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Radiological Evaluation of Acute Ischemic Stroke

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Agenda

- Background: Stroke
- Patient L and the Neuroimaging of Acute Ischemic Stroke: CT and MRI
- Neuroanatomy review: Circle of Willis
- Frontiers in Neuroimaging of Acute Ischemic Stroke
- Take Home Points

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Stroke

- Stroke is a neurologic deficit, either transient or permanent, resulting from a cerebrovascular pathologic process

Klatt EC. Internet Pathology Laboratory for Medical Education. http://www.utsa.edu/tsi/assign/anat/neuropat.htm. Accessed 2003 January 24.

Impact of Stroke

- 3rd leading cause of death in North America, after heart disease and cancer
- 500K new strokes and 200K stroke-related deaths each year
- 25% mortality at 1 year
- 3 million stroke survivors in the U.S.
  - 48% hemiparesis
  - 22% unable to walk
  - 32% clinically depressed
- Cost of annual direct/indirect care estimated at ~$45B

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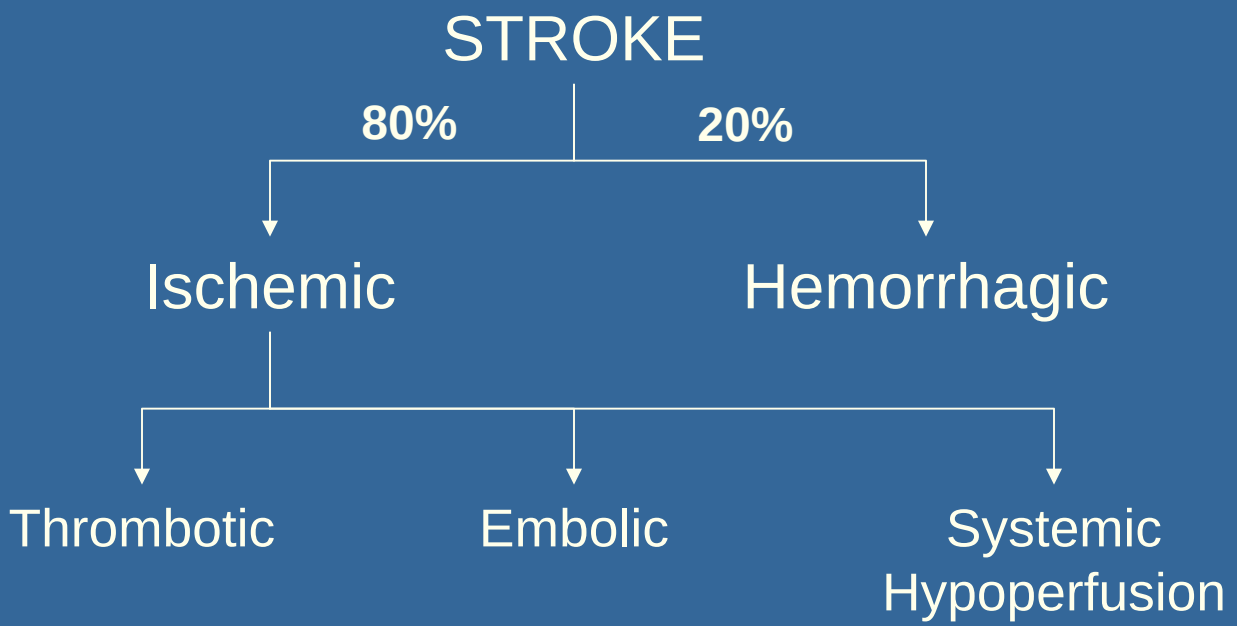
Etiologies of Stroke



Early Diagnosis of Acute Ischemic Stroke is Critical

- NINDS (National Institute of Neurological Disorders and Stroke) Stroke Study demonstrated morbidity benefit from intravenous tPA treatment for acute ischemic stroke within 3 hours of onset of symptoms
- tPA intervention from 3-6 hours after onset of symptoms is controversial

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Patient: Ms. L.

- CC: New onset L-sided hemiparesis
- HPI: 91 y.o. female with hx of severe dementia and atrial fibrillation presents with decreased movement of her left side noticed by her caretaker.
- Meds: Diltiazem, Raloxifene, Vit B12
- PE: VSS, No spontaneous movements of left upper or lower extremities
- What imaging should be performed?

Goals of Imaging in Acute Stroke

1. Exclude hemorrhage as etiology of deficit
2. Evaluate the extent of brain injury
3. Identify any specific vascular lesion responsible for the event

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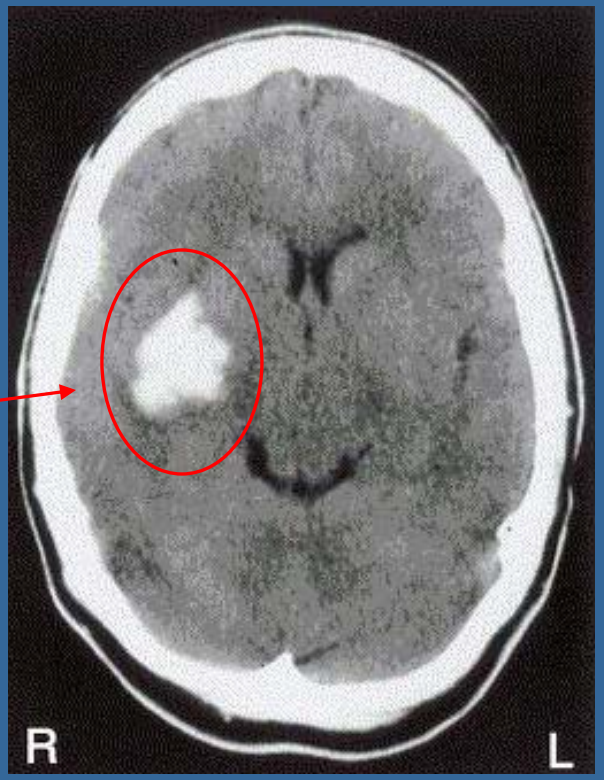
Initial Stroke Imaging Should be Non-Contrast CT

- Non-contrast CT is the modality of choice in the initial phase of stroke work-up, as it is very sensitive for detecting acute cerebral hemorrhage.
- Acute hemorrhage manifests as bright white density on non-contrast CT
- Determining whether the stroke is ischemic or hemorrhagic is critical to proper management.



Unwin H. Stroke. http://www.swmed.edu/stars/resources/neurodisslides.html. Accessed 2003 January 24.

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Patient L's Noncontrast CT Results

- What do you observe?

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CT Evidence of New Infarction

- No evidence of high attenuation region that would indicate acute hemorrhage
- Area of low attenuation involving cortex and underlying white matter in region around right Sylvian fissure consistent with early infarction
- This area also demonstrates expanded gyri and reduced sulci: evidence of cortical edema consistent with ischemic event

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CT Evidence of Old Infarction

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- Area of low attenuation encephalomalacia (volume loss) involving the region around the Sylvian fissure on the left side is consistent with an old infarction.

MRI Was Performed…

- Technique: Axial T1W, T2 FLAIR and DWI imaging were performed
- Gadolinium contrast was NOT used – no need for contrast in MRI evaluation of stroke. Much more useful in MRI evaluation of inflammatory, infectious, and neoplastic processes

MRI vs CT for Detecting Ischemic Stroke

- MRI is more sensitive than non-contrast CT for detecting the early changes of acute ischemic stroke
  - Studies of CT sensitivity for early signs of cerebral infarction have yielded results from 56% to 81%
  - A study comparing DWI MRI with CT in patients imaged within 6 hours of stroke-like symptoms yielded a 45% sensitivity for CT and >95% sensitivity for DWI MRI
  - DWI MRI has been shown to be able to detect changes related to brain ischemia within 15-30 minutes of the ischemic insult.

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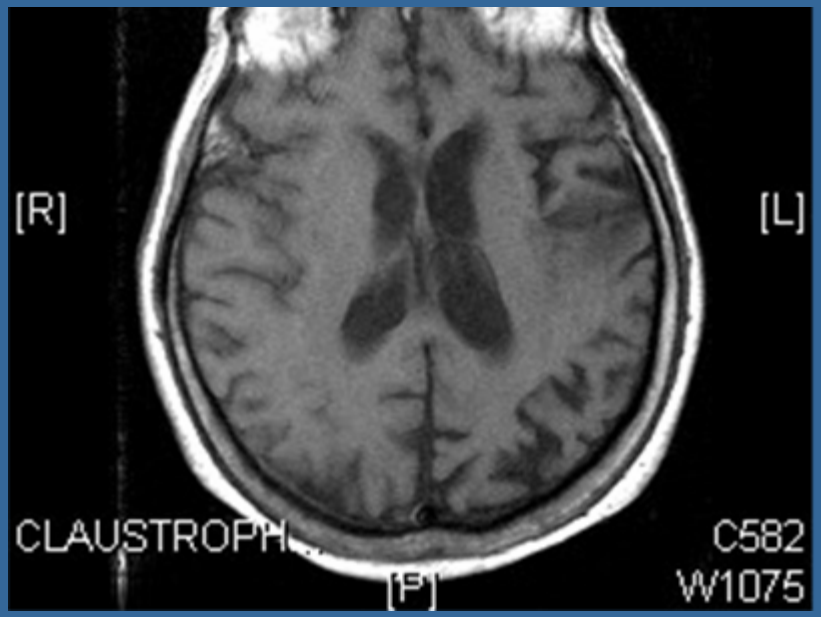
Patient L's T1W MRI Results

- What do you observe?



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T1W MRI Not Useful for Imaging Acute Ischemia

- T1 is time constant for the return of longitudinal magnetization to equilibrium
- T1W images will show regions of subtle hypointensity in areas of edematous brain
- T1W images are not very helpful in the radiological diagnosis of acute ischemic stroke and are often ignored in favor of more illuminating image sequences

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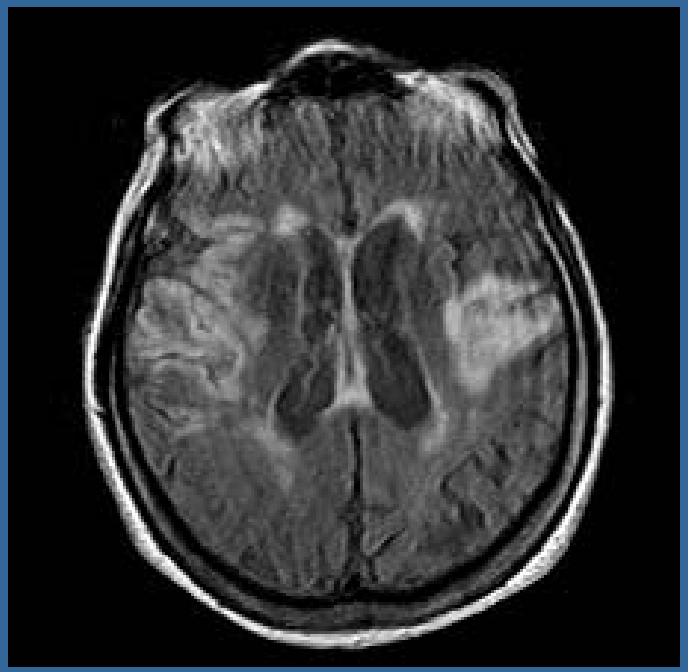
Patient L's T2 FLAIR MRI Results

- What do you observe?



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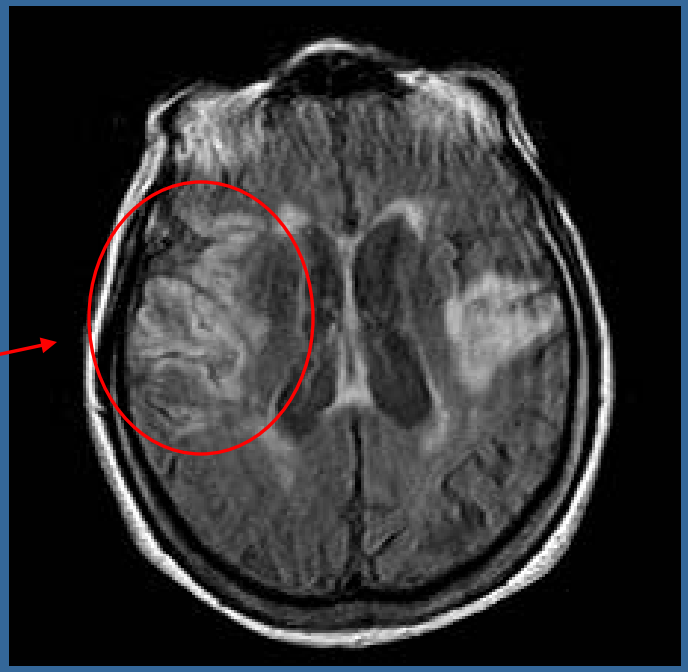
T2 FLAIR MRI Superior to T1 For Imaging Ischemia

- T2: time constant for the return of transverse relaxation time to equilibrium
- FLAIR = Fluid Attenuated Inversion Recovery
- Area of hyperintensity in right parietal cortex. Edema will manifest as hyperintensity on T2 images, so this is consistent with new ischemic insult.



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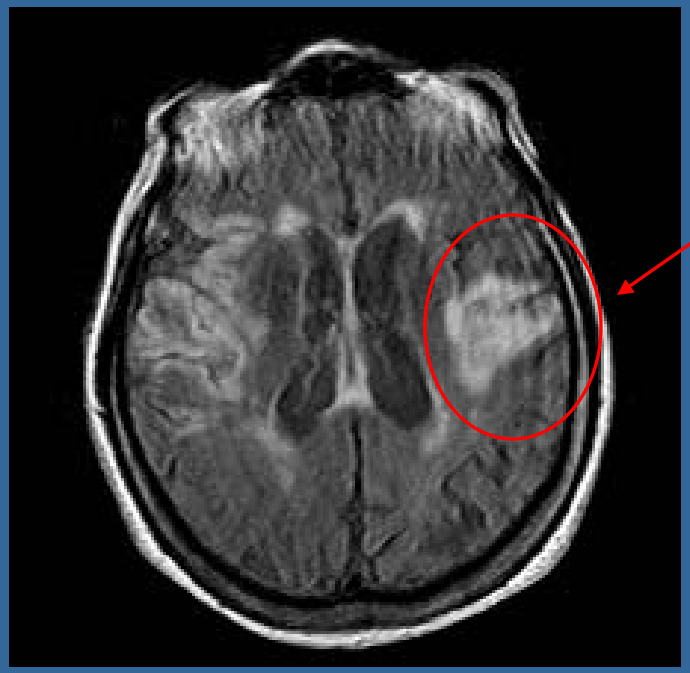
T2 FLAIR Poor at Differentiating Old vs New Ischemic Event



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- Area of hyperintensity in left parietal cortex. In this region of old infarction, the hyperintensity is indicative of gliosis, the glial proliferation in response to brain insults such as infarction which manifests as hyperintensity on T2 images

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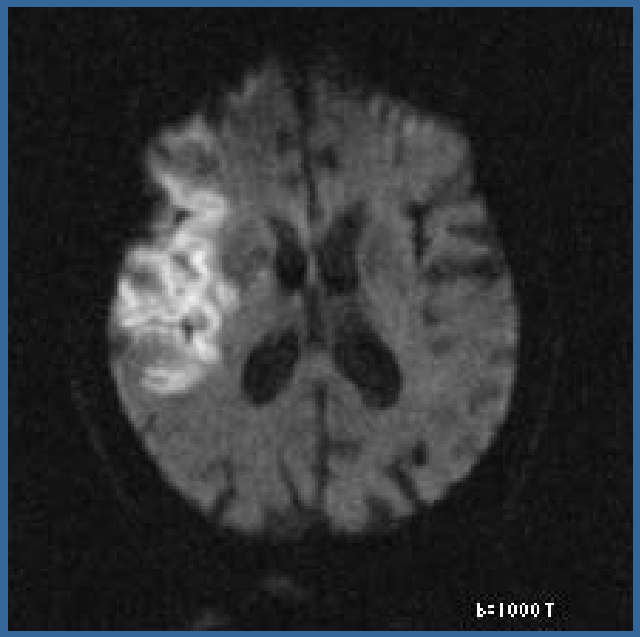
Patient L's DWI MRI Results

- What do you observe?



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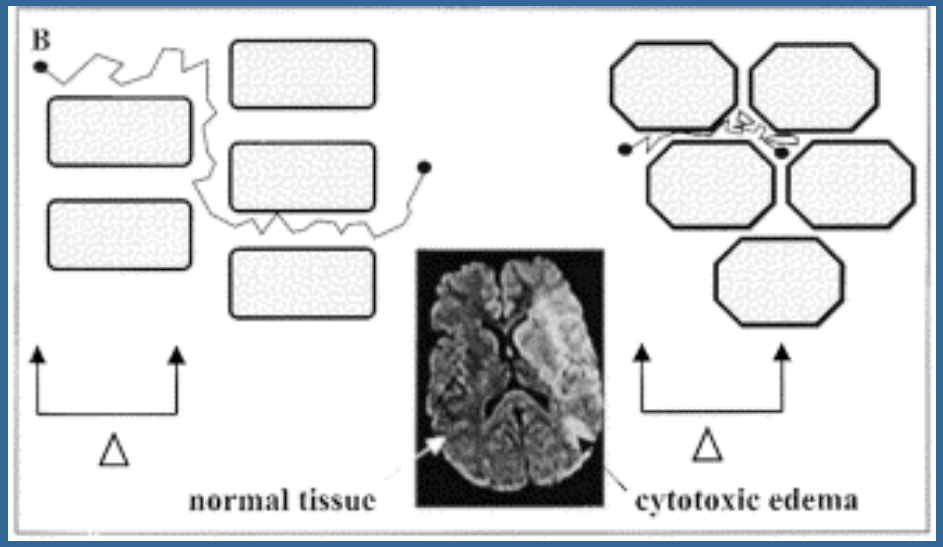
Basic Principles of DWI MRI

- DWI is designed to be sensitive to differences in water diffusion
- Intracellular water diffusion is more restricted than extracellular water diffusion
- Acute ischemia leads to cytotoxic edema and restriction of extracellular water movement
- This manifests as regional hyperintensity



Rother J. CT and MRI in the Diagnosis of Acute Stroke and Their Role in Thrombolysis.*Thrombosis Research* 2001; 103(S1): 125-133.

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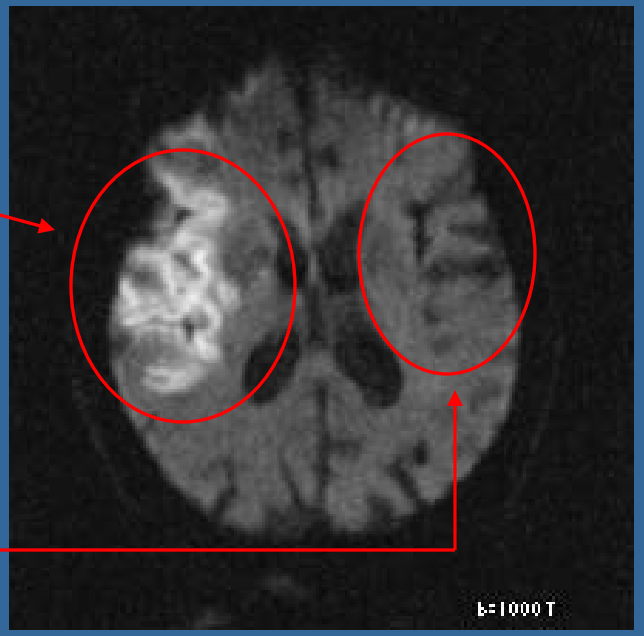
DWI Demonstrates New Ischemia But Not Old Infarct

- There is an area of hyperintensity in the right parietal cortex. This is consistent with cerebral ischemia as cytotoxic edema leads to reduction in free water diffusion.
- Note the absence of hyperintensity in the left brain region which manifested evidence of an old infarct on CT and T2 FLAIR



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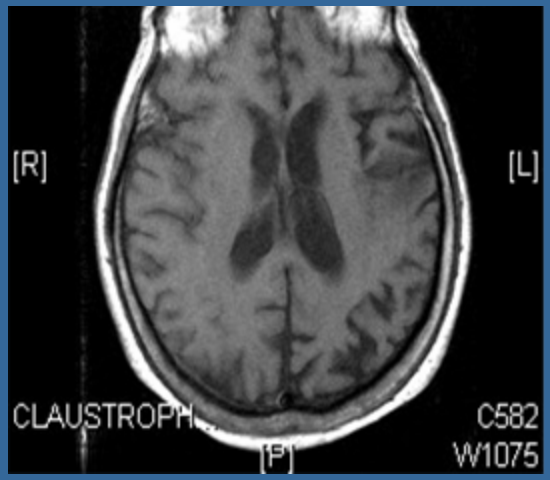
DDX of Patient L's MRI Results

T1W



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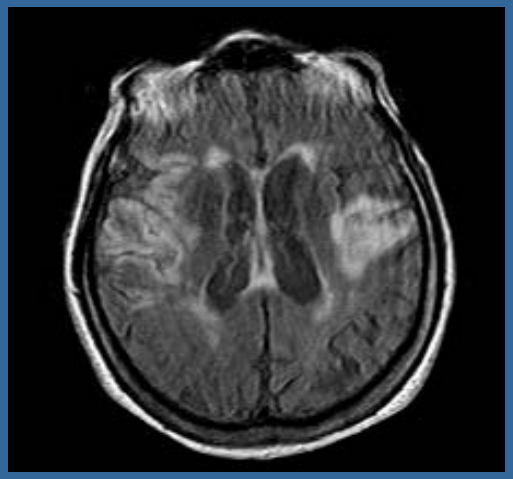
T2 FLAIR



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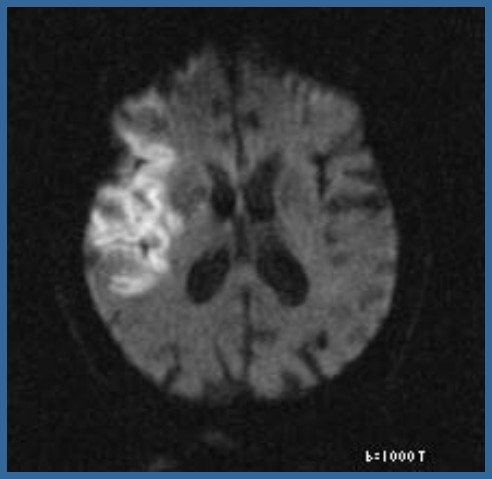
DWI



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- Parenchymal lesions hyperintense on T2 and hypointense on T1
  - Acute Stroke
  - Contusion
  - Cryptococcoma
  - Hyperacute hemorrhage
  - Low-grade glioma
  - Viral encephalitis

Diagnosis: Acute Ischemic Stroke

- What does the territory of the ischemic area tell us about the likely location of the stroke?
- Territory of ischemic stroke implicates the right middle cerebral artery
- MRA of the Circle of Willis was performed to help assess flow abnormalities in the right MCA

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MRA of Circle of Willis was Performed

- MRA demonstrates attenuated flow within the right middle cerebral artery without evidence of occlusion

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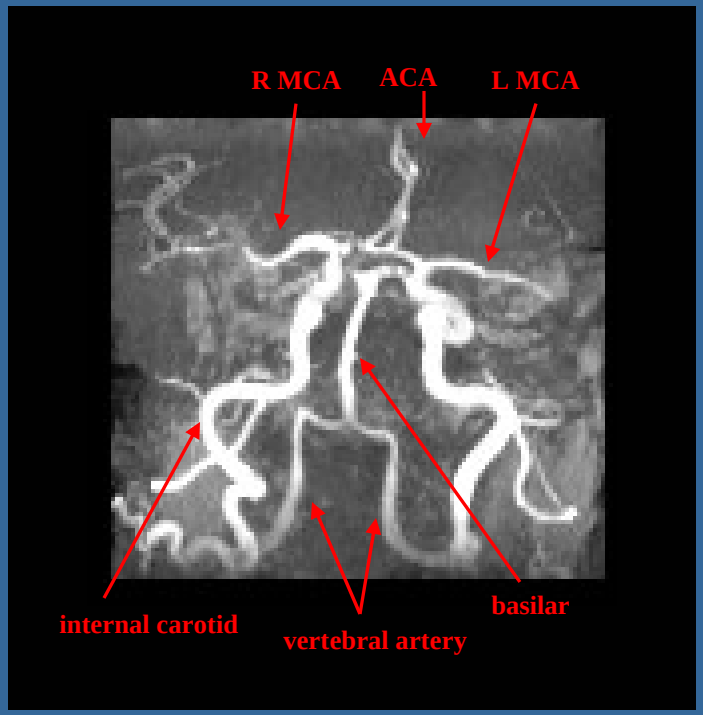
Neuroanatomy Review: The Circle of Willis



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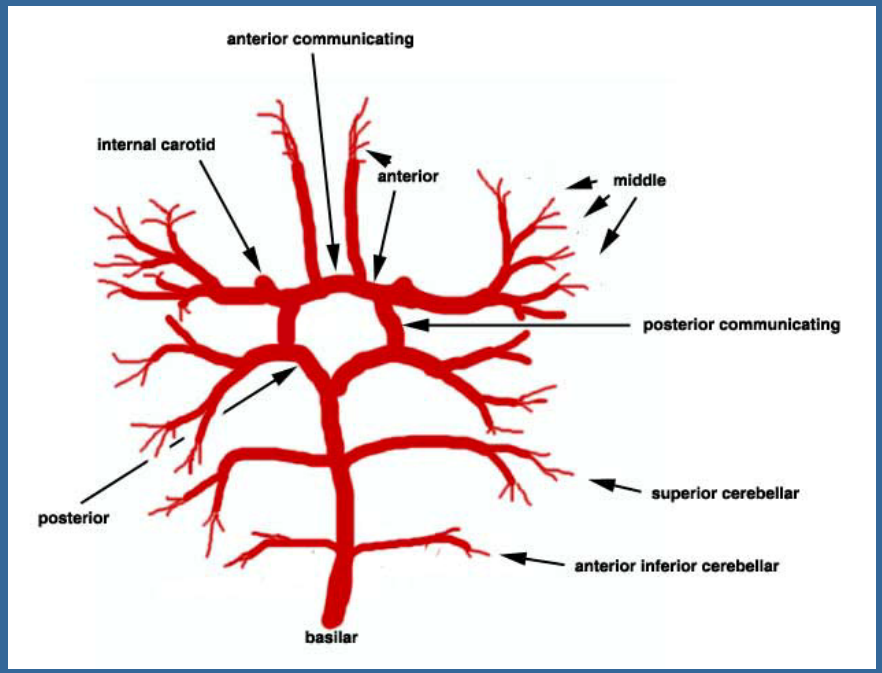

Gruen JP. http://uscneurosurgery.com/glossary/c/circle%20of%20willis.htm. Accessed 2003 January 24.

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Frontiers

- Multiple MRI and CT protocols are being evaluated in acute stroke patients for their capability to:
  - Detect tissue at risk of infarction
  - Predict prognosis
  - Identify subpopulations that would benefit from acute thrombolytic treatment even beyond the three hour window

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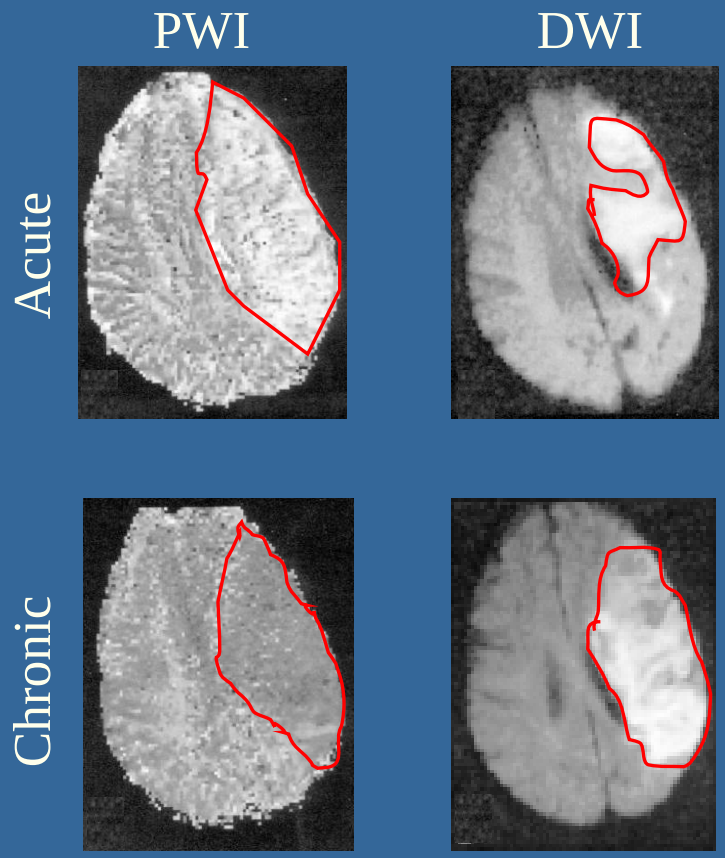
PWI MRI Lesions Correlate Well With Final Infarct Size

- PWI (Perfusion Weighted Imaging) utilizes dynamic MR tracking of gadolinium contrast to differentiate hypoperfused tissue.
- One study indicated that acute DWI lesion volumes did not correlate as closely with final infarct size as did acute PWI lesions, suggesting that acute DWI lesions do not reflect closely the extent of functionally compromised tissue.



Barber PA. Prediction of stroke outcome with echoplanar perfusion- and diffusion-weighted MRI. *Neurology* 1998; 51(2): 418-26

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Take Home Points

- Early diagnosis of acute ischemia is critical as it guides therapeutic intervention with tPA
- Non-contrast CT is the first imaging modality. It is excellent at detecting hemorrhagic stroke, but has low sensitivity for the early changes of acute brain ischemia
- T2 and DWI MRI are very sensitive for early brain ischemia which manifest as hyperintense lesions
- Studies are underway to define MRI and CT protocols that can better predict prognosis and identify salvageable brain tissue

References

- Barber PA. Prediction of stroke outcome with echoplanar perfusion- and diffusion-weighted MRI. *Neurology* 1998; 51(2): 418-26./SLIDE#32
- Gonzalez RG, Schaefer PW, Buonanno FS, Schwamm LH, Budzik RF, Rordorf G, Wang B, Sorensen AG, Koroshetz WJ. Diffusion-weighted MR imaging: diagnostic accuracy in patients imaged within 6 hours of stroke symptom onset. *Radiology* 1999; 210(1):155-62.
- Gruen JP. http://uscneurosurgery.com/glossary/c/circle%20of%20willis.htm. Accessed 2003 January 24./SLIDE#29
- Klatt EC. Internet Pathology Laboratory for Medical Education. http://www.utsa.edu/tsi/assign/anat/neuropat.htm. Accessed 2003 January 24./SLIDE#4
- Moseley ME, Kucharczyk J, Mintorovitch J, Cohen Y, Kurhanewicz J, Derugin N, Asgari H, Norman D. Diffusion-weighted MR imaging of acute stroke: correlation with T2-weighted and magnetic susceptibility-enhanced MR imaging in cats. *Am J Neuroradiol* 1990; 11(3):423-9.
- The National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group. Tissue plasminogen activator for acute ischemic stroke. *N Engl J Med* 1995;333(24):1581-7.
- Rother J. CT and MRI in the Diagnosis of Acute Stroke and Their Role in Thrombolysis.*Thrombosis Research* 2001; 103(S1): 125-133./SLIDE#23
- Unwin H. Stroke. http://www.swmed.edu/stars/resources/neurodisslides.html. Accessed 2003 January 24./SLIDE#11

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