Chronic mechanical injury to the vertebral artery at C1/C2**
- **Progressive occlusion with head turning at the level of injury**
- **Tx: surgical decompression or endovascular vertebral occlusion**

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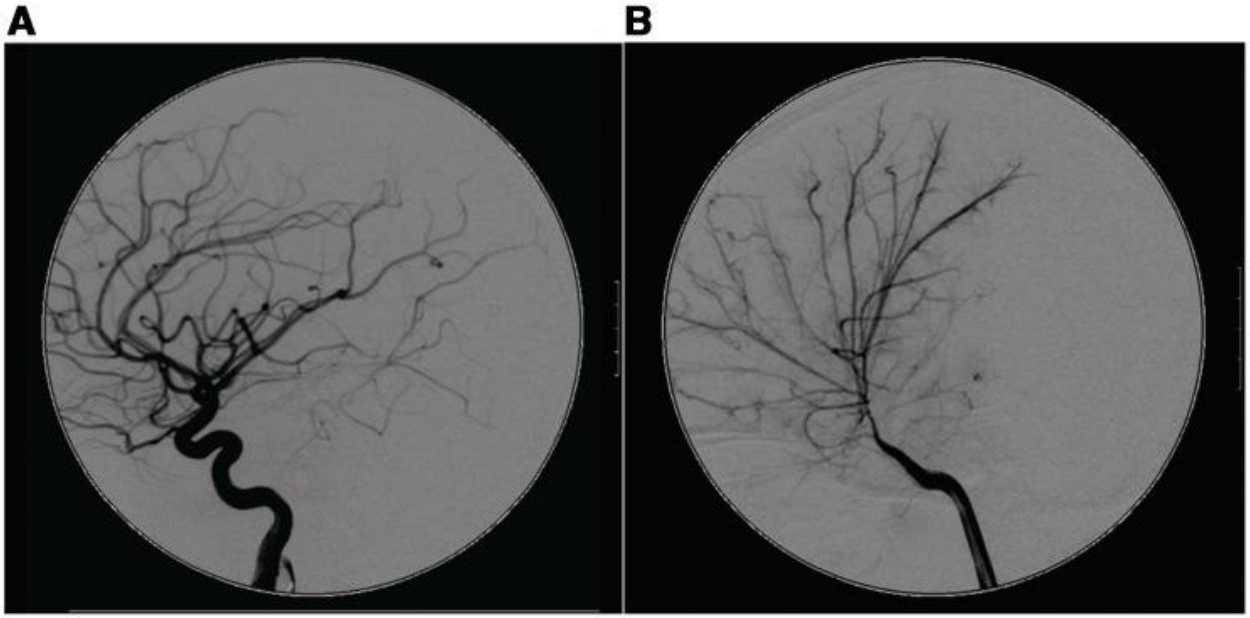

Normal

ACTA2

Moyamoya

Chronic, bilateral arteriopathies in children

Munot, Ganesan, *Brain* 2012

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Moyamoya disease/syndrome

- **Slow narrowing of the tops of the internal carotid arteries in the brain**
- **Seen in kids with sickle cell disease, Down syndrome, neurofibromatosis, brain cancer**
- **Tx: Surgical bypass**
  - *Indirect: EDAS*
  - *Direct: EC-IC bypass*

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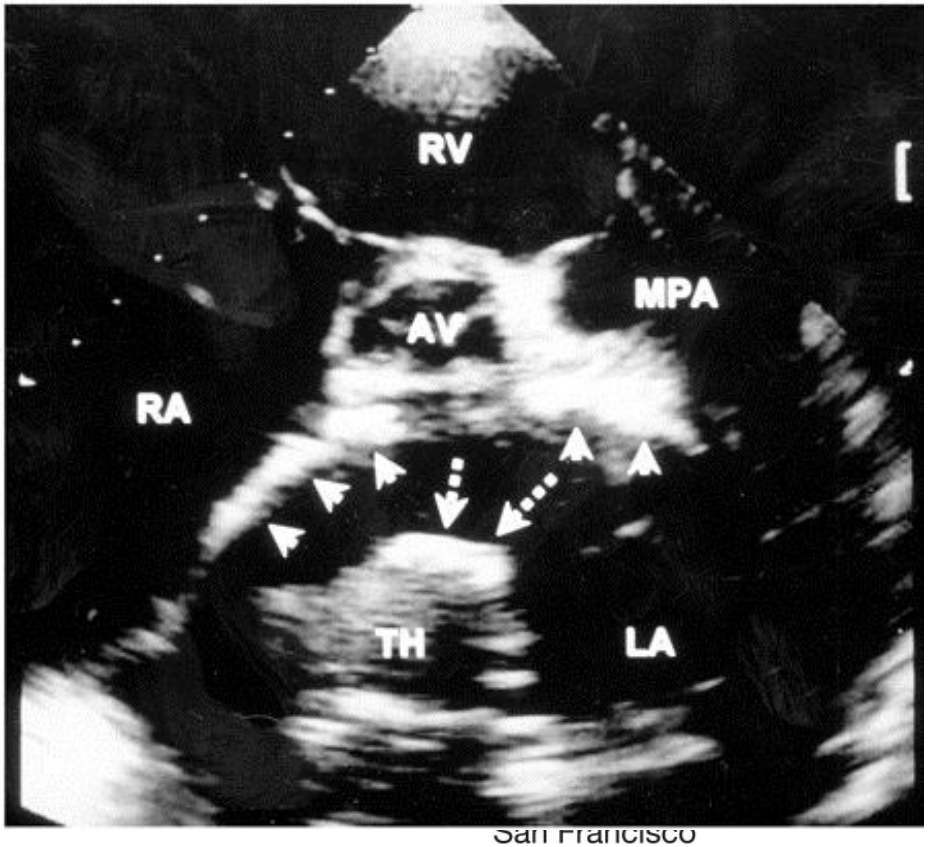
Cardioembolic:
Intracardiac Thrombus

- **Tx: anticoagulation**
- **Duration x months or until clot resolves**



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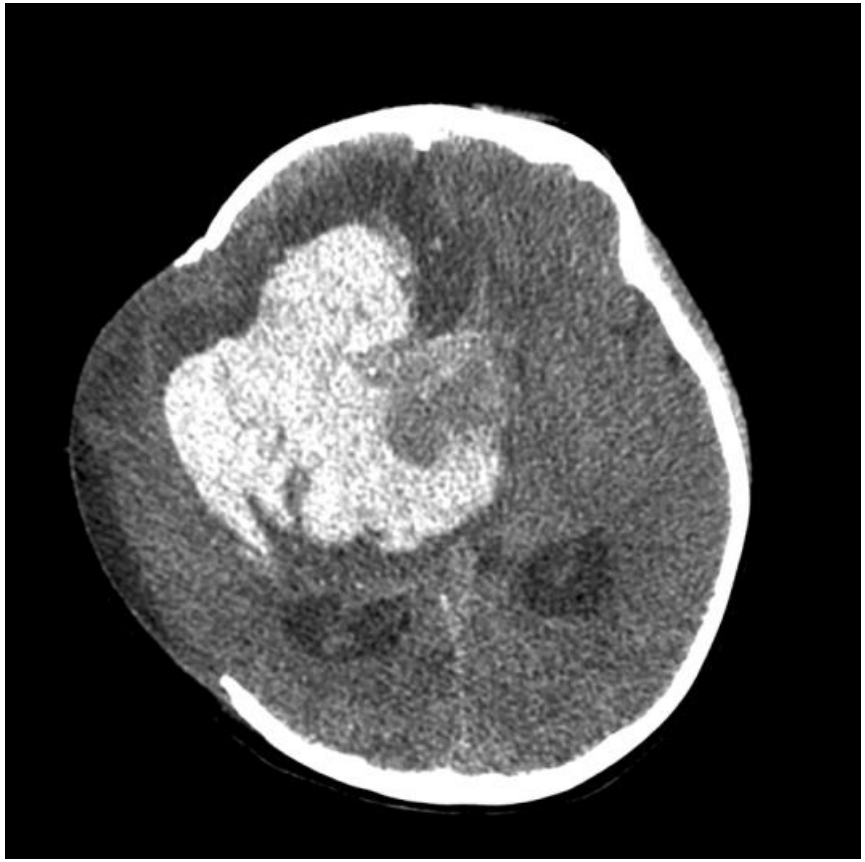
Hemorrhagic Stroke Management



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ICU mgmt: Intracerebral Hemorrhage (ICH)

- **BP control**
  - ***Allow mild HTN---improve cerebral perfusion***
  - ***Prevent significant HTN---extend bleed***
- **Indications for ICP monitor**
  - ***Altered mental status: pathologic or iatrogenic***
- **Manage elevated ICP**
- **Seizure prophylaxis? – consider for large bleeds with high herniation risk**
- **Observe for neurological decompensation: get worse (48-72 hrs) before they get better**

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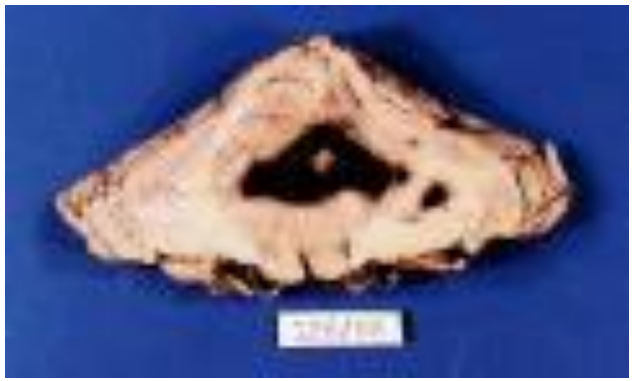
ICU mgmt: ICH

- **Neurosurgical management:**
  - ***Large ICH, ICP refractory to medical therapy***
  - ***Cerebellar ICH***
  - ***Rare for neonates***



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ICU mgmt: ICH

- **Prevent recurrent bleed—look for etiology**
  - ***Check/correct plts, PT, PTT***
  - ***MRI brain:***
    - **Cavernous malformation**
    - **Brain tumor**
  - ***Vascular imaging: MRA and/or conventional angiography***
    - **AVM—most common cause in children**
    - **Aneurysm**
    - **Arteriovenous fistula**

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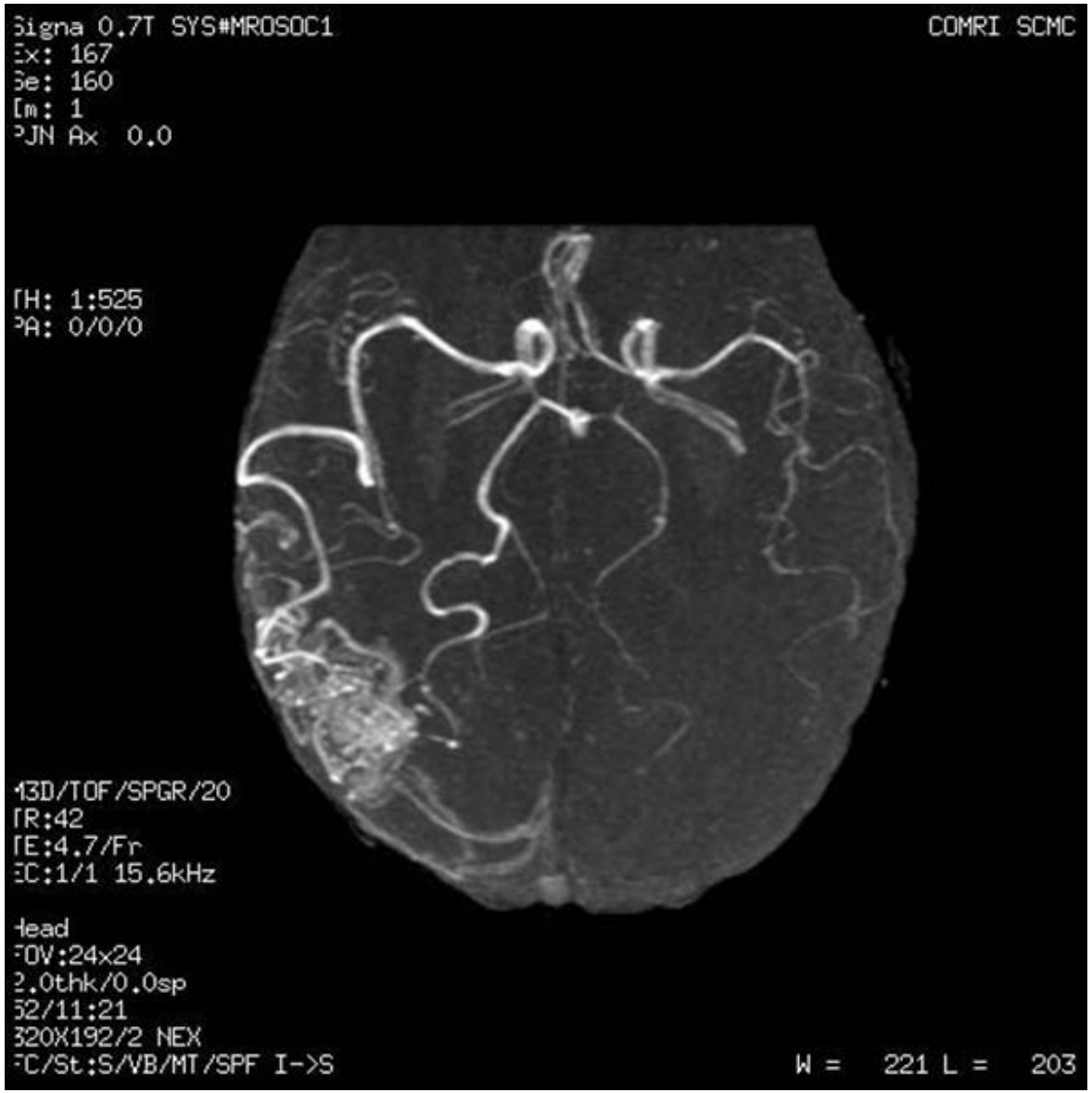

Brain Arteriovenous Malformations (AVM)

- Congenital malformations of blood vessels in the brain
- High flow
- Arteries feeding a nidus (tangle of abnormal vessels), draining into enlarged veins

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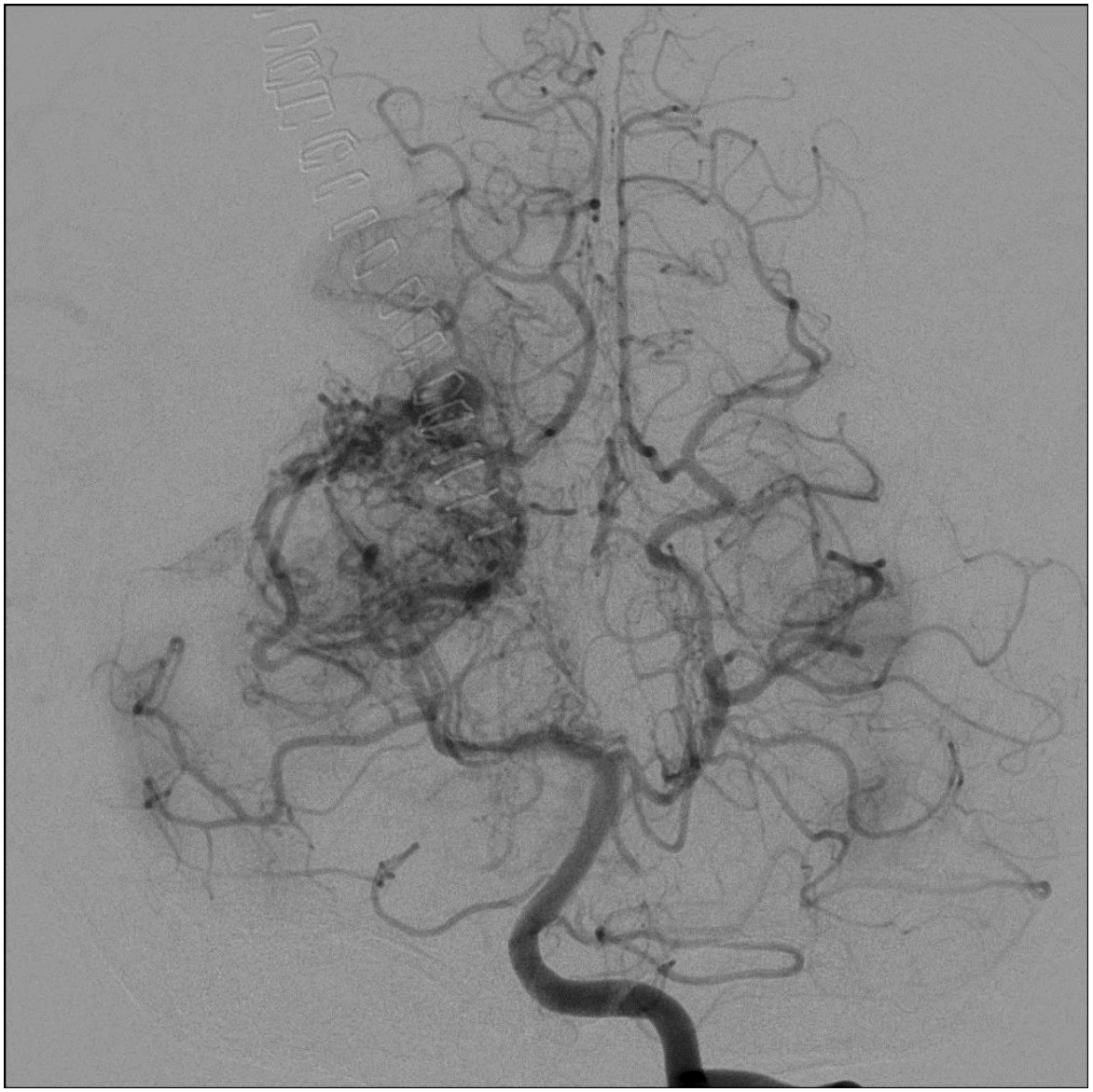

Angiogram Of a Brain AVM

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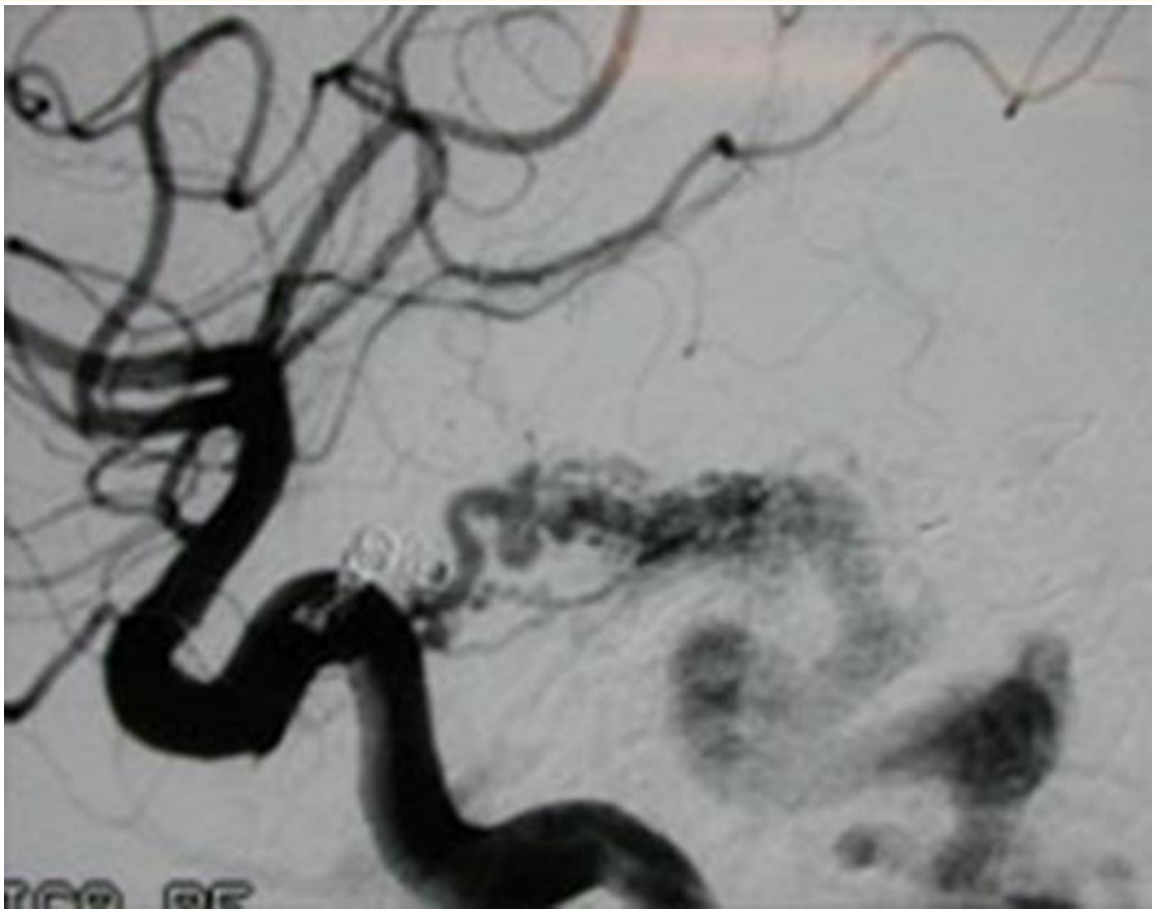
Treatment of Brain AVMs

- Embolization—usually just to decrease surgical risk, but not curative
- Surgical resection—risk based on size, location, deep venous drainage
- Radiosurgery (Gammaknife)—delayed effect (6 mo to 3 years), reserved for high surgical risk or unruptured



Brain Arteriovenous Fistula (AVF)

- Direct connection of artery to vein
- Can be congenital in children
- Tx: endovascular (embolization) first choice, or surgical

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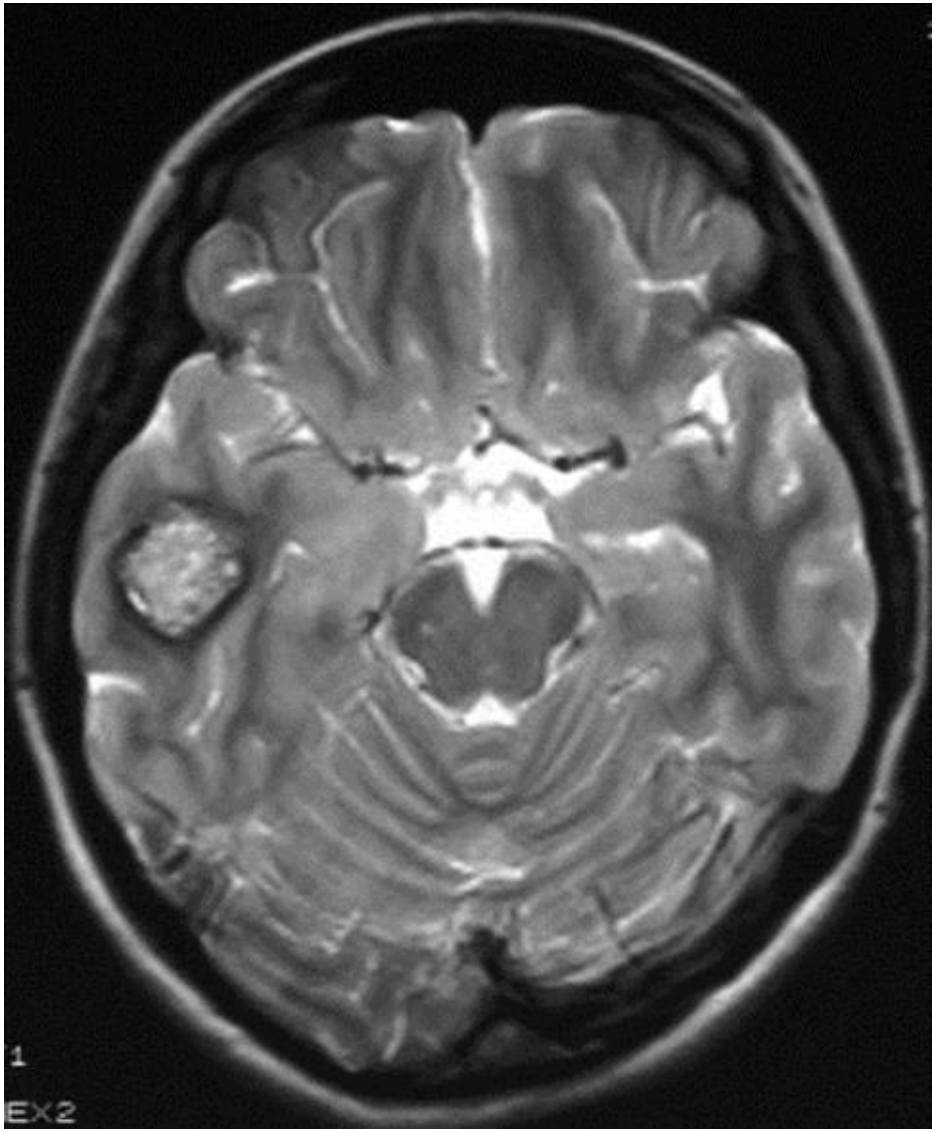

Cavernous Malformation

- congenital or acquired
- can be familial
- low flow lesion
- not seen on angiograms
- tends to cause smaller bleeds
- Tx: surgical resection

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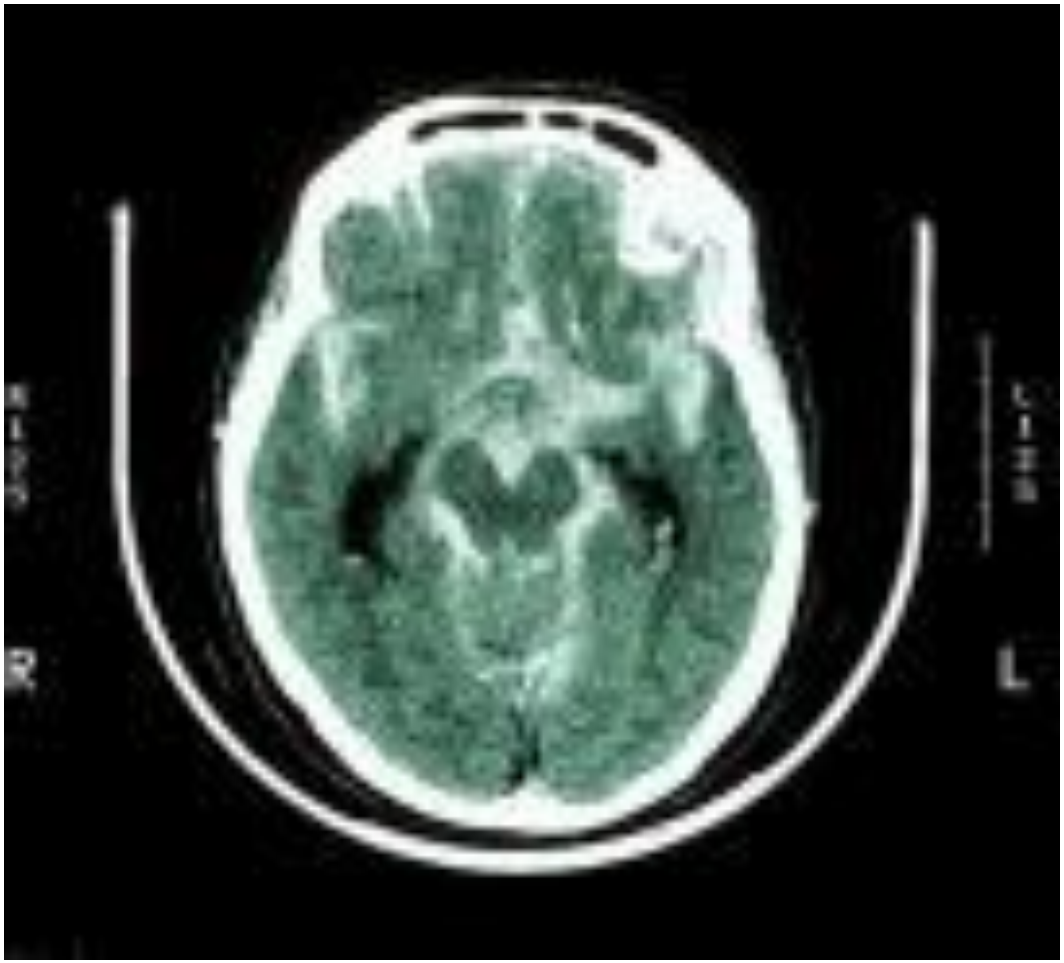
Subarachnoid Hemorrhage



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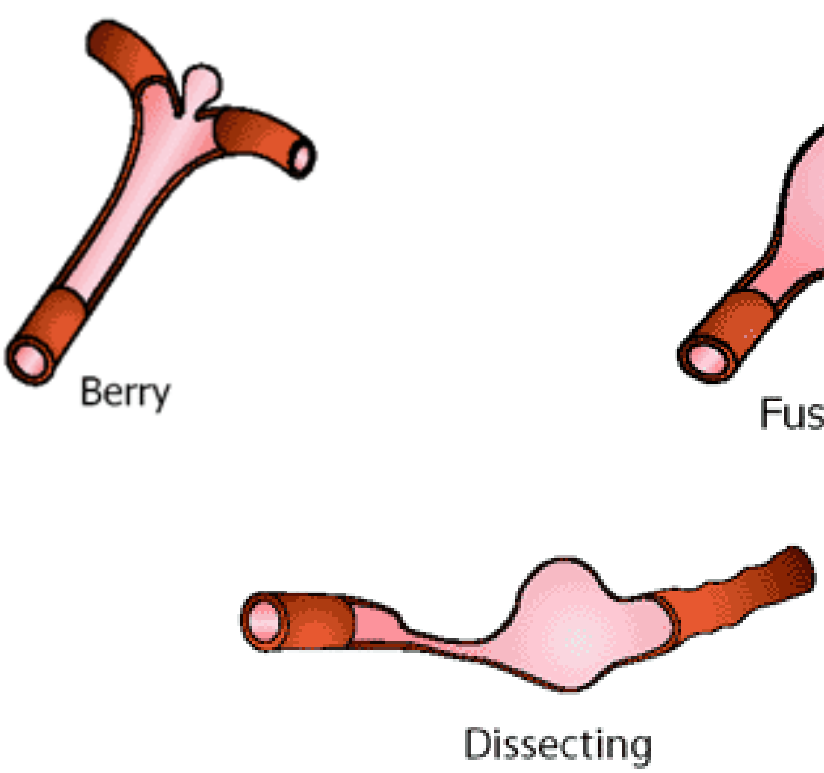
Pediatric Aneurysms

pital

Aneurysm Types



Also mycotic aneurysms

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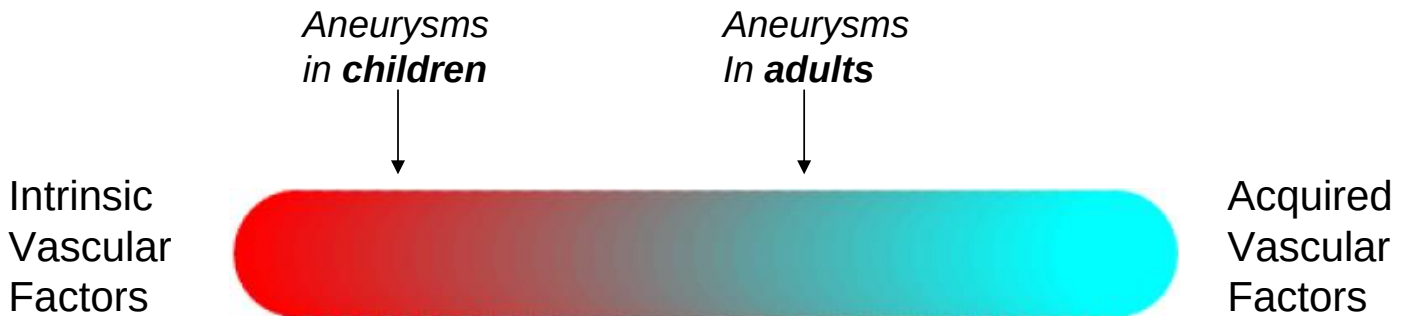
Pathophysiology of Pediatric Aneurysms??

Figure 1. Graphic representation of the concept that pediatric and adult aneurysms may result from different blends of intrinsic and acquired factors.



Connective Tissue Abnormalities

HTN
Smoking
EtOH

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ICU mgmt: SAH/IVH

- **Unsecured aneurysm: prevent rebleeding**
- **Rebleed rate: 5% at 24 hrs, 20% at 2 wks**

- **Keep patient normotensive**
  - *PRN anti-hypertensives*
  - *Analgesics for headache*
  - *Consider prophylactic anti-epileptics*
    - Load with Fosphenytoin 20 mg/kg IV

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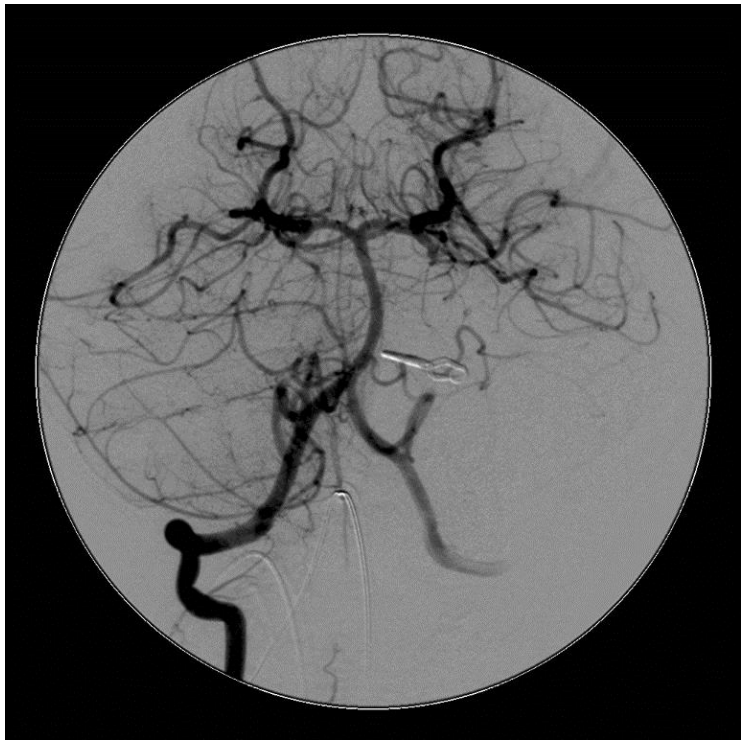
ICU mgmt: SAH/IVH

- **Identify source:**
  - ***Aneurysm or AVM***
  - ***MRI/MRA***
  - ***Conventional angiogram***



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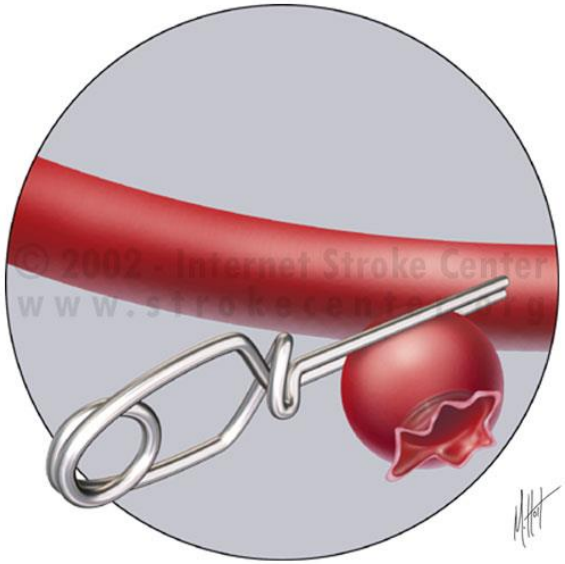
Treatment Options for Aneurysms

- **Endovascular coiling**
- **Surgical clipping**



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ICU mgmt: SAH/IVH

- **“Secured” aneurysm or AVM:**
  - ***Liberalize BP (allow HTN)***
  - ***Stop seizure prophylaxis***
- **Manage/Prevent complications of SAH**
  - ***Hydrocephalus***
  - ***Vasospasm***
  - ***Hyponatremia***

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ICU mgmt: SAH/IVH

- **Hydrocephalus**
  - ***May occur acutely or delayed (up to weeks)***
  - ***Indications for EVD:***
    - **Evidence of hydrocephalus on CT**
    - **Obtundation**
      - ***ie, you don't have an exam to follow***

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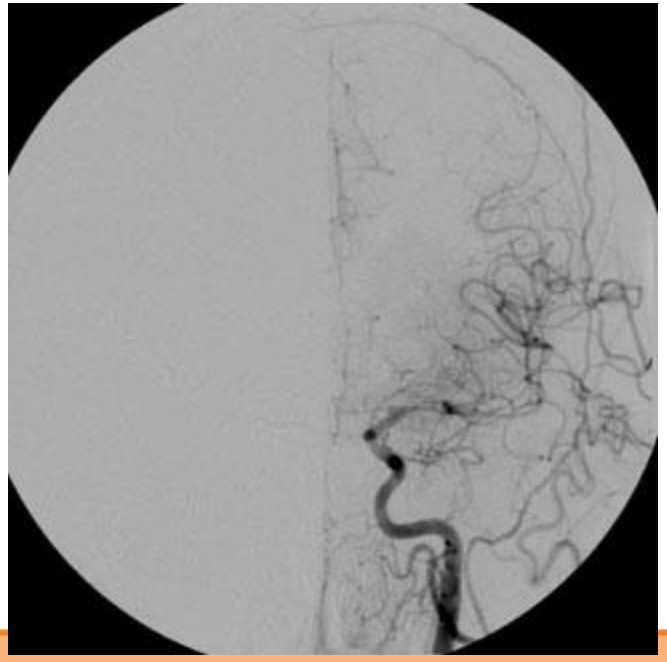
ICU mgmt: SAH/IVH

- **Vasospasm**
  - ***Usually occurs at 4-6 days (range 3 days to 3 weeks)***
  - ***Nimodipine 30 po/FT q 2hrs***
    - **Neuroprotectant**
    - **Start immediately, continue x 21 days**
    - **SE: hypotension**
  - ***Tx:***
    - **HTN, hypervolemia**
    - **angioplasty**



ICU mgmt: SAH/IVH

- **Hyponatremia**
  - ***Cerebral salt wasting (as opposed to SIADH)***
  - ***Follow Na BID initially, then q 6 hours if low***
  - ***Replace with po NaCl (N/V) or IV 3% NaCl***
- **Central (neurogenic) fever**
- **Diabetes insipidus--uncommon**

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Summary

- Pediatric stroke is heterogeneous
- Significant ICU issues
- Vigilance to prevent 2ary injury
- High risk of recurrence

Acknowledgements

- **UCSF Pediatric Stroke & Cerebrovascular Disease Center**
  - *Pedi Vascular Neurologists: Fox, Fullerton, Shapiro*
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  - *Neuropsych: Lundy*
  - *Hematology: Huang*
  - *RN: Sara Rzasa*
- *Part of the*

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