I have no disclosures
SAM: 10 you girl with lymphoma and altered mental status, what is the most likely cause of the parasagittal hemorrhage?

- A. Hemorrhagic lymphoma
- B. Vascular Malformation
- C. Venous Thrombosis
- D. Arterial ischemic stroke
- E. Chemotherapy
Emergency Pediatric brain imaging: balance speed, radiation & cost

• **Brain CT** (mainstay)
  – *ALARA*

• **Non-radiation alternatives:**
  – **Brain US** (neonate and infant)
    • Bleed, ventricles, Doppler
  – **Fast Brain MRI** (T2 3 plane)
    • Shunt malfunction
    • Extra-axial collection
Pediatric Emergency Brain Imaging

- Cerebral venous thrombosis
- Hemorrhage
- Cerebral Edema
- Acquired Infection
- Acute disseminated encephalomyelitis
- Shunt Malfunction
Cerebral Venous Thrombosis (CVT): often a challenging diagnosis

- Unlike AIS, CVT diagnosis by identification of the **thrombus**
  - less common parenchymal edema & hemorrhage
- Often **not anticipated clinically**
  - *In DDX in 5% of ordered CTs and 33% of MRIs*
- Nonspecific clinical features

Clinical Features of CVT

• Symptoms
  – *Headache* (75-95%)
  – Visual change
  – Altered consciousness
  – Nausea, vomiting
• Symptom onset
  – **Subacute**: 55% (6-30d)
  – Acute: 10-30% (0-5 d)
  – Chronic: 15% (> 30d)

• Signs
  – Papilledema
  – Focal neurol deficit
  – Cranial nerve palsy
  – Seizure
  – Coma

*Therefore imaging plays a primary role in diagnosis!*
Predisposing Factors for Cerebral Venous Thrombosis (CVT)

- **Systemic:**
  - Dehydration
  - Hypercoagulable state
    - Thrombophilia: Protein C or S deficiency
    - Malignancy
  - Systemic Infection/inflammation (IBD)
    - Surgery/immobilization
    - Pregnancy or Oral contraceptive use
- **Local:** intracranial trauma or infection
- **Idiopathic** (12-25%)
Imaging of Cerebral Venous Thrombosis

• Direct: clot
  – CT: Hyperdense sinus (20%)

• Indirect: parenchymal

SSS thrombosis
Cerebral Venous Thrombosis

- Hyperdense sinus DDX
  - Thrombus (20%)

Right Sigmoid sinus thrombosis
Cerebral Venous Thrombosis: pitfalls on CT

- Hyperdense sinus DDX
  - Thrombus (20%)
  - Hemoconcentration

* neonate

Normal newborn
Cerebral Venous Thrombosis: pitfalls on CT

- Hyperdense sinus DDX
  - Thrombus (20%)
  - Hemoconcentration
- *neonate
  - Subjacent hemorrhage
- Birth related SDH

Subgaleal hematoma
Parturitional SDH is common!

- 101 asymptomatic term neonates
- Both vaginal and cesarean deliveries
- Brain MRI & US at 3-7d, 1 mo & 3 mo
- 46% had small (most < 3mm) SDH
  - All supratentorial, 20% + infratentorial
  - Most resolved by 1 mo, all by 3 mo
  - Higher incidence than previously (8-10%)
- All had normal development at 24 mo

Imaging of Cerebral Venous Thrombosis

- **Direct: clot**
  - CT: Hyperdense sinus (20%)
  - CT: Cord sign (5%)

- **Indirect: parenchymal**
Imaging of Cerebral Venous Thrombosis

- Direct: clot
  - CT: Hyperdense sinus (20%)
  - CT: Cord sign (5%)
  - CT and MRI post contrast:
    - Empty delta sign (70%)

- Indirect: parenchymal

SSS and TS Thrombosis
Imaging of Cerebral Venous Thrombosis

• Direct: clot
  – CT: Hyperdense sinus (20%)
  – CT: Cord sign (5%)
  – CT and MRI post contrast:
    • Empty delta sign (70%)
  – MRI: subacute T1 & T2 bright

• Indirect: parenchymal

Newborn: Left TS thrombosis
<table>
<thead>
<tr>
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<th>Subacute (6-30d)</th>
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<tr>
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<tr>
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<tr>
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<td>(methemoglobin)</td>
<td>(variable)</td>
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<td>*mimics normal flow</td>
<td>*easiest to see on MRI</td>
<td>*slow flow *collaterals</td>
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<tr>
<td>10-30% of cases</td>
<td>55% of cases</td>
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Signal Relative to gray matter
# Cerebral Venous Thrombosis: MRI

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  - MRI: subacute T1 & T2 bright
  - MRI: blooming on GRE/SWI

- **Indirect:** parenchymal
Imaging of Cerebral Venous Thrombosis

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    • MRI: subacute T1 & T2 bright
    • MRI: blooming on GRE

• **Indirect: parenchymal (41-57%)**
  - Focal edema/hemorrhage
  - Restricted diffusion: 50% with inc T2

Where is the thrombosed vein?
Cerebral Venous Thrombosis: parenchymal abnormality locations

- Superior Sagittal Sinus: parasagittal frontal & parietal lobes

16 yo female on OCP with acute LLE weakness: acute SSS thrombosis
Cerebral Venous Thrombosis: parenchymal abnormality locations

- Transverse Sinus or vein Of Labbe: temporal lobe

Acute left transverse sinus thrombosis

Courtesy of Dr. David Mirsky
Cerebral Venous Thrombosis: parenchymal abnormality locations

- Deep Cerebral Veins:
  - Straight Sinus
  - Vein of Galen (VOG)
  - Internal Cerebral Veins

Acute VOG thrombosis

Courtesy of Dr. David Mirsky
Cerebral Venous Thrombosis: pitfalls

- Variant venous anatomy
  - Arachnoid granulation

7yo boy with headache
Arachnoid Granulation

• Common!
  - Up to 90% on 3D GRE

• SSS, TS > SS

• Round, contain septa, scalloping of adjacent inner table

• Follows CSF
  - CT: low density
  - MRI: T1 hypointense T2 hyperintense

2 different patients
Arachnoid Granulation

• **Common!**
  - Up to 90% on 3D GRE

• SSS, TS > SS

• Round, contain septa, scalloping of adjacent inner table

• **Follows CSF**
  - CT: low density
  - MRI: T1 hypointense, T2 hyperintense
Cerebral Venous Thrombosis: pitfalls

- Variant venous anatomy
  - Arachnoid granulation
- MRI:
  - Slow/turbulent flow

4yo with cerebellitis
Cerebral Venous Thrombosis: pitfalls

- Variant venous anatomy
  - Arachnoid granulation
- MRI:
  - Slow or turbulent flow
  - Increased T1 thrombus signal on post gad

7 yo with thalamic astrocytoma and subacute SSS thrombosis
Cerebral Venous Thrombosis: pearls

- Look at “edges” of CT
  - superior sagittal, transverse and sigmoid sinuses

Hyperdense sinus and cord signs
Cerebral Venous Thrombosis: pearls

- Look at “edges” of CT
  - Superior Sagittal, Transverse and sigmoid sinuses

- GRE and SWI: paramagnetic effect in acute & subacute phases
Cerebral Venous Thrombosis: pearls

- Look at “edges” of CT
  - Superior Sagittal, Transverse and sigmoid sinuses
- GRE and SWI: paramagnetic effect in acute & subacute phases
- Doppler US in neonates
Is this just slow flow in right transverse sinus?

Term newborn with meconium aspiration, MRI following ECMO and head cooling

Mastoid view
Yes, normal flow on US
16 day old *term* baby with seizure.
Deep Medullary Vein Thrombosis

- Cause of hemorrhage and white matter injury in **term** neonates
- In absence of venous sinus thrombosis
- Periventricular T2 hypointense linear or fan shaped
- Frontal predominance

Sphenoid sinusitis with bilateral cavernous sinus thrombosis

Left proptosis
Left sphenoid AFL

Age matched normal comparison
Expanded and nonenhancing cavernous sinuses
Cavernous sinus thrombosis

- Secondary to paranasal sinus, dental or ocular infection
- CT: enlarged, outwardly convex cavernous sinus
- MRI: signal varies depending on cause and evolution
- ** cavernous carotid artery: stenosis, mycotic aneurysm
  - MRA or CTA

Post gad T1 FS
16 yo boy with N/V, HA, dizzy
16 yo boy with N/V, HA, dizzy

Cavernous Malformation

Hemosiderin rim
Cerebral Cavernous Malformation (CCM)

- Hypertrophied capillary beds containing pockets of blood
- Familial and sporadic
  - KRIT1 (CCM1), CCM2 & CCM3 genes
- Imaging: without acute bleed:
  - CT: hyperdense mass
  - MRI: prior hemorrhage
    - Hemosiderin: blooming GRE
    - "popcorn" T1 hyperintensity
    - Heterogeneous on T1 & T2
Familial CCM: 5 mo boy with macrocephaly and tense fontanelle

- Gene mutation **KRIT1 (CCM1)** on 7q
  - 50% multiple if familial (13% if sporadic)
- Consider CCM as cause of small hemorrhage (<3cm)
Nontraumatic Pediatric Brain Hemorrhage: Etiology

• 3 series, each > 50 children

• Vascular anomaly majority for all series (28-62%)
  – Cavernoma, AVM/F, aneurysm

• Coagulopathy 2nd most common (18-32%)
  – Thrombocytopenia

• Tumor (10-15%)
  – Medulloblastoma/PNET, high gr astrocytoma

9 yo girl with sudden onset of HA and vomiting followed by lethargy

CTA: vascular nidus & draining vein

Cerebellar AVM
In children <15 yrs: AVM is the most common cause of spontaneous intracranial hemorrhage
13yo girl found down

Left M2 branch
6mm aneurysm

“nipple”
Cerebral Herniation

Subfalcine

Descending Transtentorial (Uncal)
Term newborn with coarctation and cleft lip/palate, preop head US

Coagulopathy due to Factor VII deficiency
- hemophilia
- brain, GI, MSK bleed (may be life threatening)

GMH, IVH, SAH
A 6-year-old girl with 2 weeks of intermittent headache (HA), ataxia, and emesis.

- **Medulloblastoma**
  - WHO IV
  - Most common malignant brain tumor in children (15-20%)
  - Most common to present with hemorrhage
  - Most common posterior fossa tumor (30-40%) in most series
3yo girl with vomiting and lethargy: Diffuse Cerebral Edema

Deep gray matter edema
Effacement of Suprasellar perimesencephalic & prepontine cisterns
Bright cerebellum
Diffuse sulcal effacement
Cerebral edema

• Protean causes
  – Drowning or near drowning
  – Infection: septic shock
  – Hepatic encephalopathy
  – Uremic encephalopathy
  – Diabetic ketoacidosis
  – Status epilepticus
  – Metabolic derangement
  – Toxin
  – Trauma

Severe cerebral edema
Salicylate toxicity
Cerebral edema

• Protean causes
  – Common thread: disruption of cerebral autoregulation

• Challenging CT: symmetric and subtle early changes

• Brain CT: scrutinize:
  – Deep gray matter
  – Sulci
  – Cisterns
    \[\text{most reliable}\]
  – Cerebellar density

Severe cerebral edema
Salicylate toxicity
Transient cerebral edema due to encephalopathy following GI illness

Normal CT 1 yr ago

Vertex sulcal effacement

1 day later: normalized sulci
ARS: 20 month old drowning victim, what is the prognosis?

- A. Good
- B. Fair
- C. Dismal
- D. Uncertain
ARS: 20 month old drowning victim, what is the prognosis?

- A. Good
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Reversal Sign on CT

- Severe diffuse anoxic/ischemic cerebral injury
- Supratentorial gray matter is darker than white matter
  - Relative increased density of basal ganglia
- Poor prognosis, irreversible brain damage
  - Series of 20 children (40% died, rest with profound deficit)

Han BK et al. AJNR 1989 10: 1191-1198
US analogue of reversal sign: diffuse cerebral edema

2 week old baby with complex CHD & coagulopathy

Normal US for comparison
9 yo girl with vomiting, fever & seizure

Diffuse cerebral edema:
- Bilateral uncal herniation
- Obliteration of the perimesencephalic cistern
- Diffuse sulcal effacement
- Bright cerebellum
- BUT deep and superficial gray-white differentiation preserved
9 yo girl with vomiting, fever & seizure
9 yo girl with vomiting, fever & seizure

Cerebral edema due to Mycoplasma Meningitis
Acquired Brain Infection: Meningitis, Empyema, Cerebritis, Abscess

- **Etiology**
  - Hematogenous
    - Neonates, infants
  - Local Extension
    - Child/adolescent
      - Paranasal sinus
      - Otomastoid
    - Other: postop, trauma

10 yo boy with headache: acute sinusitis with epidural abscess
10 yo boy with headache and altered mental status
Complicated sinusitis with meningitis and epidural abscess

Epidural abscess may be remote from infected sinuses
Meningitis complications

- Effusion
- Empyema
- Cerebritis
- Ventriculitis
- Abscess
- Hydrocephalus
- Venous thrombosis
- Arterial Vasculopathy

All may be life threatening

Neonate with E. Coli meningitis
Diffuse meningeal enhancement
6 month old with fever and dysconjugate gaze

Post-contrast

Post Gad T1
Meningitis complications: Effusion vs Emypema

- Subdural or subarachnoid
  - Rarely epidural
- Group B strep, E. Coli, S. pneumoniae
  - Rarely H Flu (vaccine)
- Frontal-parietal-temporal
  - Convexity > parafalcine
  - Loculated by MRI in 50%
- Distinguish on DWI
  - Empyema: restricted
4 month old with group B Strep meningitis and lethargy

T1 pre  T1 post  Restricted diffusion

Subdural empyema
2 yo girl with seizure and altered mental status
Meningitis complications: Cerebritis (encephalitis)

- Earliest stage of purulent brain infection
  - Bacterial or viral (HSV)
- With empyema in 20%
- Imaging: ill-defined edema on US, CT or MRI
- Resolves with Abx or evolves to abscess
- DDX ischemia due to venous or arterial occlusion
  
HSV meningoencephalitis
3 week old girl with seizures and poor feeding

Neonatal herpes simplex encephalitis
Neonatal vs Child/adolescent Herpes Simplex Encephalitis (HSV)

**Neonatal (HSV 2)**
- Hematogenous
- Widespread
- Watershed pattern (40%)

**Child (HSV 1)**
- Reactivation of latent
- Medial temporal lobe, cingulum and insula

Both require a high index of suspicion
*May mimic infarction- especially in neonate*
4 month old with macrocephaly and tense fontanelle

Brain abscess
Staph Aureus
This infant was treated with trans-fontanelle needle drainage
Brain Abscess

NEONATE
- Large at diagnosis
- Poor capsule formation
  - Often incomplete
- Begin in periventricular white matter

CHILD (similar to adult)
- Small at diagnosis
- Capsule formation 7-14 d
- Begin in subcortical white matter or Basal ganglia

4 month old 12 year old

T1 post DWI
Brain Abscess: Risk factors in children

- Paranasal sinus or otomastoid infection
- Congenital heart disease
- Endocarditis
- Sepsis
- Pulmonary infection
- Immunodeficiency or immunosuppression
- Head or neck trauma
Brain abscess: child

7 year old girl with headache and vomiting

Strep anginosus, undiagnosed PFO
Brain Abscess Imaging

- Capsule thicker on **cortical** side (increased vascularity)
- DWI to distinguish cystic/necrotic tumor:
  - Abscess: restricted
  - Nec tumor: increased
  - BUT: if aspiration performed, susceptibility from blood (use GRE, SWI)

![Magnetic Resonance Imaging (MRI) Images](image)
14 month old boy: vomiting & lethargy

T1 post gad
14 month old boy: vomiting & lethargy
Tuberculous Meningitis

- *Family member with TB
- Intense basilar cistern meningeal reaction
  - Hydrocephalus (50-75%)
  - Vasculitis
  - Infarction: BG, thalamus
- Imaging: improved conspicuity
  - Delayed post Gad (5 min)
  - Post contrast FLAIR
- **DWI not reliable (conflicting)**
9yo girl with HA, vomiting, confusion

- Multifocal asymmetric subcortical white matter and deep cerebellar white matter hypodensity DDX:
  - ADEM (Acute Disseminated EncephaloMyelitis)
  - Viral encephalitis
  - Multiple sclerosis
  - Neurosarcoidosis
9yo girl with HA, vomiting, confusion:
ADEM

FLAIR
ADEM

- Autoimmune
  - Post viral, vaccine > > bacterial (mycoplasma), drug
- Deep gray matter lesions 50%
- Brain stem and cerebellar lesions (each 30-50%)
- Spinal cord involvement 24%
- Rx: steroids, 70-90% complete recovery
- 25% later DX: MS (>10Y)

11yo girl ADEM
Fussy and lethargic 7mo old

Baseline 4mo

Trapped 4th ventricle
Trapped 4th Ventricle

- Chronic sequela of shunt
- Rare: incidence 2.3-3%
- Due to repeated hemorrhage/infection leading to scarring of cerebral aqueduct and foramina of Magendie and Luschka
- *Fast MRI: visualize aqueduct
- Mass effect on brainstem
- Treatment: 2nd catheter
Shunt malfunction

• Common: incidence:
  – 14% 1st mo; 50% 1st year

Causes:

• 1. obstruction (most common)
• 2. breakage (2nd)
• 3. infection (3rd)
• 4. slit ventricle syndrome (rare)
• 5. malposition or migration

Shunt malfunction: Imaging Evaluation

- **Brain US**- neonate and infant
- **Brain CT**: change in ventricle size
  - *Temporal* horn 1st; *Occipital* horn in infants
- "Quick brain MRI": 3 plane fast T2
  - As sensitive as CT in diagnosis, no radiation
  - **must re-evaluate valve setting after MRI**
- **Radiographic shunt series** (highest yield if swelling along shunt tract): discontinuity, kink, migration;
  **sutural diastases, wide sella**
14 yo girl with HA, pain along shunt

6 mo ago

Shunt series: intact, non-radiopaque valve noted...
Disconnection just below valve diagnosed by fast MRI

6 mo ago
Pediatric Emergency Brain Imaging

- Cerebral venous thrombosis
- Hemorrhage
- Cerebral Edema
- Acquired Infection
- Acute disseminated encephalomyelitis
- Shunt Malfunction
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Superior Sagittal Sinus Thrombosis

- Risk factor: lymphoma
  - Hypercoagulable state
- MRI: T1 and T2 hyperintense clot
  - Subacute
- Typical infarct location: paramedian
Thank you for your attention!

Enjoy San Antonio!
References for SAM


