A Picture is Worth a Million Neurons

Neuroimaging in Acute Stroke

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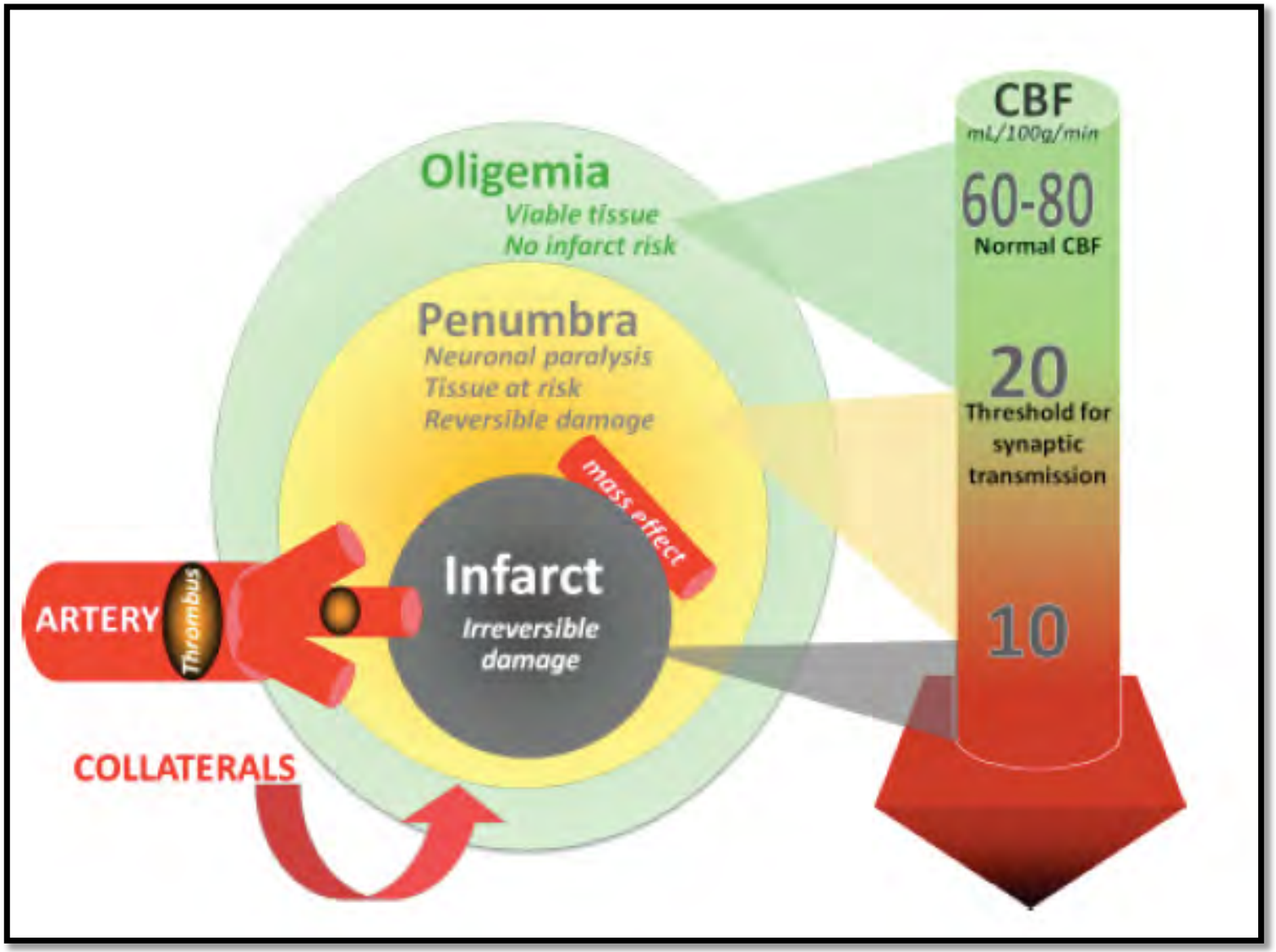
Disclosures

- None

Outline

- Discuss the role of acute neuroimaging in
  - Acute Ischemic Stroke (AIS)
  - Intracerebral Hemorrhage (ICH)
  - Diagnosis of Subarachnoid Hemorrhage (SAH)

Acute Ischemic Stroke



Eur Neurol 2014;72:309–316

12
1
TIMEX
2
3
4
QUARTZ
5

Current Guidelines: IV rtPA

- Non-Contrast HCT (NCCT) or MRI prior to rtPA to evaluate for:
  - ICH, SAH, or Mass -> no rtPA
  - Frank Hypodensity c/w completed infarction
    - If involves >1/3 of MCA territory -> no rtPA
  - **Of note: rtPA is recommended with early ischemic changes (NOT hypodensity), *regardless of their extent*

Stroke. 2013 Mar;44(3):870-947

Endovascular Guidelines

2. **Patients should receive endovascular therapy with a stent retriever if they meet all the following criteria *(Class I; Level of Evidence A)*.** (New recommendation):
   a. **Prestroke mRS score 0 to 1,**
   b. **Acute ischemic stroke receiving intravenous r-tPA within 4.5 hours of onset according to guidelines from professional medical societies,**
   c. **Causative occlusion of the ICA or proximal MCA (M1),**
   d. **Age ≥18 years,**
   e. **NIHSS score of ≥6,**
   f. **ASPECTS of ≥6, and**
   g. **Treatment can be initiated (groin puncture) within 6 hours of symptom onset**

Stroke. 2015;46: 3024-3039.

NCCT in AIS

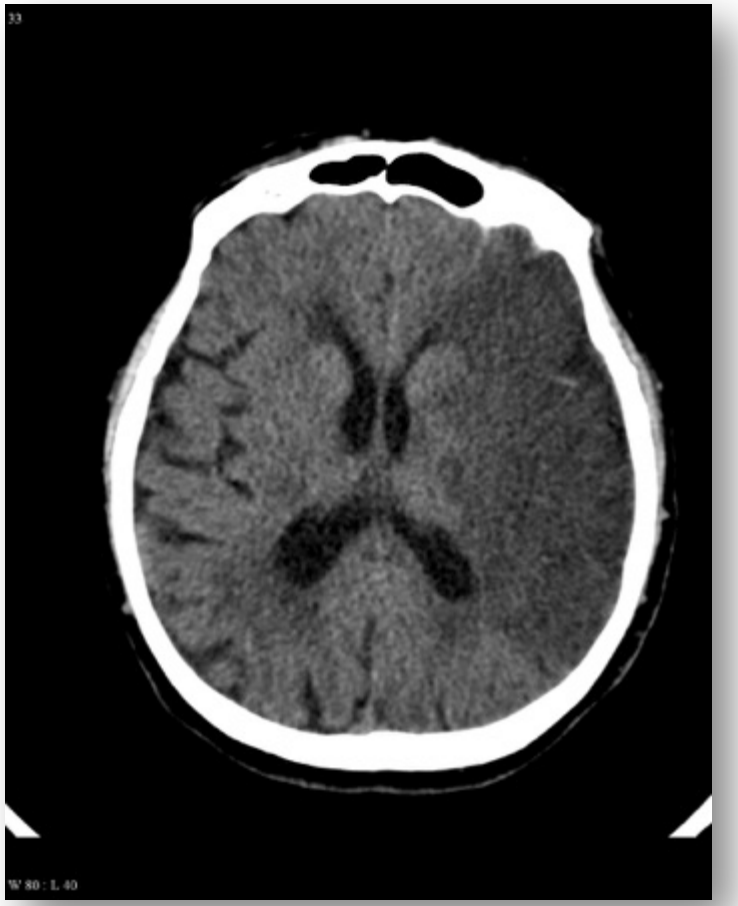
Early Ischemic Changes (EIC)

vs

Frank Hypodensity

?ASPECTS?

“Frank” Hypodensity

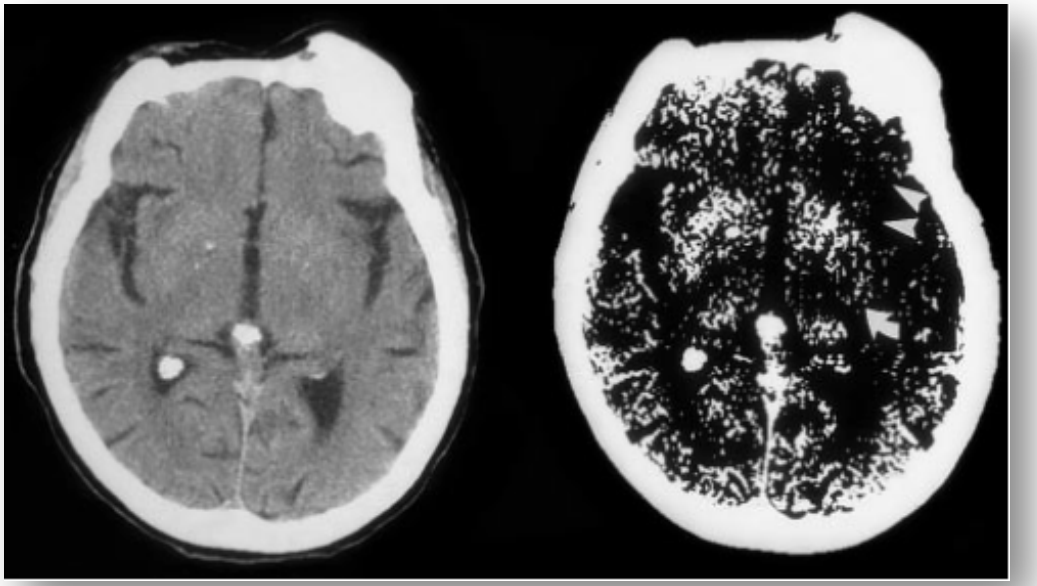


Courtesy Jordan Bonomo, MD

Early Ischemic Changes- NCCT

- Loss of Gray-White Differentiation
  - Basal Ganglia (Lenticular Obscuration)
  - Insula (Insula Ribbon Sign)
  - Cortex (Cortical Ribbon Sign)
- Cerebral Edema
  - Cortical sulcal effacement

Adjusting NCCT "Windows"



Radiology 1999; 213:150–155

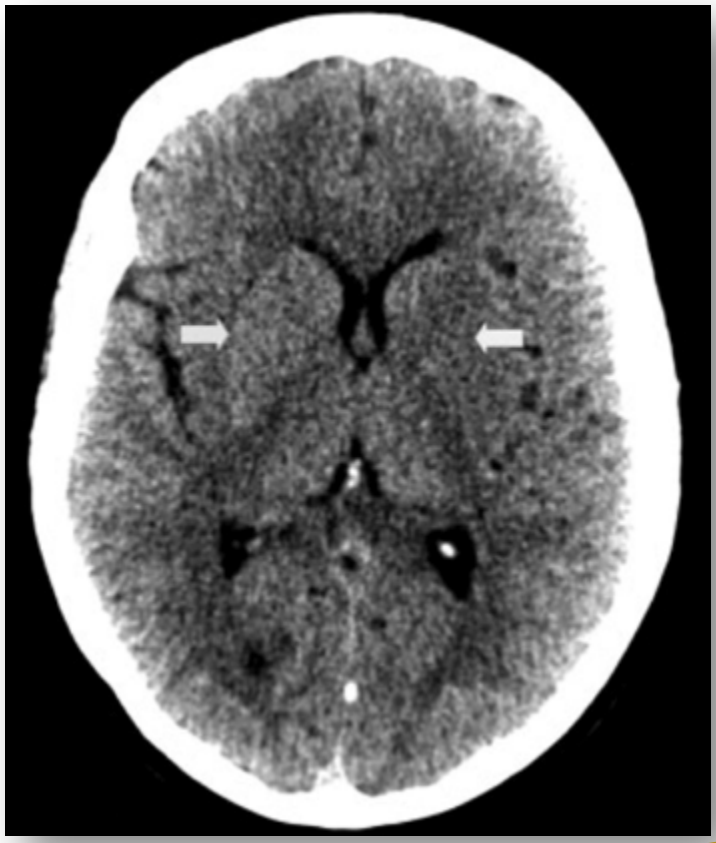
Window Options:
W 30-45 / L 30-45

Courtesy Jordan Bonomo, MD

Lenticular Obscuration

Standard NCCT Window

“STROKE WINDOW”



The British Journal of Radiology, 84 (2011), 1061–1066

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Cortical Ribbon Sign

Standard NCCT Window

“STROKE WINDOW”

The British Journal of Radiology, 84 (2011), 1061–1066

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Insular Ribbon Sign

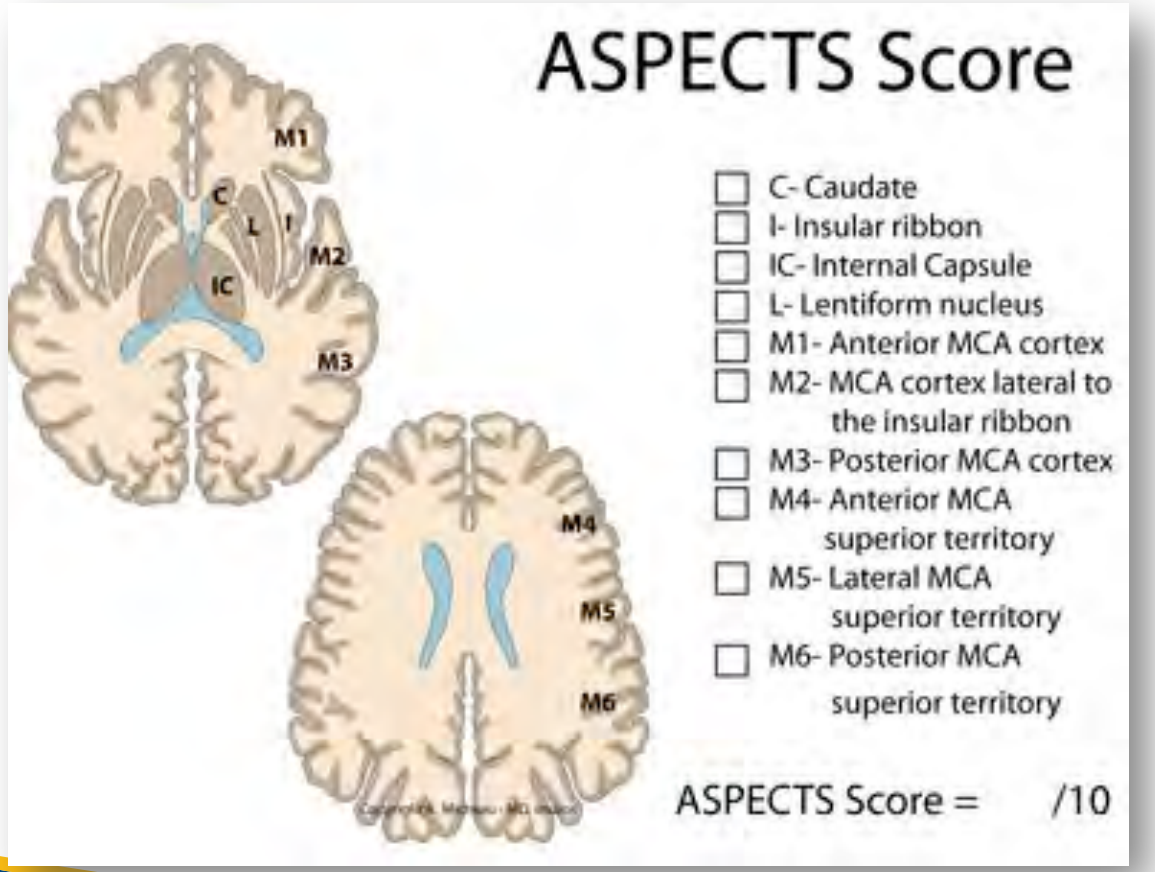
Standard NCCT Window

“STROKE WINDOW”

The British Journal of Radiology, 84 (2011), 1061–1066

ASPECTS: MCA Territory

Alberta Stroke Program Early CT Score



Look at all Cuts

CT cuts at level of Basal Ganglia

C/ IC/ L/ I

M1/ M2/ M3

CT Cuts > 1 cm rostral to Basal Ganglia:

M4/ M5/ M6

Lose 1 point for each area with EIC

http://www.aspectsinstroke.com/

Lancet 2000; **355:** 1670–74

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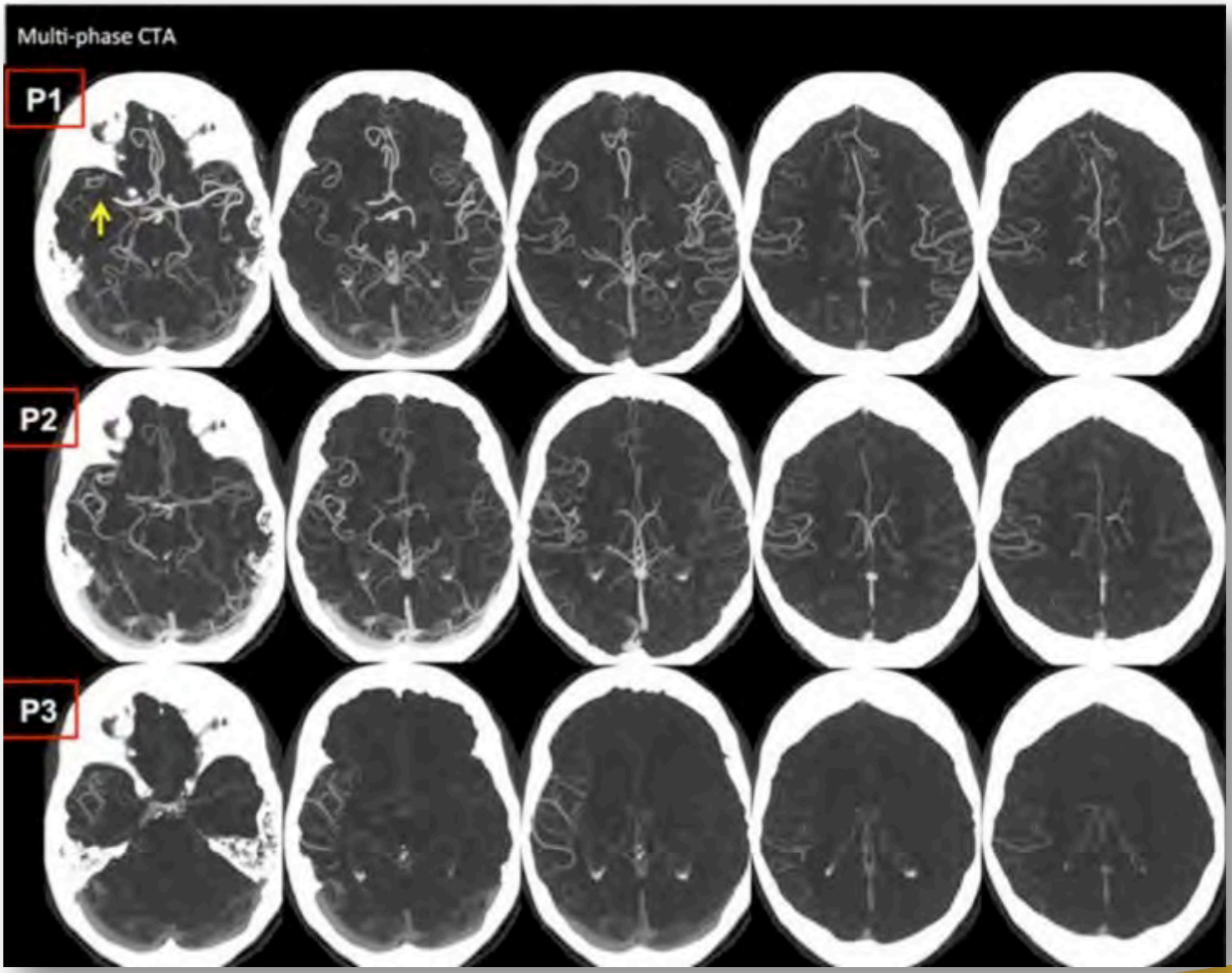
CTA Head and Neck

- NIHSS > 5
- Lethargy to Coma + ->
  - Spontaneous Tonic Posturing or
  - Brainstem Findings
    - CR, VOR, Pupils
- Distal ICA, M1, Basilar
  - > EVT Candidate
- Source Images vs MIPs

Courtesy Jordan Bonomo, MD

Collaterals on Multiphase CTA

- 3 Phases:
  - Peak Arterial: from Aortic Arch to Vertex
  - Mid Venous: Skull Base to Vertex
  - Late Venous: Skull Base to Vertex
- Good/ Adequate
  - CTA ASPECTS > 5
  - > 50% of territory of ischemia
  - Uncertain incremental benefit over NCCT ASPECTS



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Stroke. 2015;46:1453-1461

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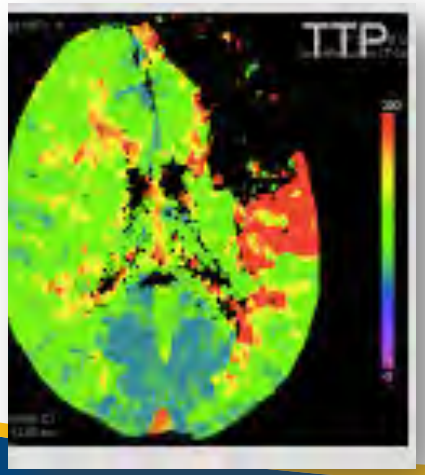
CT Perfusion

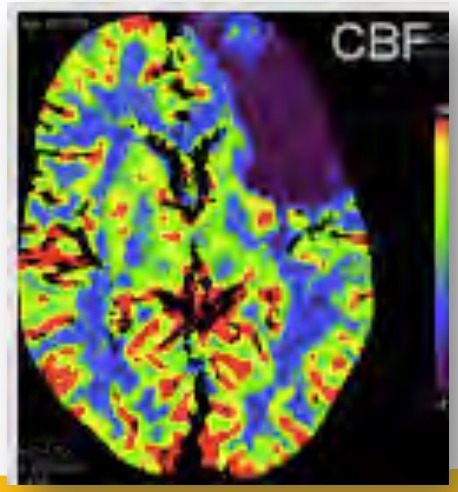
Time To Peak (TTP)/ Tmax

- Tmax > 10 sec
  - Core Infarct
- Tmax 6-10 sec
  - Penumbra



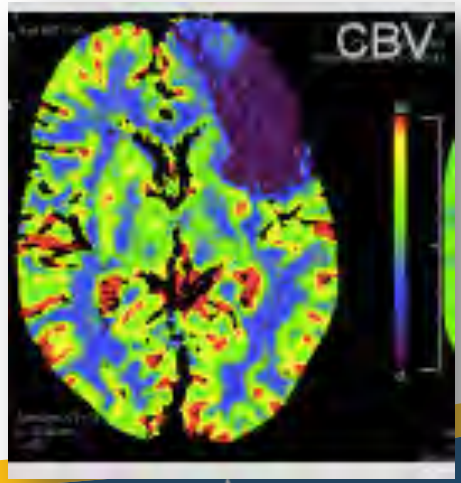
Cerebral Blood Flow (CBF)

- < 30% ”normal”
  - Core Infarct
- 30-100%
  - Penumbra



Cerebral Blood Volume (CBV)

- < 40% ”normal”
  - Core Infarct
- Normal to ↑
  - Penumbra



Images Courtesy Jordan Bonomo, MD

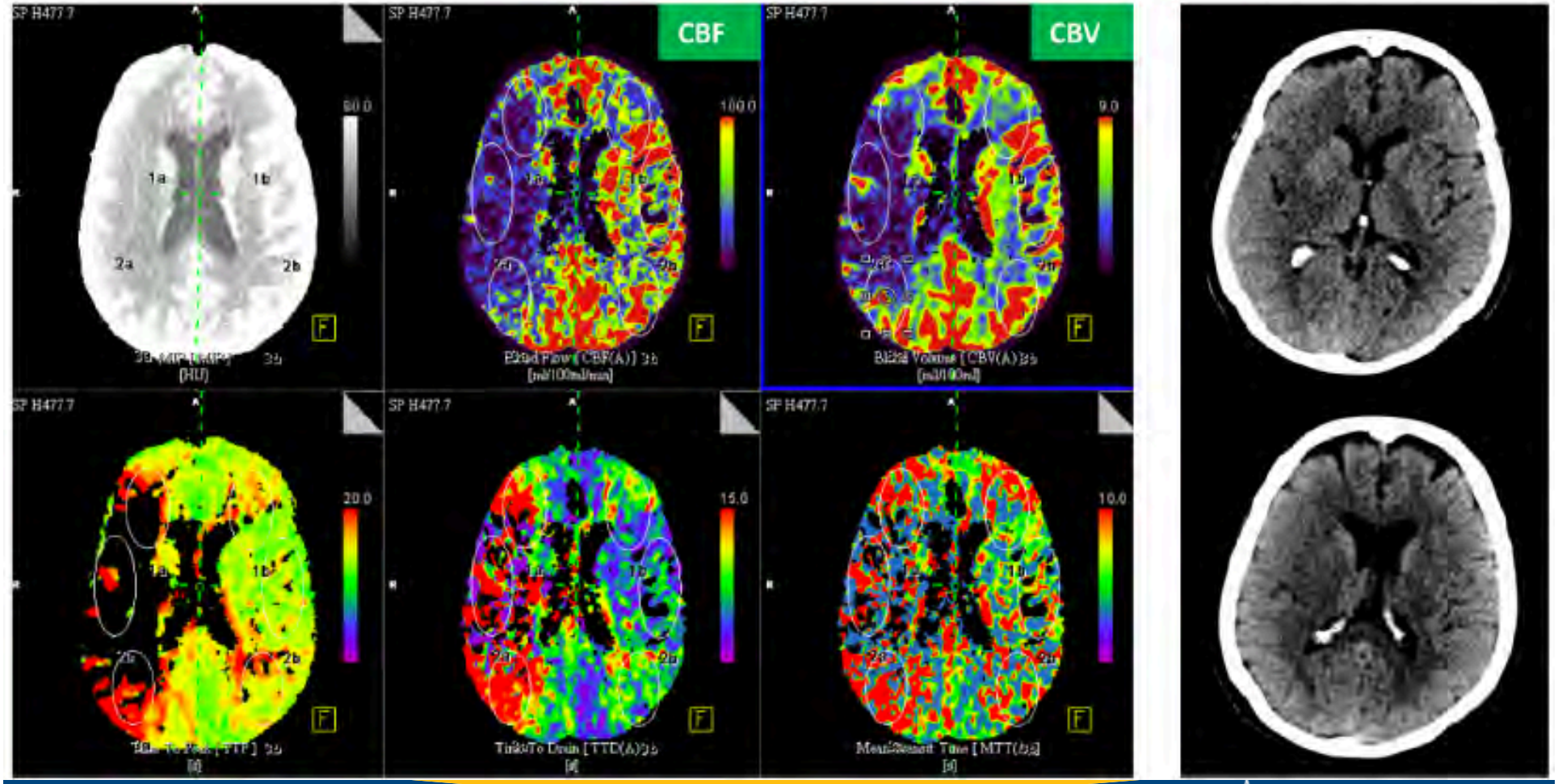
CT Perfusion

- Criteria (not standardized)
  - Small Core < 70 ml; many definitions
  - Penumbra: Infarct Ratio > 1.2
  - Penumbra Volume > 10 mL
- Limitations
  - Normal Values for Basal Ganglia, WM, GM
  - Standardization of Software, performance methods, and values across populations
  - May over-call core infarct size when done early

Admission CT perfusion may overestimate initial infarct core: the ghost infarct core concept

Admission CTP

24h CT



Boned S, *et al. J NeuroInterv Surg* 2017;**9**:66–69.

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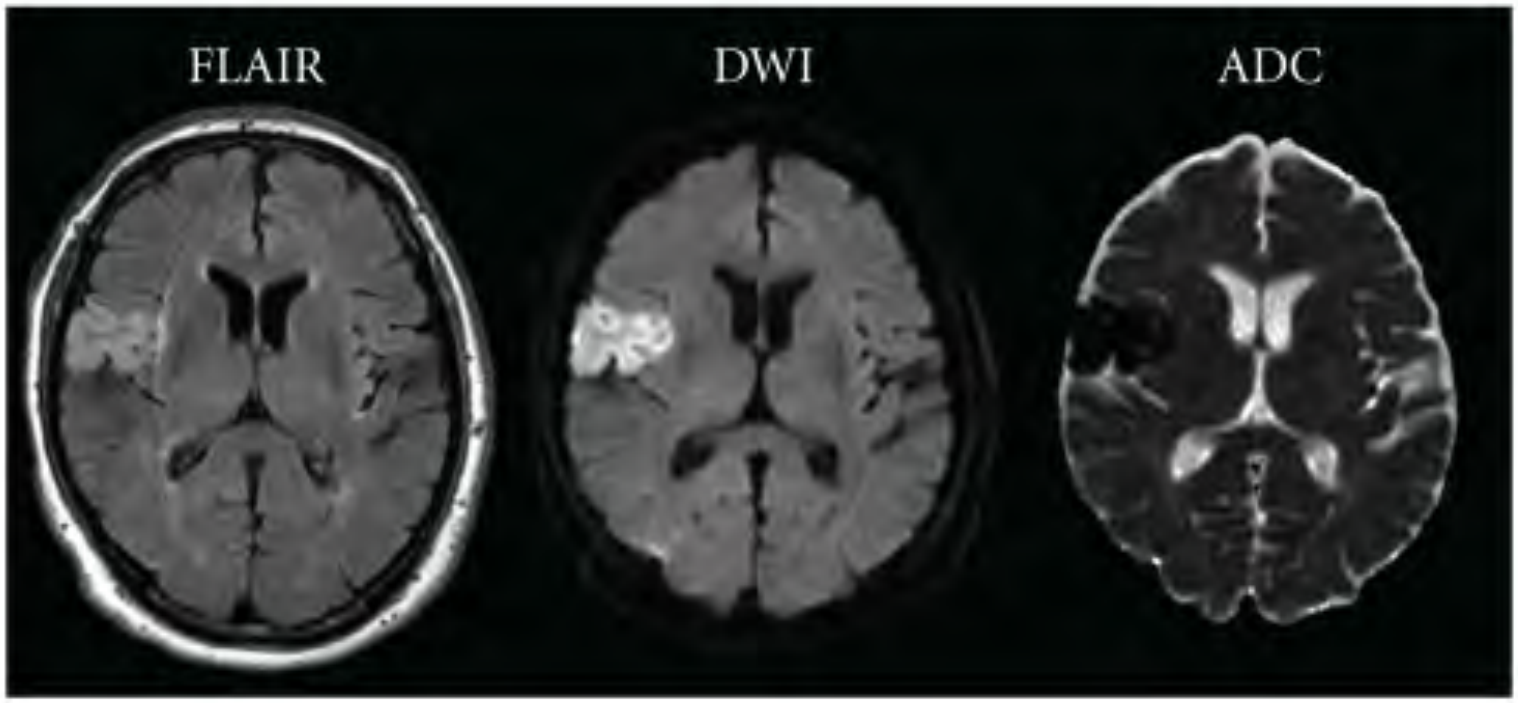
MRI Images



“Wake Up” Stroke: Trials on Going

- MR Witness: DWI/ FLAIR mismatch; 4.5- 24 hrs
  - Phase 2 complete
  - Applying for I-Witness, MRI or NCCT
- DIFFUSE 3: CTP; 6-16 hrs
- WAKE UP: Europe, DWI/ FLAIR mismatch
- DAWN: 6-24 hours MRP or CTP
  - Stopped early for efficacy on 3/9

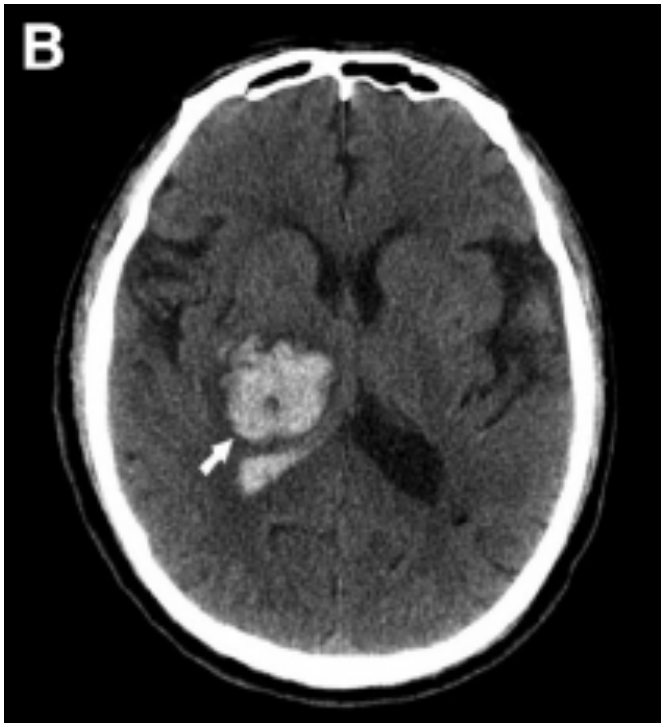
Hemorrhagic Stroke (ICH)

Acute Neuroimaging in ICH

- NCCT 100% Sensitive
  - MRI with Gradient Echo (GRE) or Susceptibility Weighted Imaging (SWI) also 100%
- Predicting Hemorrhage Expansion
  - NCCT: ”Black Hole Sign”, “Swirl Sign”, Meniscus, Heterogeneous Hematomas
  - CTA contrast extravasation (“spot sign”)
- Etiology of ICH: CTA

Black Hole Sign

- ~15% Prevalence
- ~30% Sens,~95% Spec



(*Stroke*. 2016;47:1777-1781.

Heterogeneity, Meniscus, Swirl Sign

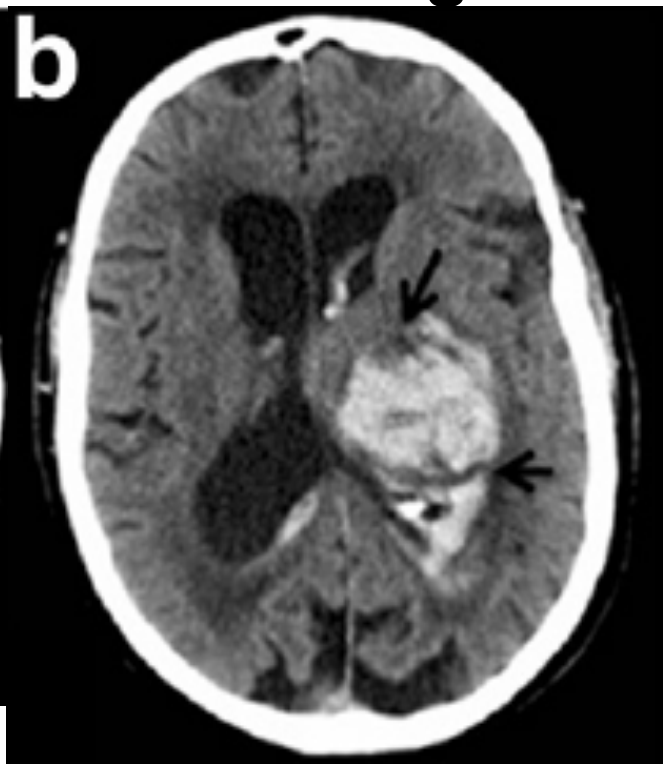
Heterogeneity

(*Stroke*. 2009;40:1325-1331.)

Meniscus

Selariu *et al. BMC Neurology* 2012, **12**:109

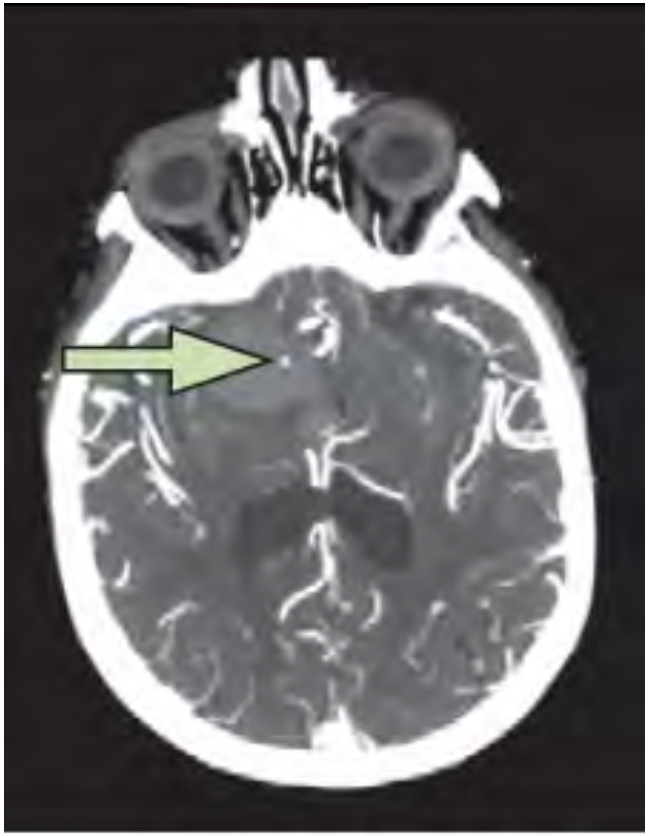
Swirl Sign



Selariu *et al. BMC Neurology* 2012, **12**:109

Spot Sign

- CTA ~ 3 hours from LKWT
- ~30% Prevalence
- ~50% Sens, 85% Spec
- Outcomes
  - 8.4 mL vs 0.6 mL expansion
  - mRS 3 vs 5
  - Mortality 20% vs 43%



Baseline CTA (single spot-sign positive)

Lancet Neurol 2012; 11: 307–14

Secondary ICH Score

- High Prob NCCT
  - 1) enlarged vessels or calcifications along the margins of the ICH
  - 2) hyperattenuation within a dural venous sinus or cortical vein along the presumed venous drainage path of the ICH
- Low Prob NCCT
  - Basal ganglia, thalamus, or brain stem ICH
  - No High Prob features

Table 2: Calculation of the SICH score

Parameter	Points
NCCT categorization[a]	
High probability	2
Indeterminate	1
Low probability	0
Age group	
18–45 years	2
46–70 years	1
≥71 years	0
Sex	
Female	1
Male	0
Neither known HTN nor impaired coagulation[b]	
Yes	1
No	0

AJNR Am J Neuroradiol 31:1653–60

Secondary ICH Score

Table. Predictive Value of the SICH Score

	Derivation Cohort (ICH, n=623; SICH, n=91)		Validation Cohort (ICH, n=204; SICH, n=48)	
SICH Score	ICH, n (%)	SICH, n (%)	ICH, n (%)	SICH, n (%)
0	37 (5.9)	0	3 (1.5)	0
1	145 (23.3)	2 (1.4)	33 (16.2)	0
2	209 (33.5)	11 (5.3)	56 (27.5)	9 (16.1)
3	138 (22.2)	25 (18.1)	55 (27.0)	15 (27.3)
4	61 (9.8)	24 (39.3)	45 (22.1)	19 (42.2)
5	28 (4.5)	24 (85.7)	8 (3.9)	2 (25)
6	5 (0.8)	5 (100)	4 (2.0)	3 (75)
AUC (95% CI)	N/A	0.86 (0.83–0.89)	N/A	0.73 (0.65–0.80)

AUC indicates area under the curve; CI, confidence interval; ICH, intracerebral hemorrhage; N/A, not applicable; and SICH, secondary ICH.

(*Stroke*. 2013;44:2904-2906.)

- 1376 patient series from Dartmouth
  - > 65 yoa, PMHx of HTN with a BG or cerebellar ICH
    - -> 0% yield on CTA

J Neurosurg 117:761–766, 2012

Subarachnoid Hemorrhage (SAH)

Sensitivity of Early Brain Computed Tomography to Exclude Aneurysmal Subarachnoid Hemorrhage

A Systematic Review and Meta-Analysis

(*Stroke*. 2016;47:750-755.

- 5 studies, 8907 patients
- NCCT within 6 hours of symptom onset
  - 98.7 % sensitive (95% CI 97.1% – 99.4%)

- Is real world sensitivity lower due to Hawthorne effect and/ or when non-neuroradiologists are reading HCTs out of EDs?

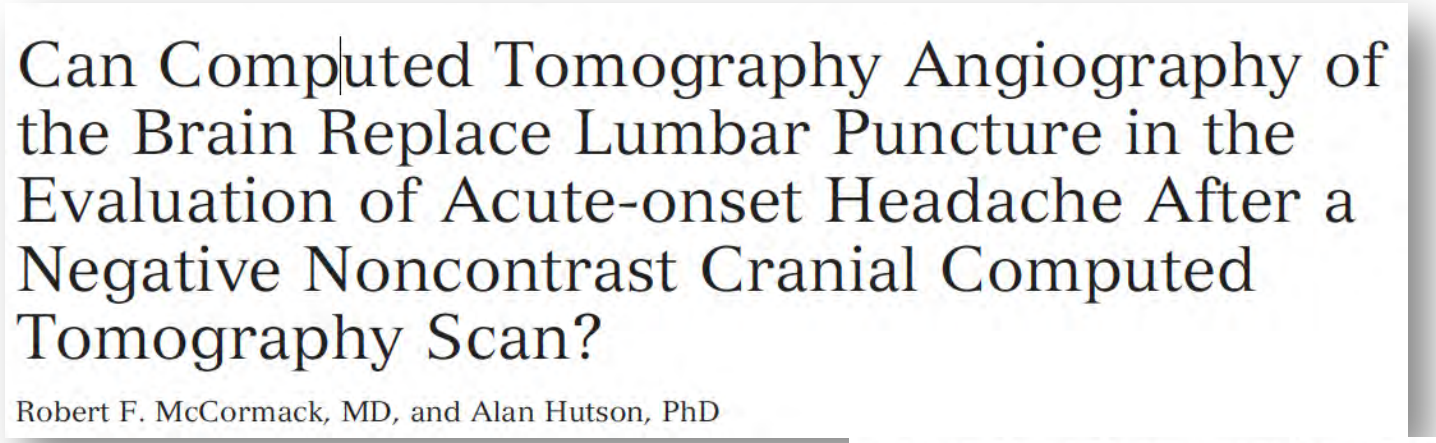
Hawthorne Effect?

False-negative Interpretations of Cranial Computed Tomography in Aneurysmal Subarachnoid Hemorrhage

Dustin G. Mark, MD, D. Christian Sonne, MD, Peter Jun, MD, David T. Schwartz, MD, Mamata V. Kene, MD, MPH, David R. Vinson, MD, and Dustin W. Ballard, MD, MBE

ACADEMIC EMERGENCY MEDICINE 2016;23:591–598

- 4% of diagnosed SAH with NCCT read as negative
  - Half were blindly re-read as being definite or probably SAH



- CT/LP sensitivity and specificity approach 100%
  - LPs too early (< 12 hours) may not have xanthrochromia
    - Will have RBCs -> risk of difficulty interpreting traumatic tap
- CT sensitivity alone varies by time from onset
  - ~50% on PBD 7
- With Mathematical Modeling
  - CT + CTA 99.43% Sensitive (95% CI = 98.86% to 99.81%).

CTA: Pro/ Con

Pro

- May help evaluate for
  - Dural Sinus Thrombosis
  - Cervical Vessel Dissection
  - RCVS
  - Could obviate LP and its associated discomfort and complications

Con

- Incidental aneurysms
  - If CTA+ -> need to do LP to determine if it ruptured
- Exposure to Radiation, contrast
- Sensitivity dependent on
  - Timing, 3D formatting
  - Read by Neuroradiologist
- False negatives
  - ~10% of aSAH with neg 1st CTA
- Doesn't assess for CSF inflammation or ↑ ICP

Questions?

Image Courtesy Jordan Bonomo, MD

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