

Ischemic Stroke: Diagnostic Imaging and Treatment

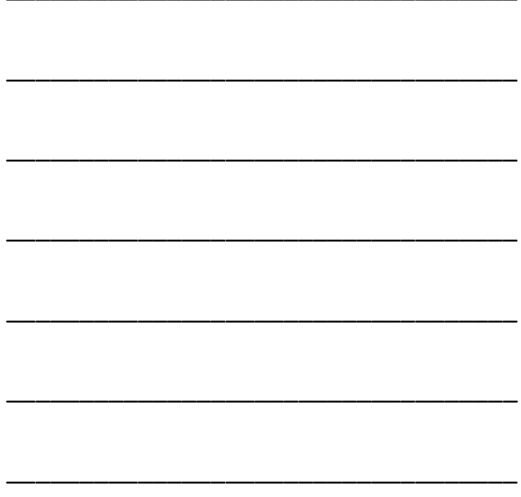
Debbie Summers, MSN, RN, ACNS-BC,
CNRN, SCRNI

Disclosure


Debbie Summers, MSN, ACNS-BC
Nothing

Objectives

- › Identify anatomical location of stroke on CT, MRI, and perfusion scans and angiography.
- › Relate underlying pathology to anatomical location.
- › Discuss treatment options and patient outcomes based on imaging.



Left is Right and Right is Left



An axial CT scan of the brain. The image is oriented such that the patient's right side is on the left of the image and the patient's left side is on the right. Two blue labels with white text are positioned above the scan: 'Patients Right Hemisphere' on the left and 'Patients Left Hemisphere' on the right. The scan shows the cerebral hemispheres, ventricles, and skull. The text '100' is visible on the right side of the image, and '100' is visible on the left side of the image.

Anatomy


Right Cerebral Hemisphere

Gray Matter

White Matter

This diagram shows a superior view of the human brain. The right cerebral hemisphere is labeled on the left side of the image. The outer layer of the brain is labeled as Gray Matter, and the inner, lighter-colored region is labeled as White Matter. Red lines connect the text labels to the corresponding anatomical structures in the brain image.

Anatomy



This diagram shows an axial MRI scan of the brain with three anatomical regions highlighted by red lines and labels:

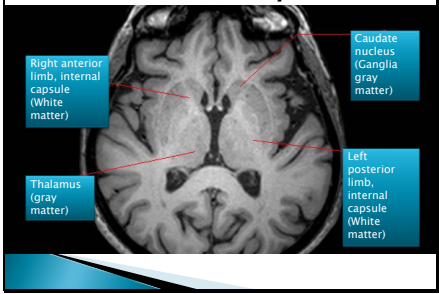
- Insula (Cortex / Gray matter)**: Located on the left side of the image, pointing to the outer cortical layer.
- Putamen (Ganglia gray matter)**: Located on the right side of the image, pointing to the basal ganglia region.
- Corpus callosum (White matter)**: Located at the bottom center of the image, pointing to the white matter tract connecting the two hemispheres.

[illegible]


Anatomy

This axial MRI scan shows the brain at the level of the lateral ventricles. The caudate nucleus is visible as a small, bean-shaped structure on either side of the lateral ventricle. The thalamus is located posterior to the lateral ventricle. The internal capsule is the large, white, wedge-shaped structure that separates the thalamus from the cerebral cortex. Red lines connect the labels to the corresponding structures in the image.

- Right anterior limb, internal capsule (White matter)
- Thalamus (gray matter)
- Caudate nucleus (ganglia gray matter)
- Left posterior limb, internal capsule (White matter)



Density Differences



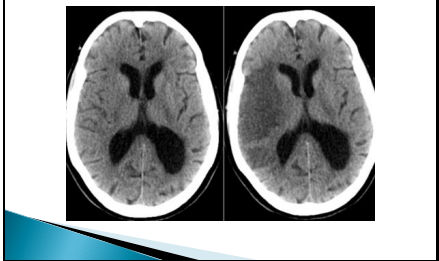
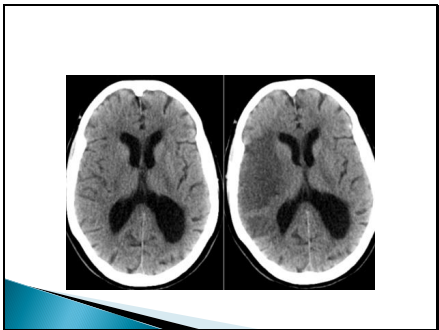
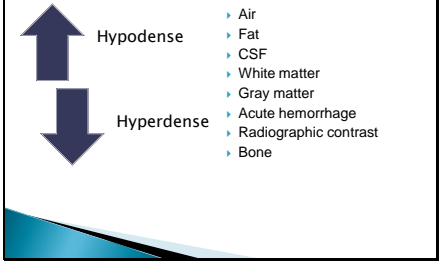
The diagram features two large, dark blue arrows. The top arrow points upwards and is positioned to the left of the word 'Hypodense'. The bottom arrow points downwards and is positioned to the left of the word 'Hyperdense'.

Hypodense

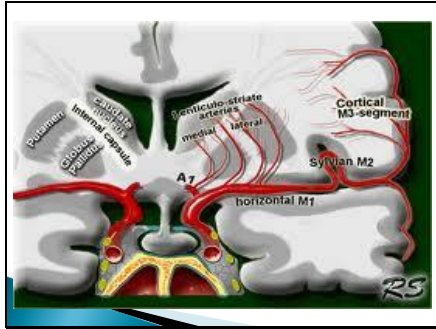
- ▶ Air
- ▶ Fat
- ▶ CSF
- ▶ White matter
- ▶ Gray matter

Hyperdense

- ▶ Acute hemorrhage
- ▶ Radiographic contrast
- ▶ Bone

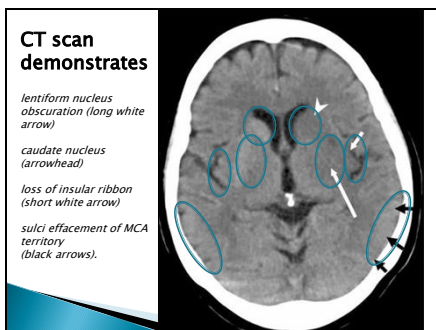
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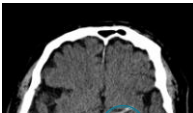
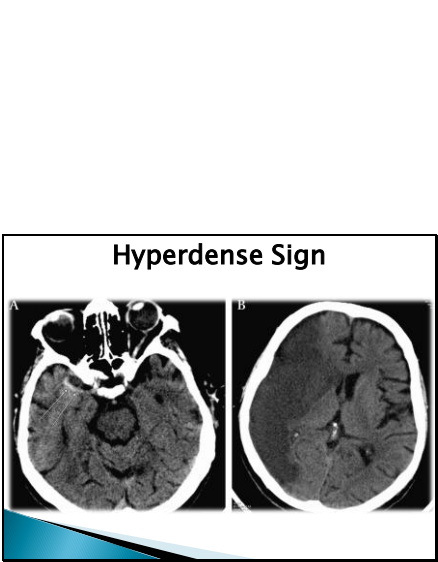
Pathophysiology

Failure of the ion pump during ischemia causes cytotoxic edema leading to sulcal effacement and hypodensity

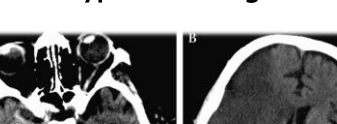


Hyperdense Sign

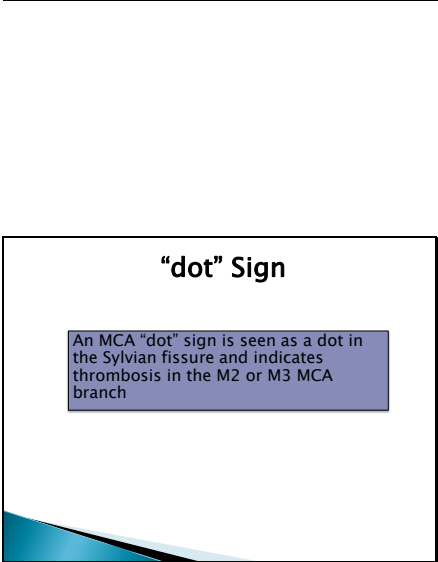
- Hyperdense vessel is seen when a thrombus is located in an intracranial vessel showing a high attenuation causing it to look bright white
- Hyperdense MCA sign has a high specificity indicating clot in the M1 branch but has poor sensitivity occurring only 38% of the time on CT

An axial CT scan of the brain. A blue circle highlights a hyperdense (bright white) area in the left middle cerebral artery (MCA) territory, which is a sign of an acute thrombus. The surrounding brain parenchyma appears normal.

Hyperdense Sign



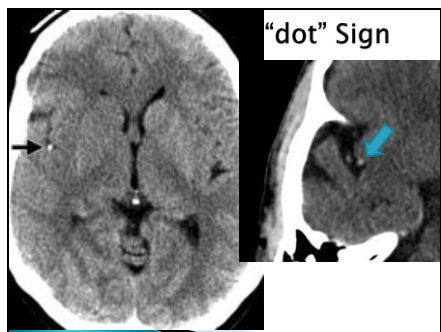
Two axial CT scan images of the brain. Image A shows a hyperdense (bright) area in the right parietal region, indicating an acute intracerebral hemorrhage. Image B shows a hyperdense area in the right parietal region, indicating an acute intracerebral hemorrhage.



“dot” Sign

An MCA “dot” sign is seen as a dot in the Sylvian fissure and indicates thrombosis in the M2 or M3 MCA branch

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What does this mean to treatment?

These early ischemic changes occur in the first 2 to 3 hours and **DO NOT** exclude the administration of IV rt-PA.

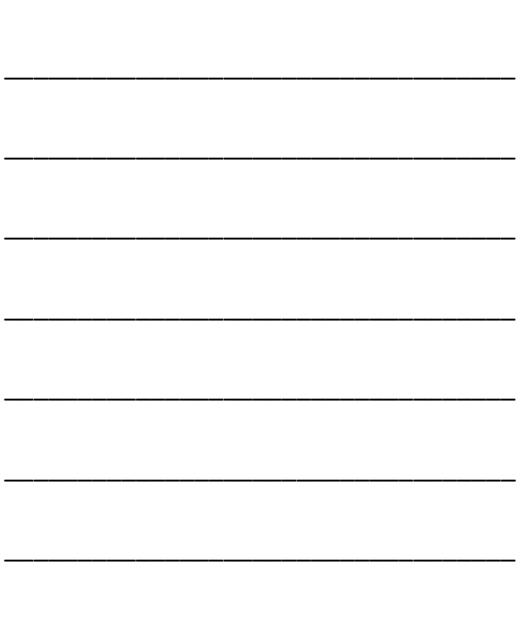
CT Angiogram and CT Perfusion

- › CTA - confirms the location of the thrombus
- › CTP - indicates the viability of the cerebral parenchyma

CTA and CTP


- ▶ Requires injection of contrast
 - Contrast allergy
 - Renal function
- ▶ Visualize and reconstruct in 3 dimensional display
- ▶ Detect large vessel thrombi and vascular stenosis
- ▶ Determine if further therapy is warranted

-
-
-
-
-
-



What are we looking for?

- ▶ **Penumbra** – an area peripheral to one of ischemia where metabolism is active but blood flow is diminished
- ▶ **Salvageable tissue**



-
- The diagram illustrates a cross-section of the brainstem and surrounding structures. The central part is labeled 'Brainstem', and the surrounding area is labeled 'Penumbra'.



CTP Viability Map

A CT scan of a brain slice with a CTP viability map overlaid. The map uses color to indicate different tissue states: green for penumbra and red for dead tissue. The green area is larger and surrounds the red area. The red area is located in the right hemisphere of the image. The green area is labeled 'Potential salvageable tissue' and the red area is labeled 'Dead tissue'.

Green - Indicates Penumbra

Red - Indicates Infarct

Potential salvageable tissue

Dead tissue

[illegible]

Primary Indicators



Cerebral Blood Volume (CBV)

- If CBV is preserved there will likely be salvageable tissue.
- Patients BP can elevate and vessels dilate to attempt



Cerebral Blood Flow (CBF)

- Amount of blood flow to the brain tissue.
- Normal range 50–60 mL/100 g/min

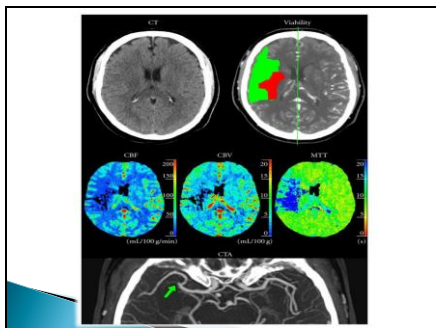


Mean Transit Time (MTT)

- Represents the period of time the contrast is in the cerebral artery to the cerebral vein.
- MTT is increased because the flow is very slow and contrast dye remains in the vessels longer.

CT Perfusion Data Analysis

Pathology of Tissue	MTT	CBF	CBV
No Ischemia	Normal	Normal	Normal
Tissue viable	Increased	Moderately Reduced	Normal or Hyperemia
Tissue at Risk	Increased	Markedly reduced	Moderately reduced
Tissue irreversible	Increased	Severely reduced	Severely reduced



- ▶ 10 point quantitative topographic CT scan score to assess early ischemic changes of the MCA region
- ▶ Assessed at 2 standardized regions
 - Ganglionic Level where the thalamus, basal ganglia and caudate are visible
 - Supraganglionic level which includes the corona radiata and centrum semiovale

ASPECT score

Normal ASPECT score is 10

- Deduct 1 point for each area involved.

A score of 7 or less

- Correlates with poor functional outcome and hemorrhage.

*Limitation - Only scores the Middle Cerebral artery

What about MRI?



Infarct on MRI

Conventional MRI plays a relatively minor role in evaluating acute cerebral ischemia, however since the development of *diffusion-weighted* MRI, it has become the most sensitive tool for detecting early ischemia



MRA

MR angiography or MRA provides information on the status of the blood vessels including detection of a high-grade stenosis or thrombotic occlusion

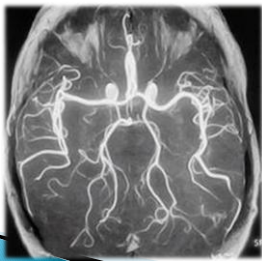
A low- or high-intensity vessel sign on an MR T2-weighted gradient echo may indicate a thrombus similar to a hyperdense vessel sign on CT

MCA Sign Artery Susceptibility Sign



T2 weighted GRE scan

Normal MRA Head



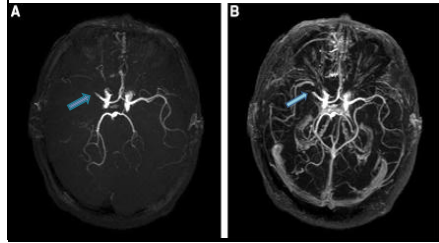
Right MCA occlusion

Precontrast MRA

Postcontrast MRA

The figure consists of two axial MRA scans of the brain, labeled A and B. Image A is the precontrast scan, and Image B is the postcontrast scan. Both images show the cerebral vasculature. In Image A, a blue arrow points to a filling defect in the right MCA. In Image B, the same area is highlighted with a blue arrow, showing contrast enhancement and a filling defect, indicating a right MCA occlusion.

Postcontrast MRA



DWI vs. PWI

- ▶ Diffusion Weighted Image or DWI
 - Lesions on a DWI are considered irreversibly damaged tissue
- ▶ Perfusion weighted image or PWI
 - Lesions on a PWI shows hypoperfused or hypoxic tissue

- 

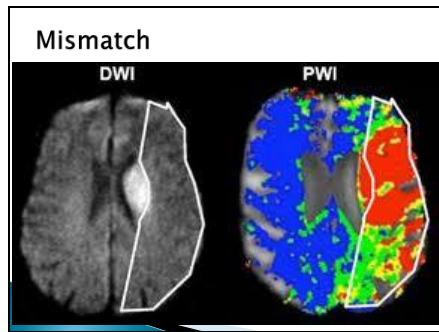
Mismatch

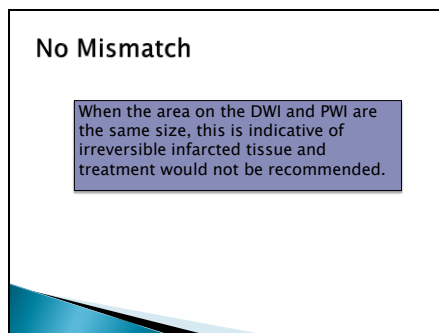
The volume difference between the DWI and PWI is referred to as a PWI/DWI mismatch.

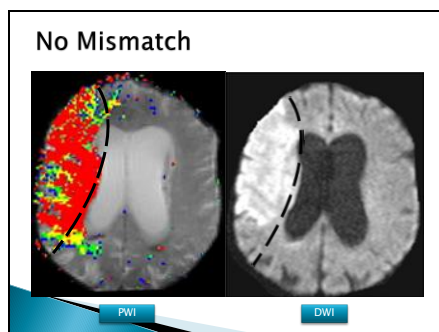
The mismatched tissue is considered to be the **penumbra**

The mismatched tissue is considered to be the **penumbra**

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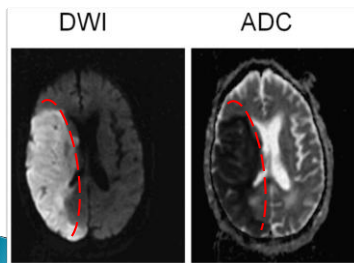


Role of the ADC Map

Apparent Diffusion Coefficient (ADC) map as a post processing of the DWI data that produces images showing abnormal tissue as darker than normal tissue.

The purpose of ADC **mapping** is to differentiate T2-signal (T2 shine through) effect or artifact from true ischemic lesions.

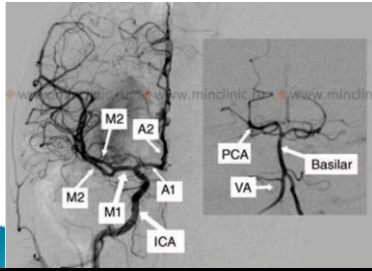
True Ischemic Tissue



Diagnostic Angiography



Cerebral Arteries



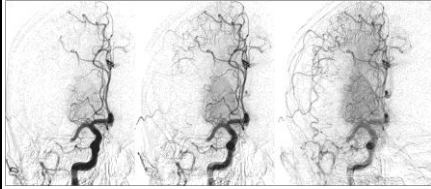
Collateral Flow Grading



American Society of Interventional and Therapeutic Neuroradiology Collateral Grading System

Grade	Cerebral Collateral Flow Grading Description
Grade 0	no collaterals visible to ischemic site
Grade 1	slow collaterals to the periphery of the ischemic site with persistence of defect
Grade 2	rapid collaterals to the periphery of ischemic site with persistence of some of the defect and to only a portion of the ischemic territory
Grade 3	collaterals with slow but complete angiographic blood flow of the ischemic bed by the late venous phase
Grade 4	complete and rapid collateral blood flow to the vascular bed in the entire ischemic territory by retrograde perfusion

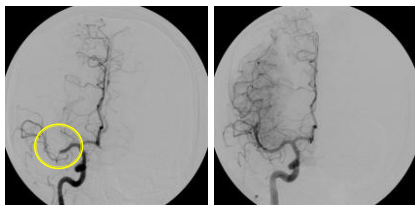
Collateral Flow Grading



Treatment Options

- ▶ IV rt-PA within 3 – 4.5 hours of onset
- ▶ IA rt-PA (off label use) within 6 hours
- ▶ Mechanical clot retrieval within 6 hours
 - MERCI retriever
 - Penumbra retrieval system
 - Stent retrievals

Recanalization of Rt MCA using IA t-PA



Case: MERCI Retrieval (L MCA)

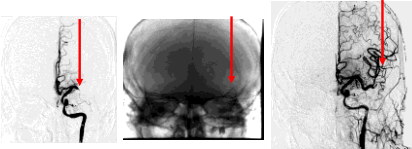


Intervention with Merci Retriever

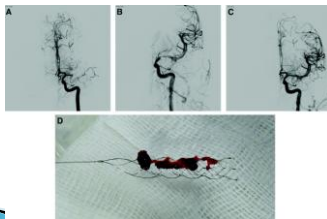
Clot completely blocking flow in the left middle cerebral artery

Merci Retriever positioned in the left middle cerebral artery

Pre-intervention Cerebral Angio 1st pass Merci Retriever Recanalization



STENT Retrievers



Case Studies

CASE STUDY

63 Y/O male

Case Study 1

- ▶ 63-y/o female with flu symptoms 2 weeks prior
- ▶ 02/27/2013, the patient started developing dyspnea, which was present at rest and exertion, cough productive of white-yellow sputum, not being frothy. There was no hemoptysis
- ▶ Admit Impression
 - Congestive heart failure
 - Bilateral pleural effusions
 - COPD exacerbation
 - Tobacco use
 - Possible diabetes.

Case Study 1

- ▶ States – no medical past history but has not been to physician since children born.
 - EKG shows sinus tachycardia with diffuse nonspecific T wave changes in the inferior and lateral leads as well as amenable Q-wave with non-diagnostic ST elevations in the inferior leads.
 - Chest x-ray which was personally reviewed by myself shows bilateral pulmonary edema, left greater than right, as well as bilateral pleural effusions, large left greater than right.

Diagnostic Work up

- ▶ Decompensated heart failure suspect LV Syst heart failure from either CAD versus myocarditis versus viral cardiomyopathy
- ▶ Tobacco abuse. The patient recently quit three weeks ago
- ▶ Recent upper respiratory infection which is currently resolved approximately one and a half weeks ago
- ▶ Persistent leukocytosis and thrombocytosis
- ▶ 16 seconds of nonsustained ventricular tachycardia.

Stroke Risk Factors

- ▶ 60 pack year tobacco history
- ▶ Cardiomyopathy – EF 25%
 - Akinetic inferolateral and inferior segments
 - Severe functional mitral regurgitation
- ▶ Dyslipidemia – Total Chol 181, Triglycerides 136, HDL 33, LDL 121
- ▶ Hemoglobin A1C 6.1

In Hospital Stroke

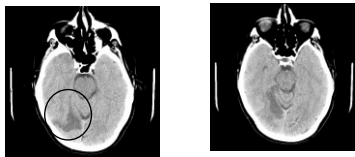
- ▶ She has been improving and doing well until 3:00 p.m. when the family who were at bedside noticed a **sudden change in her status**.
- ▶ She was having a conversation and suddenly **stopped talking** they also thought that in the right arm movement was decreased.
- ▶ They were not sure when she stopped moving her leg. The last they say her bearing weight on the leg was this morning when she was able to transfer into the wheelchair.
- ▶ SWAT team was called around 1535 and she was found to have NIH stroke scale score of 14.

Neurology Assessment

1. LOC 1a - 2 On exam the patient is somnolent.
 - LOC 1b - 2
 - LOC 1c - 1 Intermittently follows commands.
2. Best Gaze - 0 She was able to track. She transiently opens her eyes.
3. Visual - 0
4. Facial - 1
- 5/6 Motor Arm, Leg - No movement of RU or RL 4/4
7. Ataxia - 0
8. Sensory - 1
9. She is nonverbal - 3
10. Dysarthria - 0
11. Neglect - 0

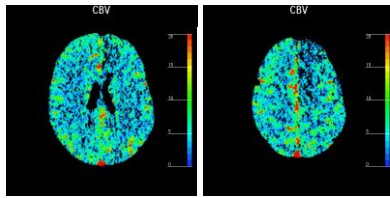
Total NIH 18

Initial CT Head Scan

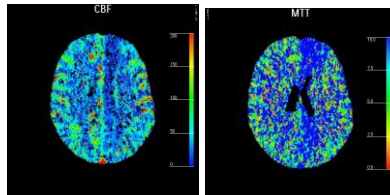


Chronic right putamen, right inferior frontal/corona radiata, and bilateral superior cerebellar lacunar infarcts

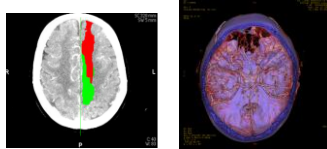
CT Head Scan Perfusion



CT Head Scan Perfusion

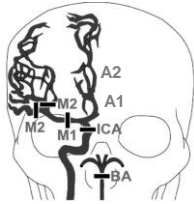


CT Head Scan Perfusion

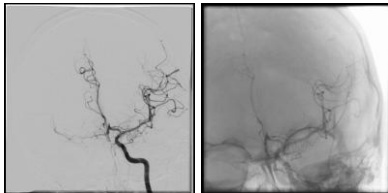


Matched perfusion defect in the distribution of the left ACA which correlates with occlusion of the left proximal A2 seen on CTA

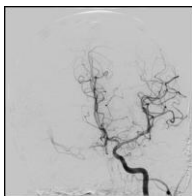
A Little Anatomy



Cerebral Angiogram

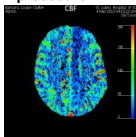


Cerebral Angiogram



- ▶ Retrieval of clot with Solitaire
- ▶ Admitted to ICU – NIH 6

**New stroke
compared to
penumbra at
time of
procedure**



53 Y/O male

- ▶ Last known well at 2030
- ▶ Told wife he was tired was going to bed
- ▶ At 1050 PM wife heard him make noise, went to bedroom and found cross way in bed
 - Unable to speak or move the right side
- ▶ 911 called
- ▶ Arrived at SLH at 11:20

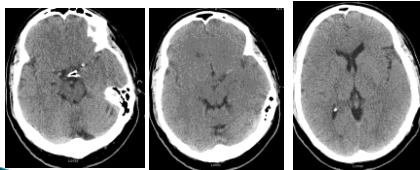
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Case Study 2

- 53 y/o male with non significant medical history (no family history)
 - Father living at age 96
 - Mother living at age 94
 - No medical hx in siblings

BASELINE NIHSS ED	TOTAL 25
Level of Consciousness	0
LOC Questions	2
LOC Commands	2
Best Gaze	2
Visual	2
Facial Palsy	1
Motor Arm, Left	0
Motor Arm, Right	4
Motor Leg, Left	0
Motor Leg, Right	4
Limb Ataxia	0
Sensory	1
Best Language	3
Dysarthria	2
Extinction and Inattention (Formerly Neglect)	2

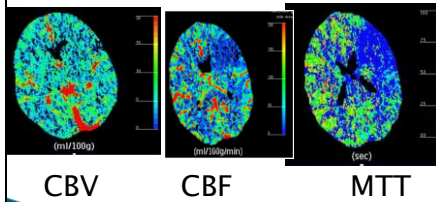
INITIAL NON-CONTRAST CT HEAD



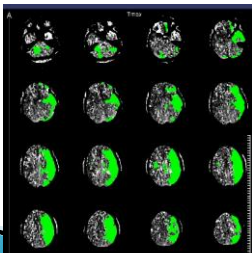
STROKE WORK – UP

- › BP 100/60, Heart rate – 80, O2 sat 99
- › Glucose 92
- › INR 1.0
- › Cr 1.0
- › No contraindications to IV rt-PA
- › Wife at bedside – discussion of benefit versus risks
- › IV rt-PA given at 0005

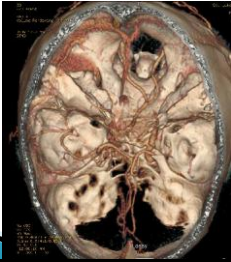
CT Perfusion



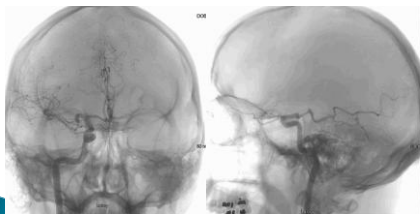
VOLUME OF ISCHEMIA



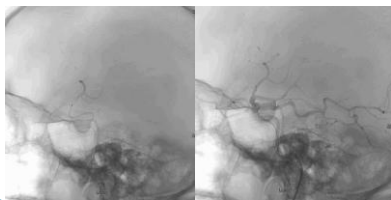
CT ANGIO - M1 OF LMCA



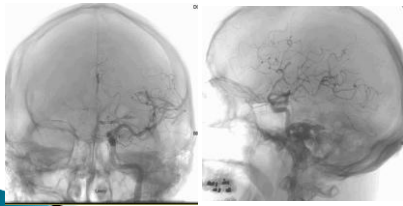
DSA



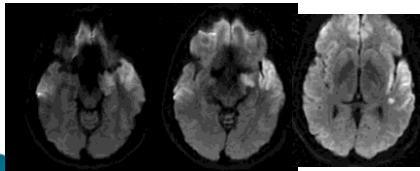
Embolectomy



Thrombectomy



Next Day MRI – DWI



Follow-up

- › NIHSS admit to ICU – 12
- › Next AM 6
- › Dyslipidemia – Chol 182, Triglycerides 331, HDL 32, LDL 84
- › Hemoglobin A1c 5,7
- › Medications – antiplatelet (ASA) and statin
- › Echo – no abnormality
- › Loop recorder inserted to evaluate for AF
- › Discharged on day 4 with NIH 0

CASE STUDY

23 Y/O male

Case Study 2

- 23-year-old right-handed woman generally in excellent health, who presented with very rapid or abrupt onset of right hemiplegia (weakness) and aphasia this afternoon after a very short nap for about 15 minutes.
- She apparently laid down about 4:00 with no neurological symptoms. A day or so before, with a respiratory infection present, she had complained of some headache. Apparently when she awoke, she was unable to speak and had right-sided paralysis.
- I believe the family observed her for perhaps 10 minutes and then called 911. She arrived here at just after 6:30 p.m.

Case Study

- Arrival – was awake with initial blood pressure of 144/103, coming down shortly thereafter to 134/79. She has been in sinus rhythm and afebrile.
- Upon arriving here, she remained aphasic, unable to say any words. She began moving the right leg but has been unable to move the right arm.
- There is no family history of early onset of stroke.
- She generally is in excellent health. She has a 1-year-old and a 2-year-old child. She has been on birth control for some time, but in recent weeks, perhaps, was put on a slightly higher dose. This is her only medication

Case Study

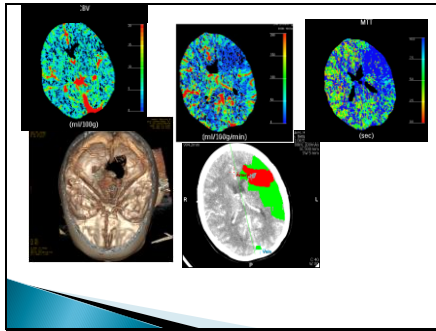
- ▶ She underwent a CT perfusion with CT head and neck. There is an abrupt occlusion with a long clot in the left M1 part of the left MCA, beginning where the lenticulostriatae take off and extending beyond to the posterior division.
- ▶ The rest of the vessels are normal.
- ▶ There is a large perfusion deficit in the distribution of the anterior branch of the left MCA. There is mainly ischemia with just a small red area.

Initial CT Head

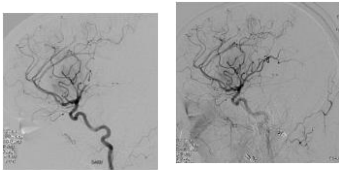


Management

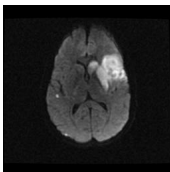
- ▶ Probable cardioembolic stroke to the left MCA (middle cerebral artery) proximal portion, perhaps due to patent foramen ovale (PFO).
- ▶ With the large embolus evident on CT angio and the large perfusion deficit, she was given full dose IV t-PA of 0.9 mg/kg and then taken directly to interventional radiology after discussion with her husband and her mother.
- ▶ The IV dose was 0.9 mg/kg. She received a total of 54 mg IV t-PA with 6 mg in the first minute and 48 mg over the next hour.

[illegible]

Cerebral Angiography

[illegible]

24 HOUR MRI



Discharge

- Cardioembolic stroke status post intravenous t-PA, clot retrieval, and intraarterial t-PA with resultant expressive greater than receptive aphasia.
- Home with outpatient speech
- Family will help with transportation – no to drive for month or be at home alone with children
- Coumadin with INR testing
- PFO closure in 2 months

CT – 5 month post stroke



At that time caring for kids by self, states the only real concern is her emotional lability post stroke. Word finding when tired.

Thank you!!