

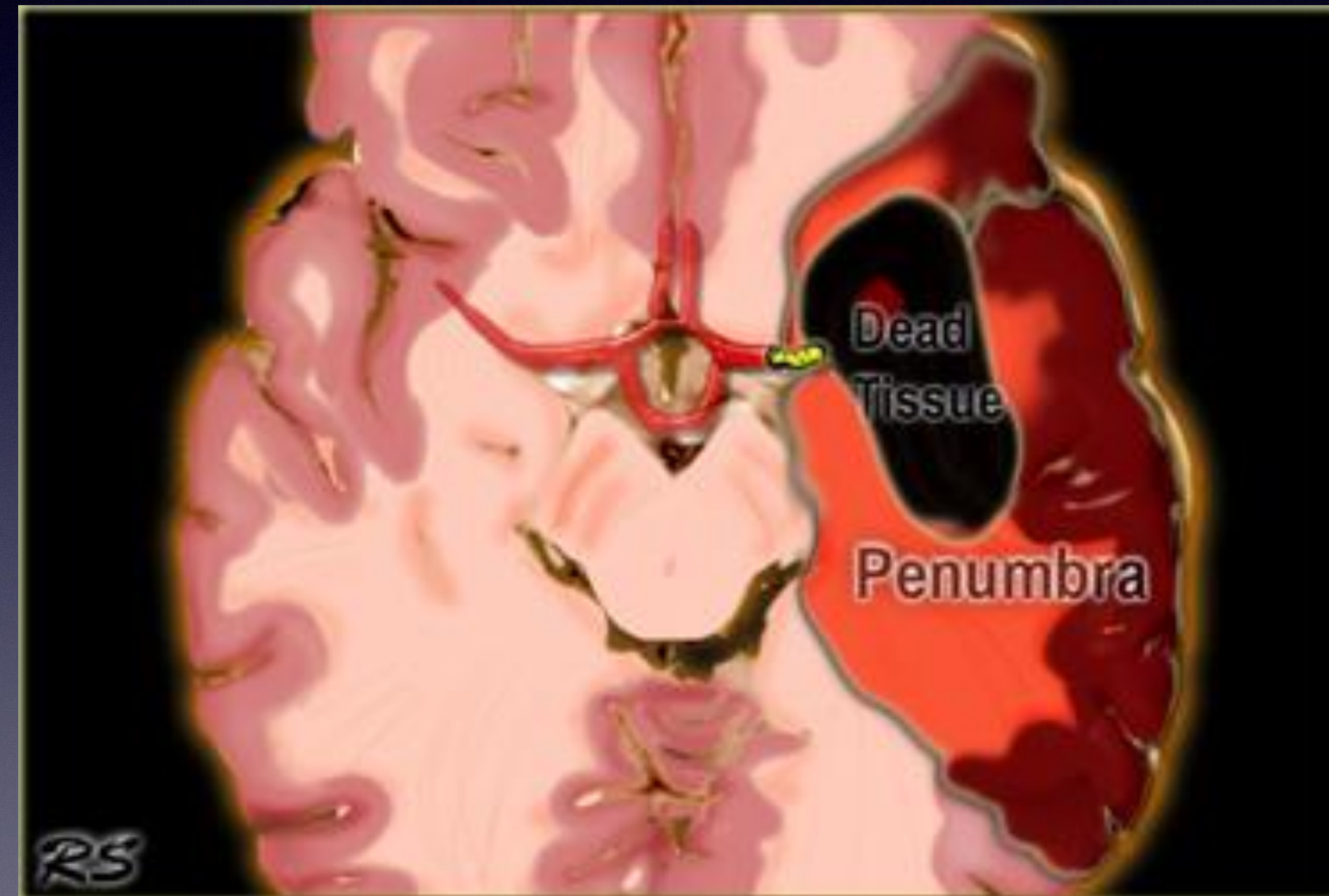
# Stroke Imaging in the emergency setting

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# Infarct or Penumbra

- Ischemia or Infarction
- **Infarct** is an irreversible injury to the brain tissue due to lack of blood, which makes the cells swell (Cytotoxic edema)
- This is also named the infarct core or core
- **Ischemia** is a potentially reversible dysfunction of the neurons due to insufficient blood supply
- This is also labeled the penumbra
- Ischemia will progress to infarction if the blood supply is not restored

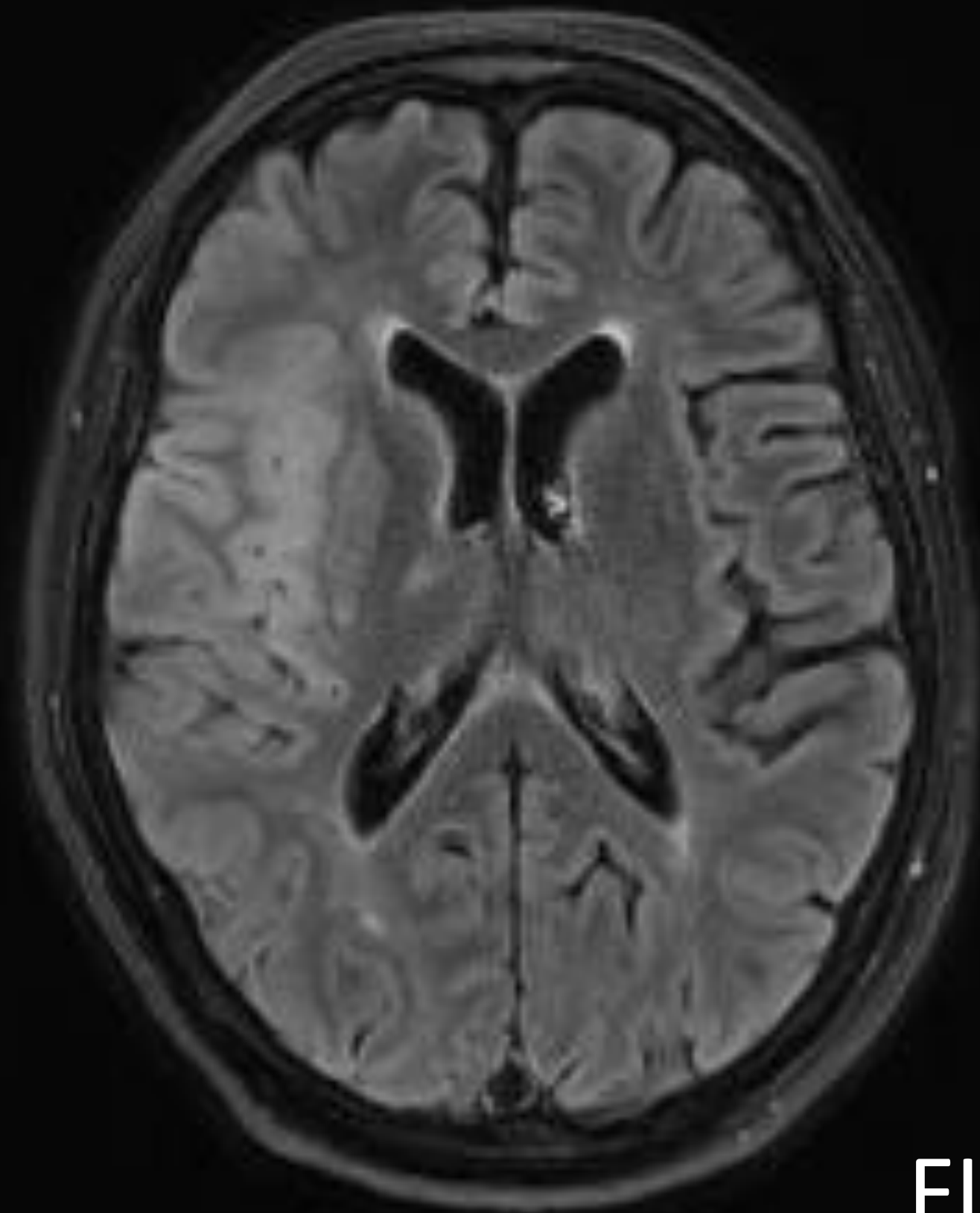
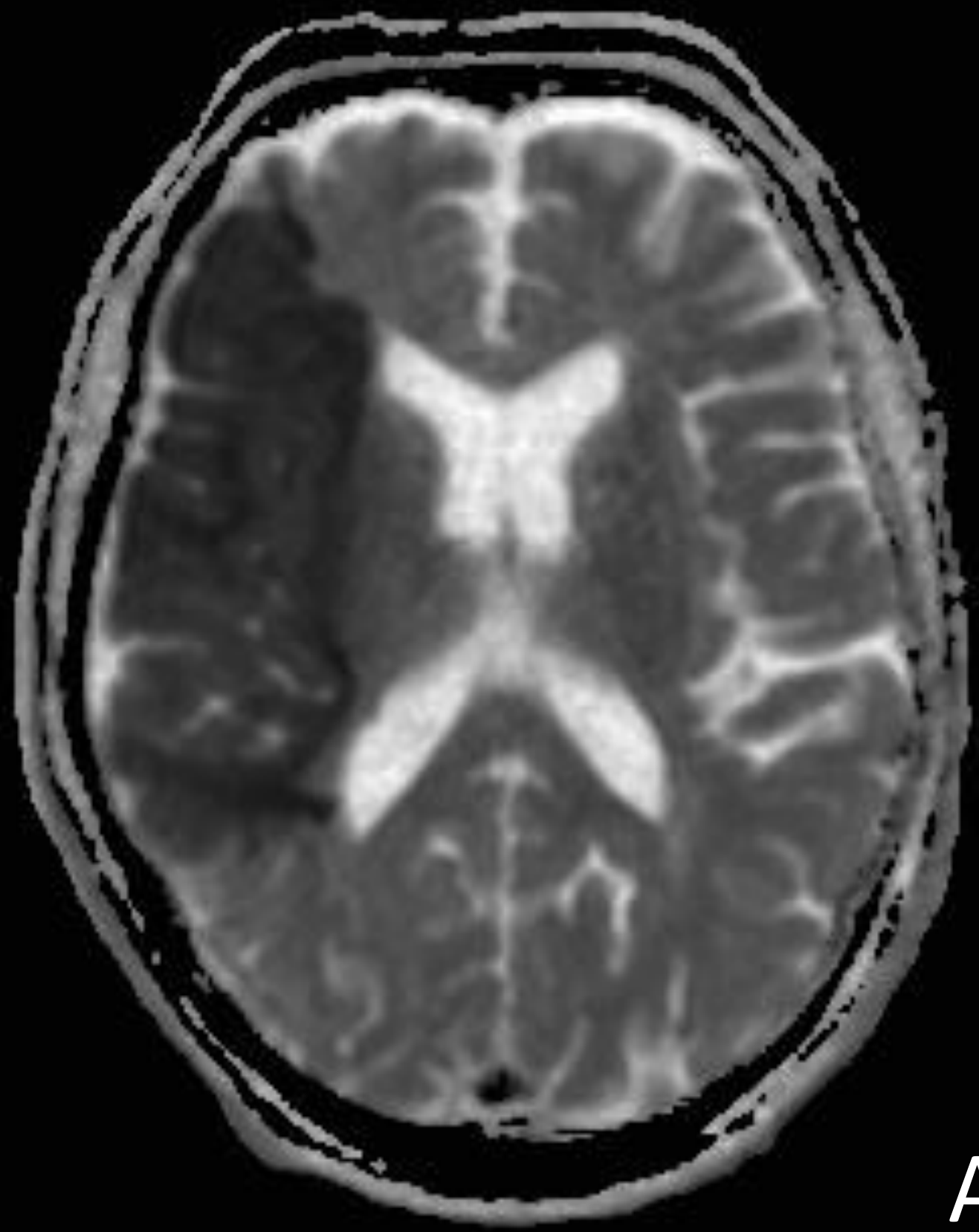
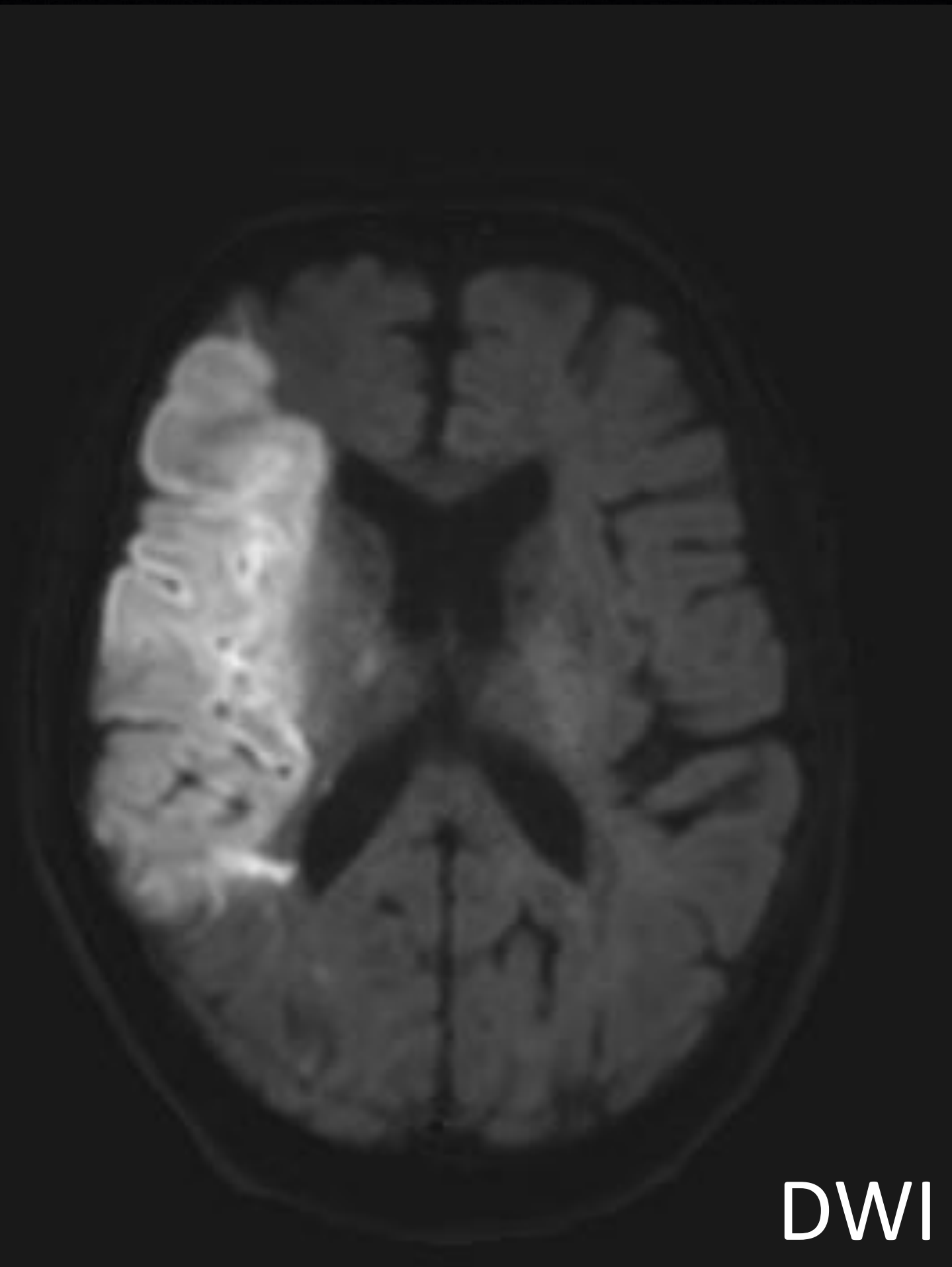


<https://radiologyassistant.nl/neuroradiology/brain-ischemia/imaging-in-acute-stroke>

# Visualization of infarcts

- CT is excellent to visualize haemorrhage, which is the main differential diagnosis
- Infarcts can't be detected with certainty using non-contrast CT until 4-6 hours after symptoms, since the cytotoxic edema is difficult to see.
- MRI with diffusion weighted imaging can detect the cytotoxic edema, and therefore the infarct, almost momentarily
- The FLAIR sequence helps to estimate the age of the infarct, but doesn't change the fact that the damage is irreversible







# Virtual Ischemia Maps

- Is a Dual Energy reconstruction developed to help detect infarction and thereby better estimate the core in candidates for mechanical thrombectomy
- It removes the difference between grey- and white matter, making the total water content (i.e. cytotoxic edema) more visible
- It can be created automatically, doesn't use contrast, excess radiation or time.

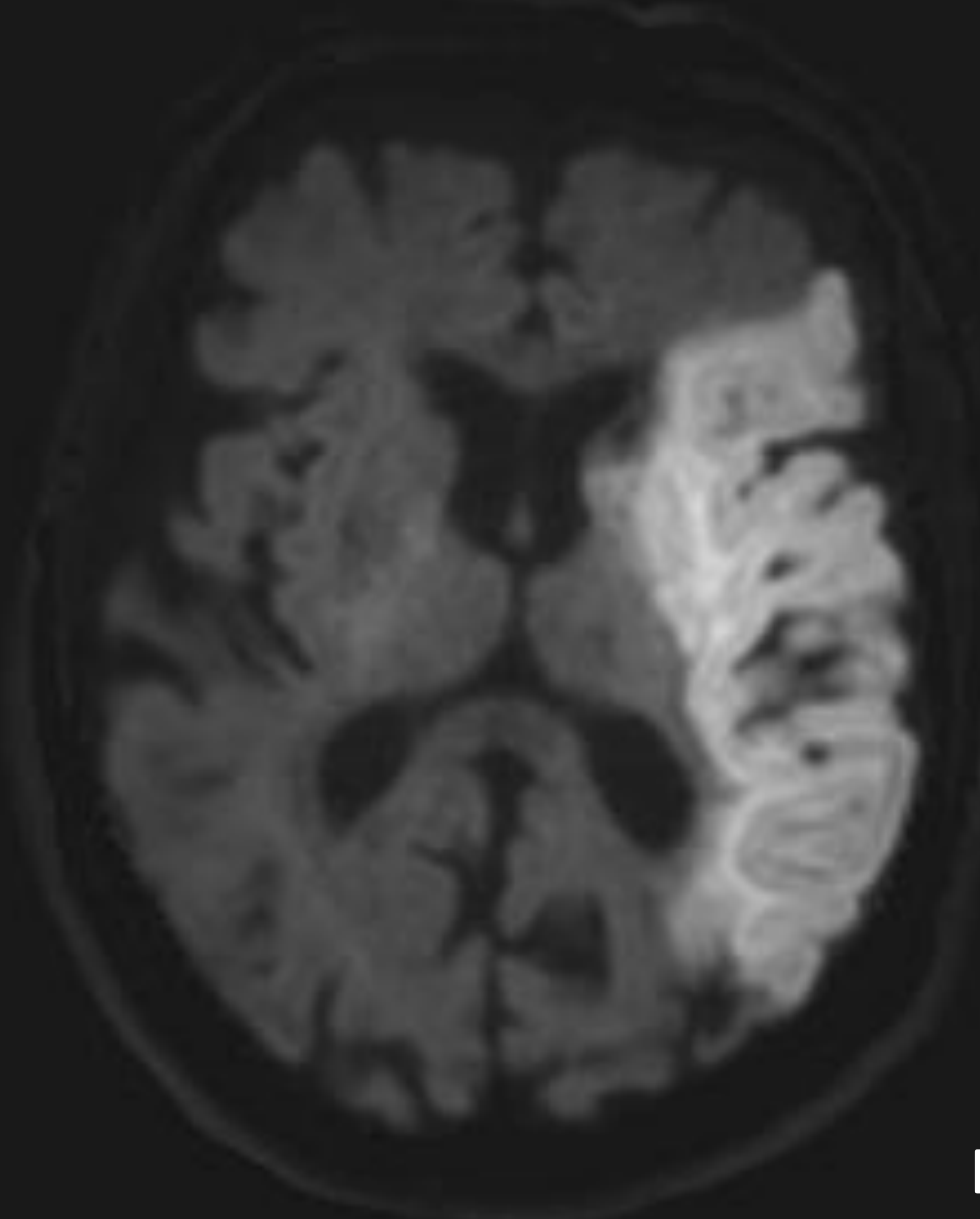


NCCT

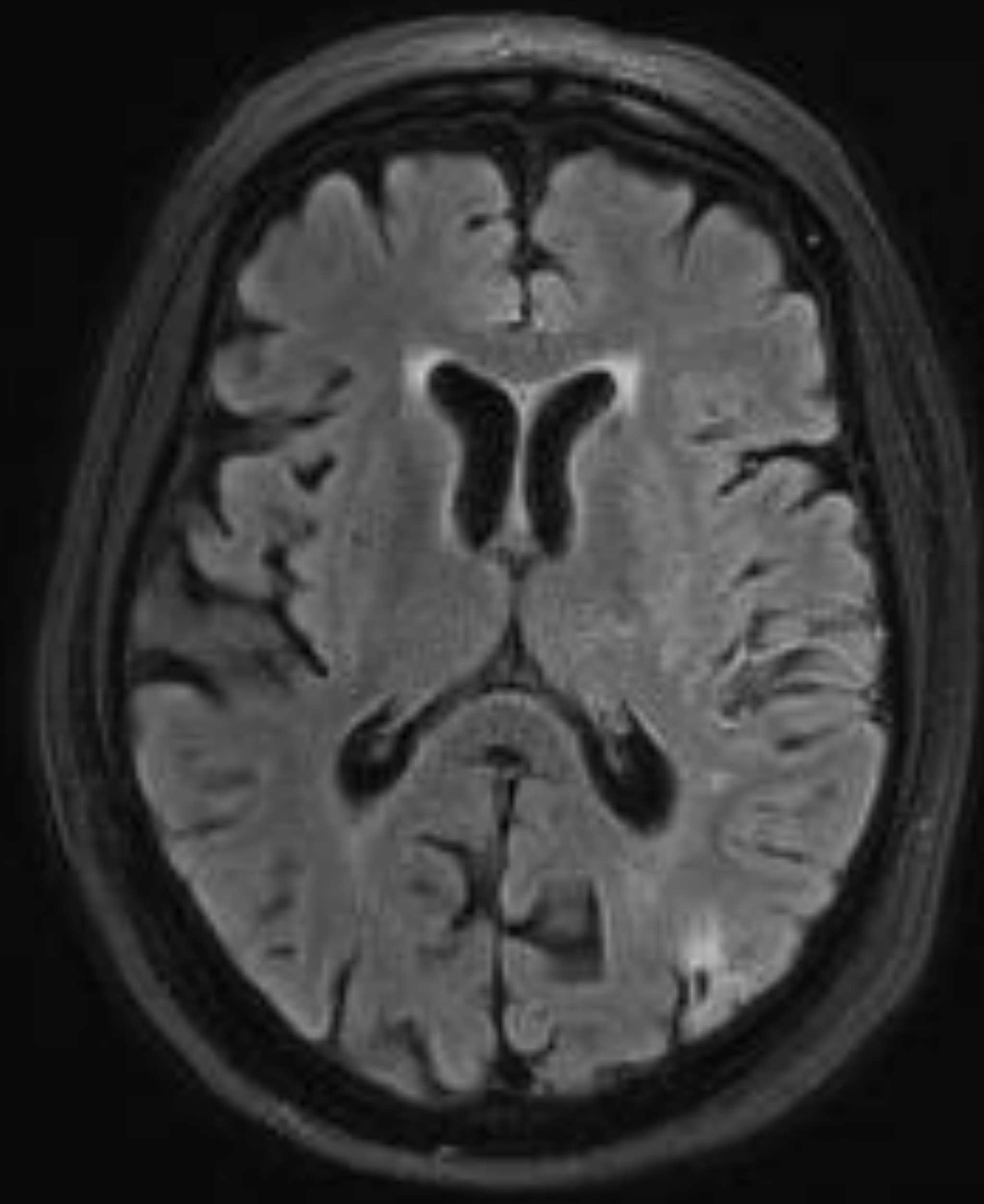


VIM





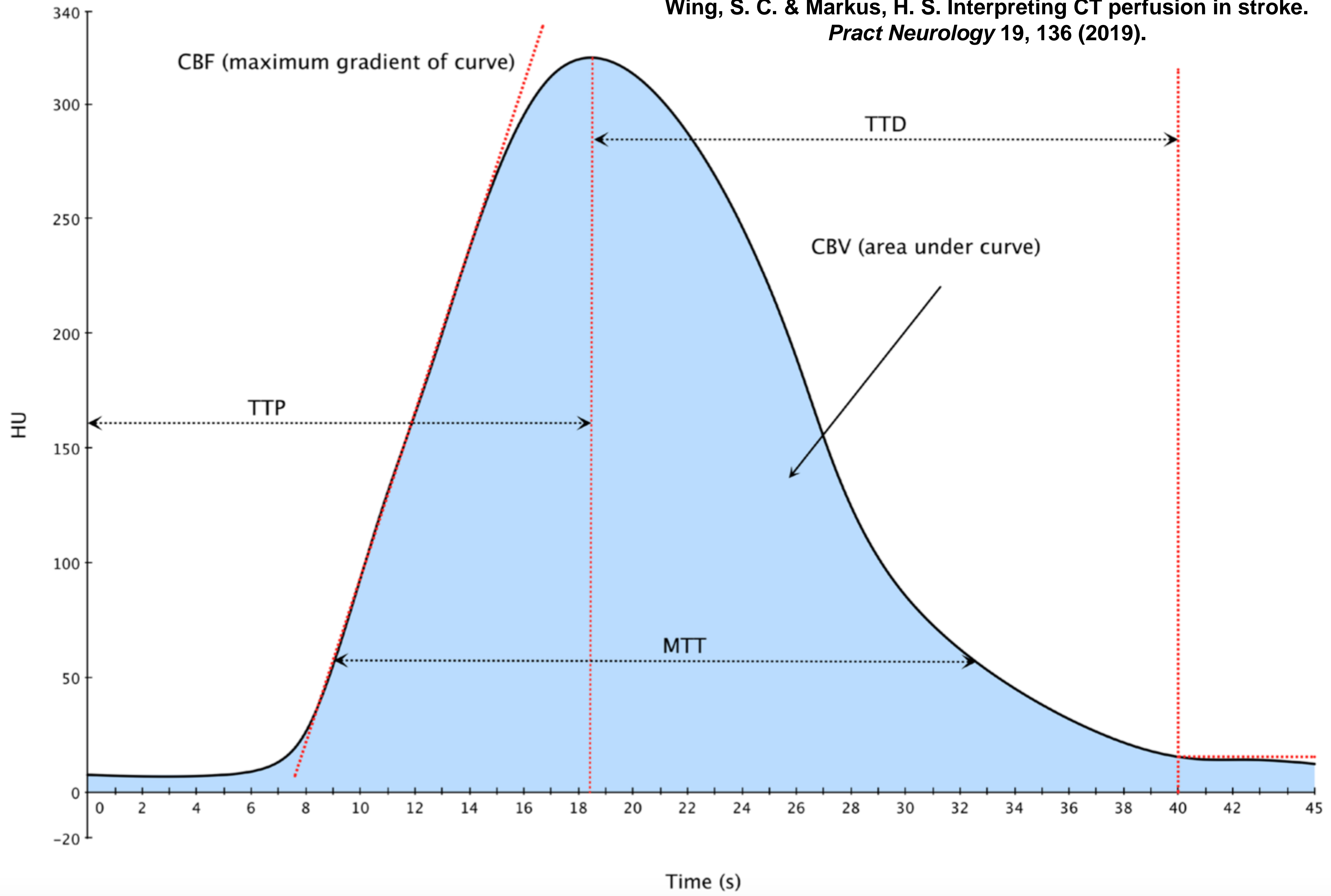
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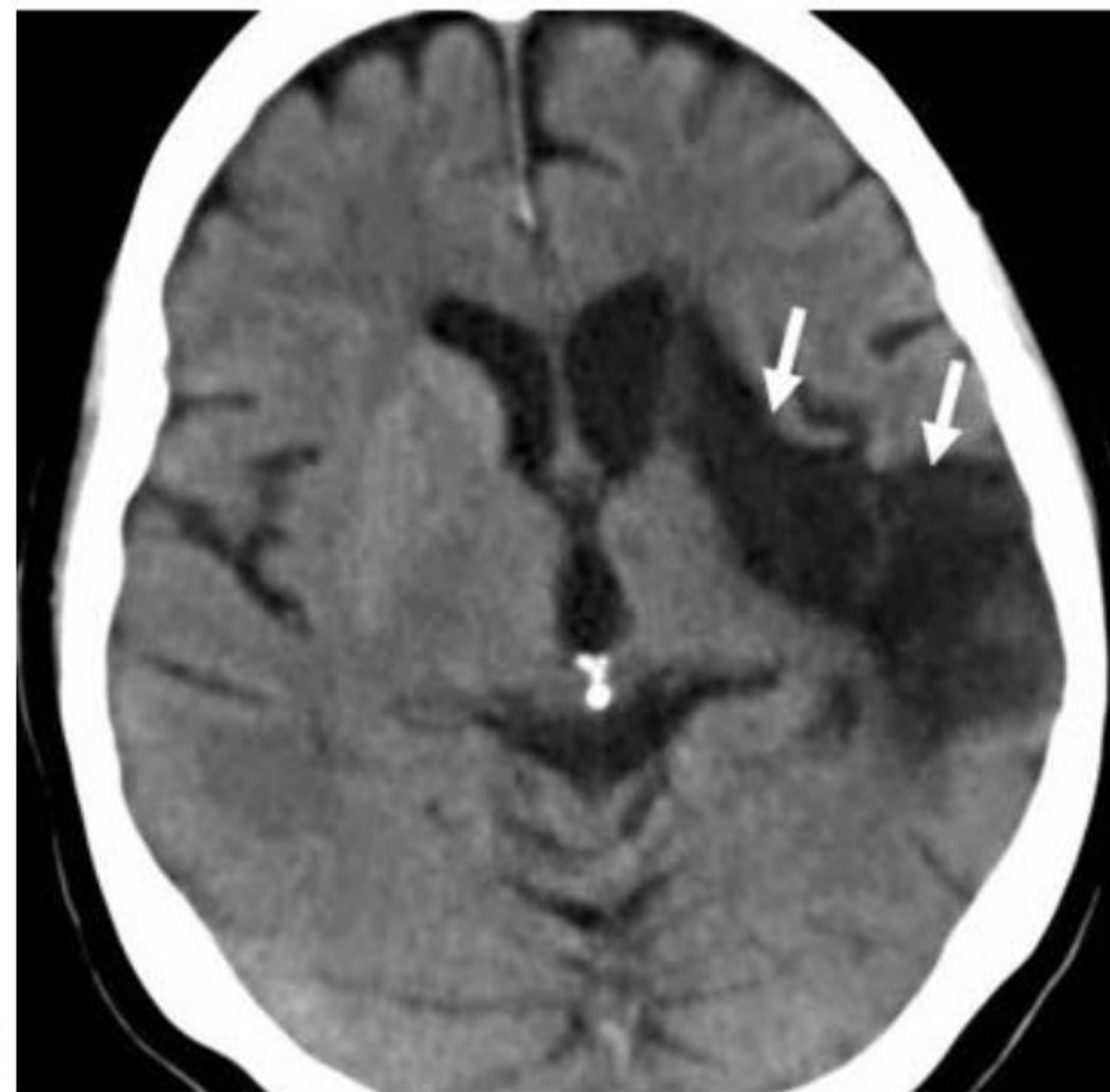
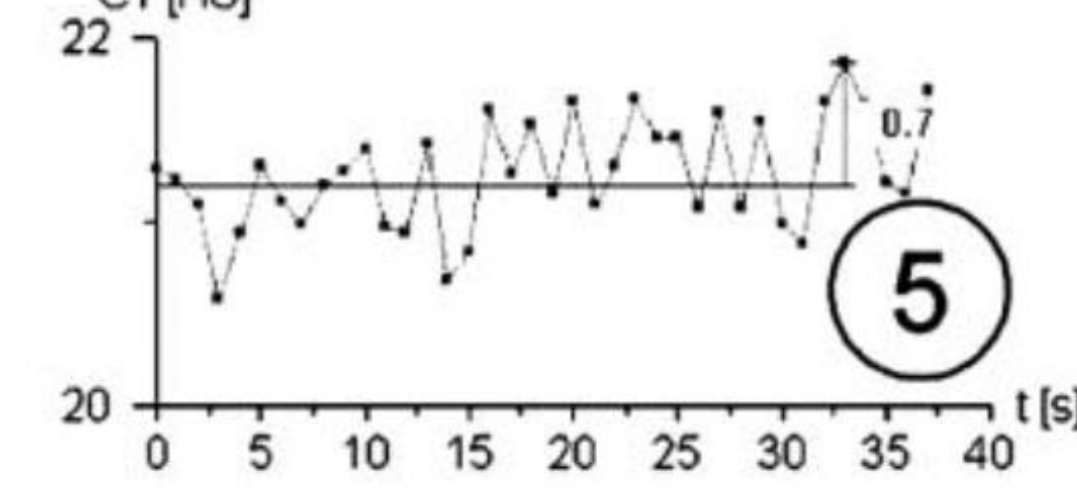
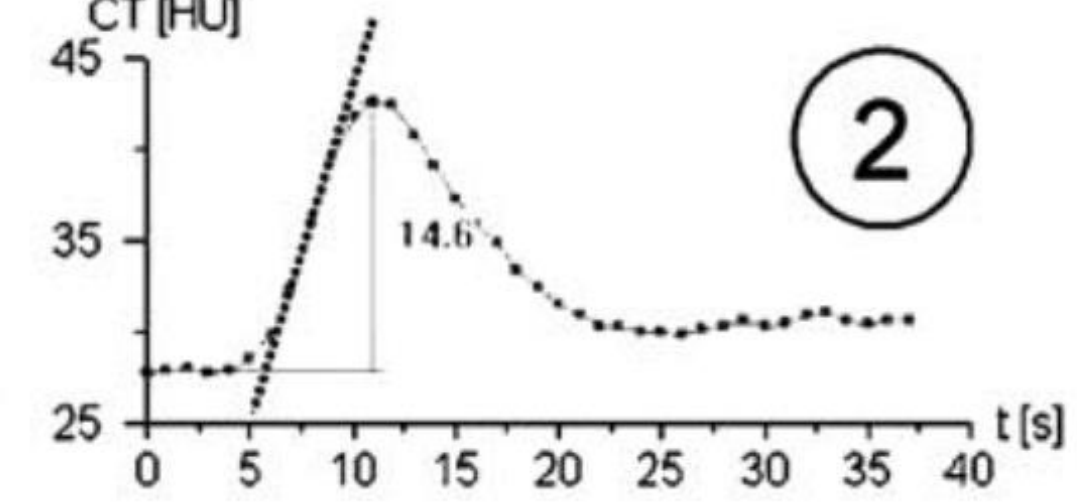
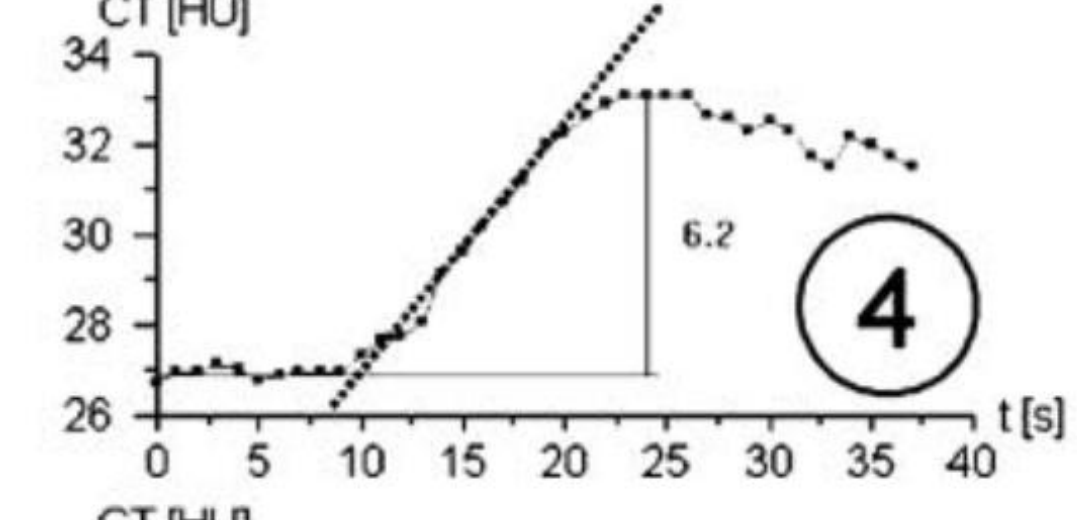
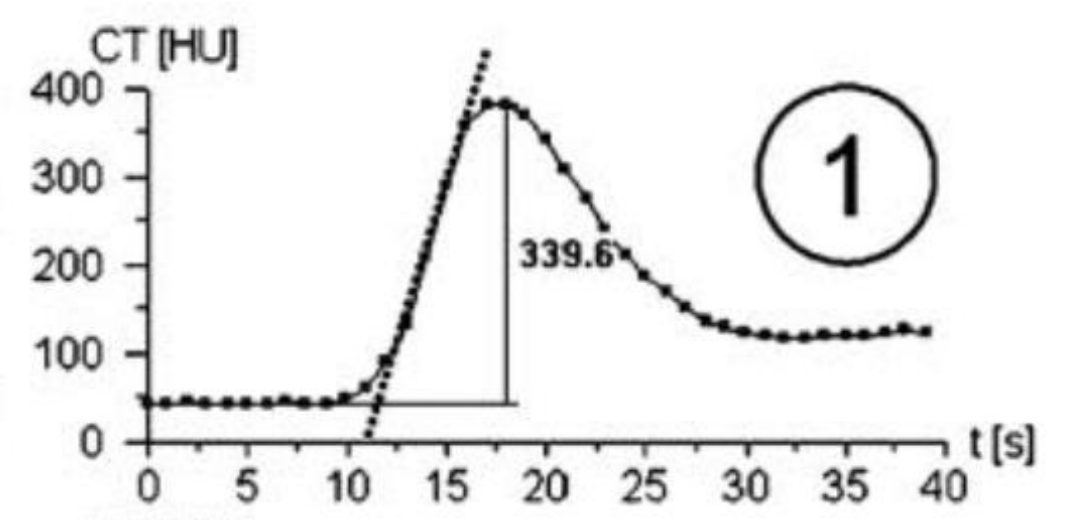
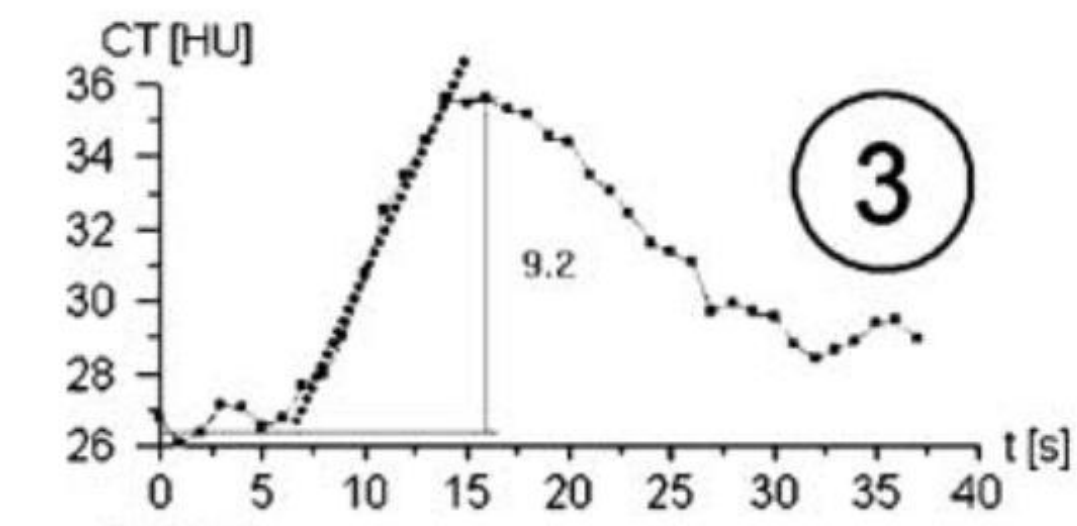
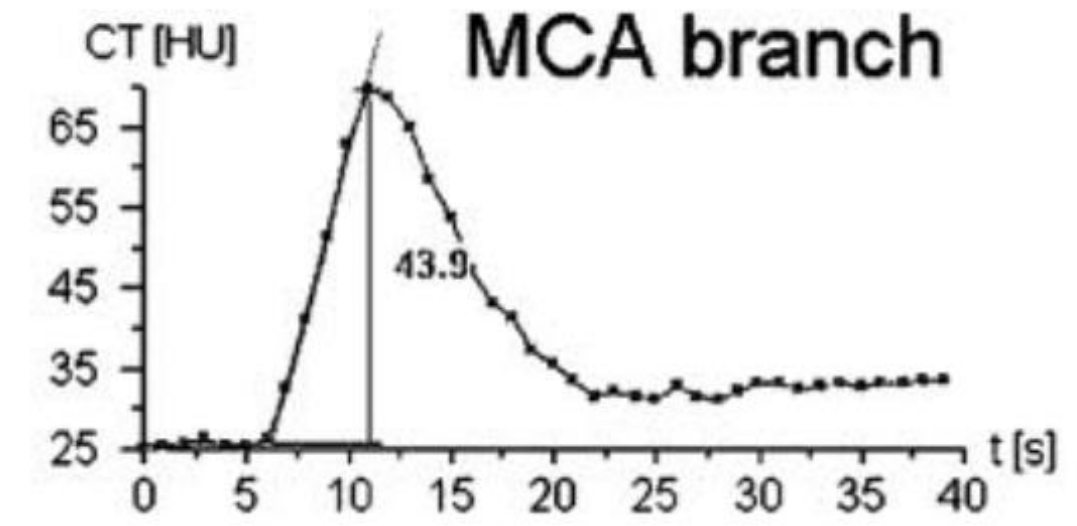
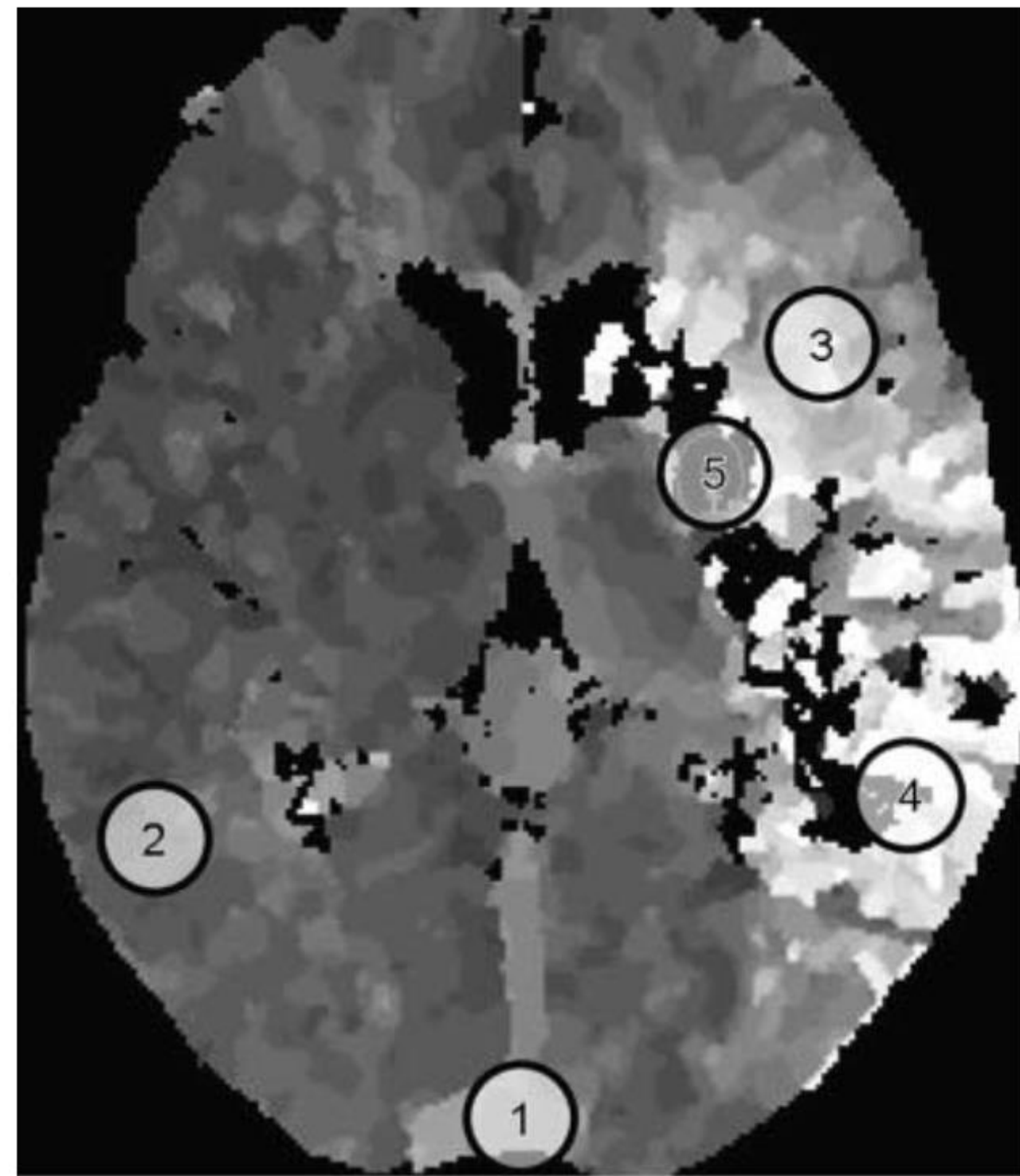


FLAIR

# Visualizing the penumbra

- The penumbra corresponds to the clinical symptoms, and therefore these can be used to estimate the penumbra
- In both CT and MRI perfusion, contrast is injected and serial scans are subsequently performed to track how the contrast passes from the arterial to the venous phase
- In MRI Slow-Flow on FLAIR or prominent veins on gradient weighted imaging (SWI) can also be used to estimate the penumbra
- There is also Arterial Spin Labeling for MRI which is another way of performing perfusion imaging





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# Interpretation of data

- The best parameter for the infarct core is CBF < 30 %
- The best parameter for the penumbra is Tmax > 6 sek
- In the early time window (< 3 hours) the infarct core can be overestimated, known as the Ghost Infarct Core
- In the late window (> 6 hours) the core can be underestimated due to spontaneous reperfusion, know as the Perfusion Scotoma

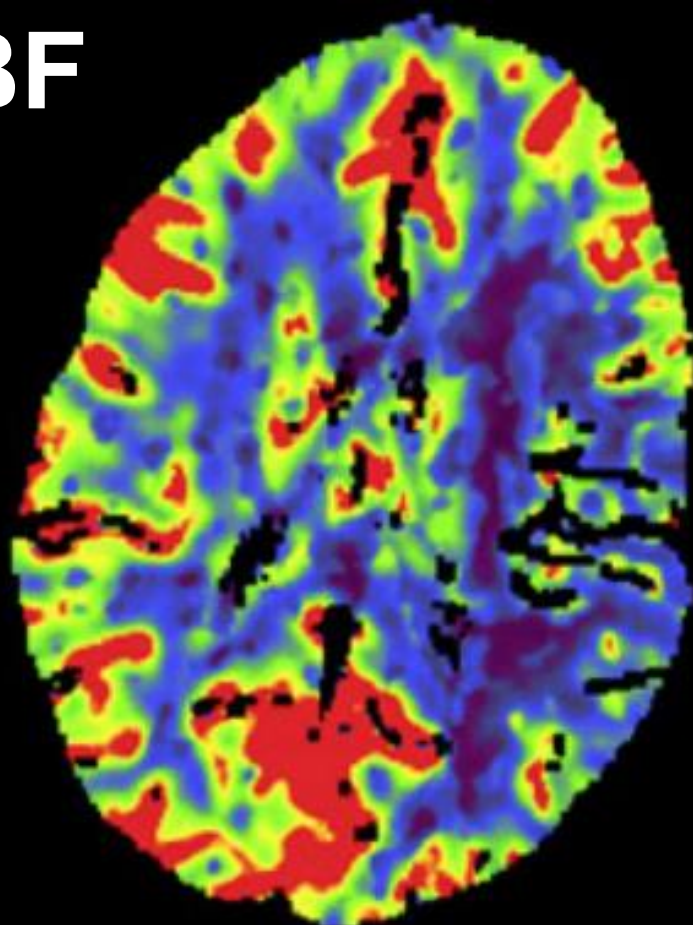
**Table 1** Perfusion measurements derived from CT perfusion acquisitions and their usual findings for core and penumbra in acute stroke

Measurement	Core	Penumbra
Time to peak	↑↑	↑
Mean transit time	↑↑	↑
Cerebral blood flow	↓↓	↓
Cerebral blood volume	↓	↔ or ↑
Flow:volume ratio	Matched	Unmatched

**NCCT**

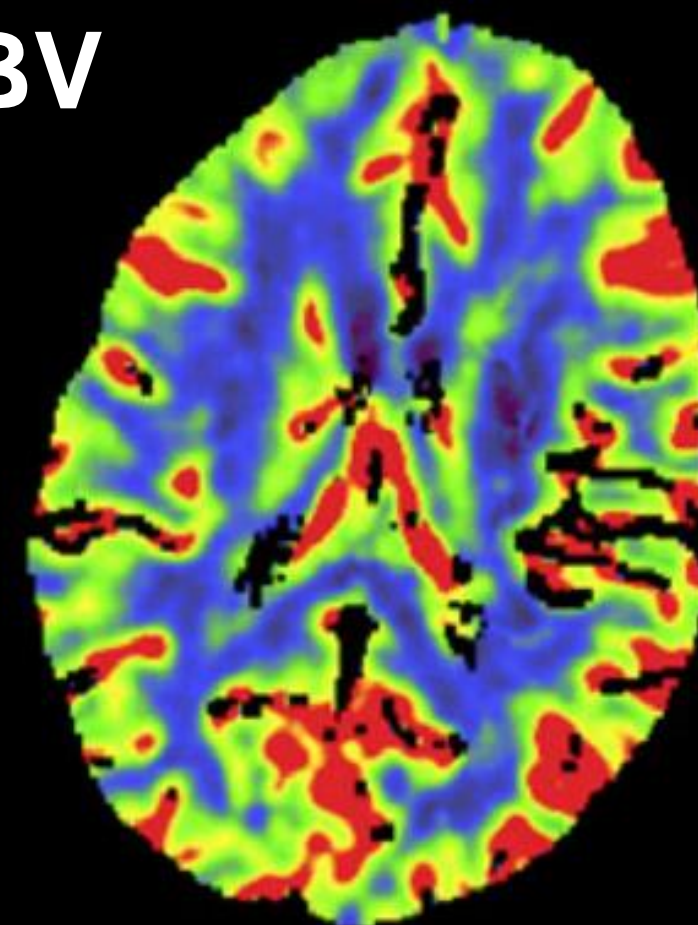


**CBF**



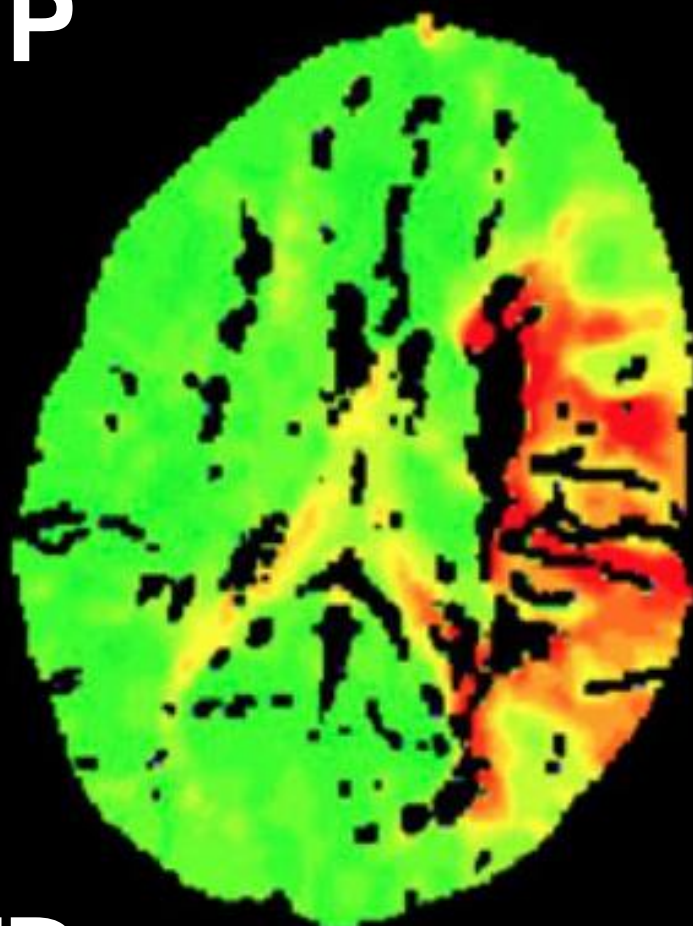
100.0

**CBV**



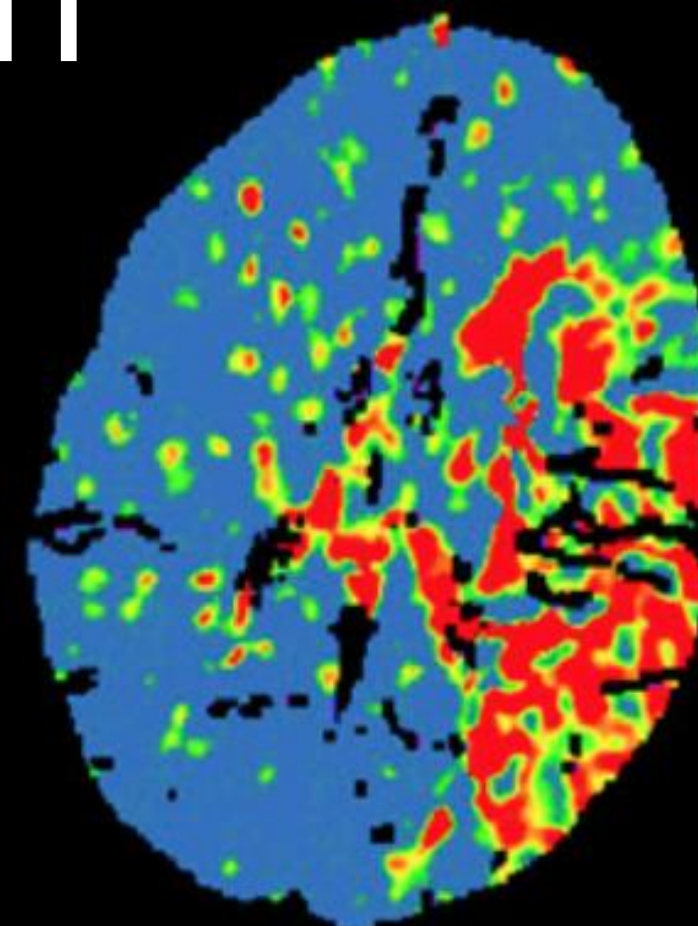
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**TTP**



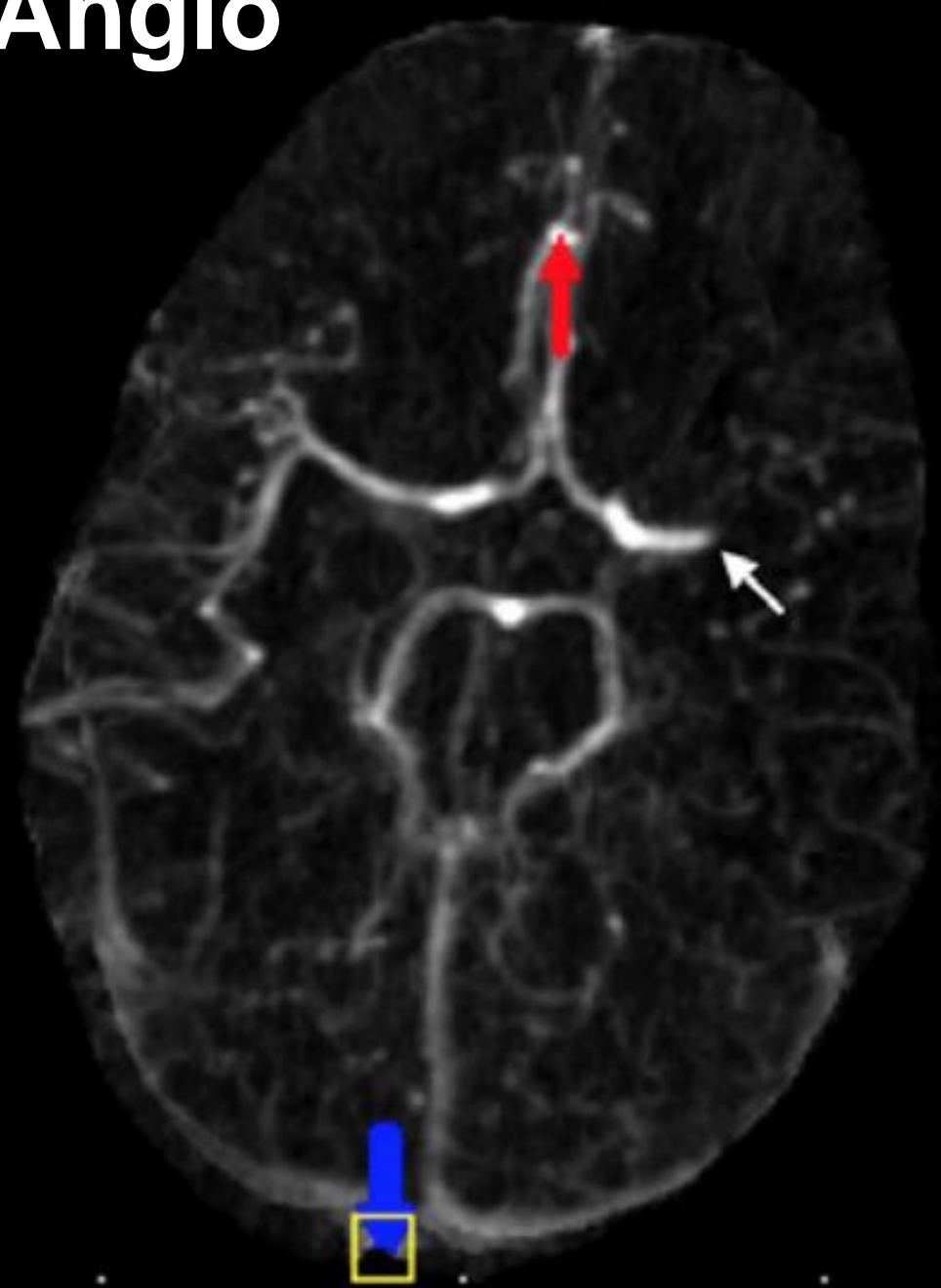
20.0

**MTT**

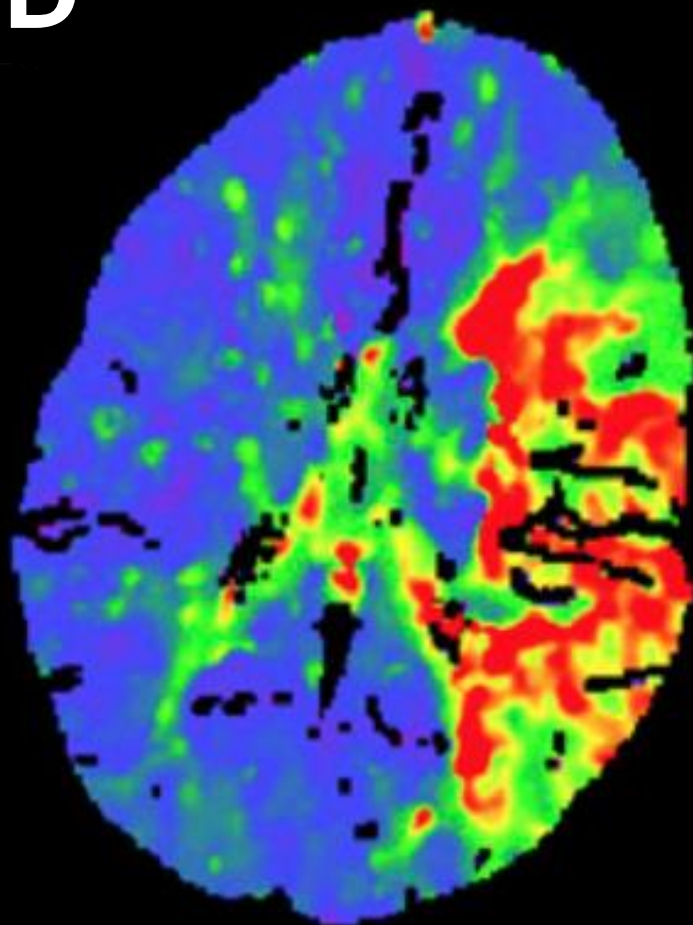


10.0

**Angio**

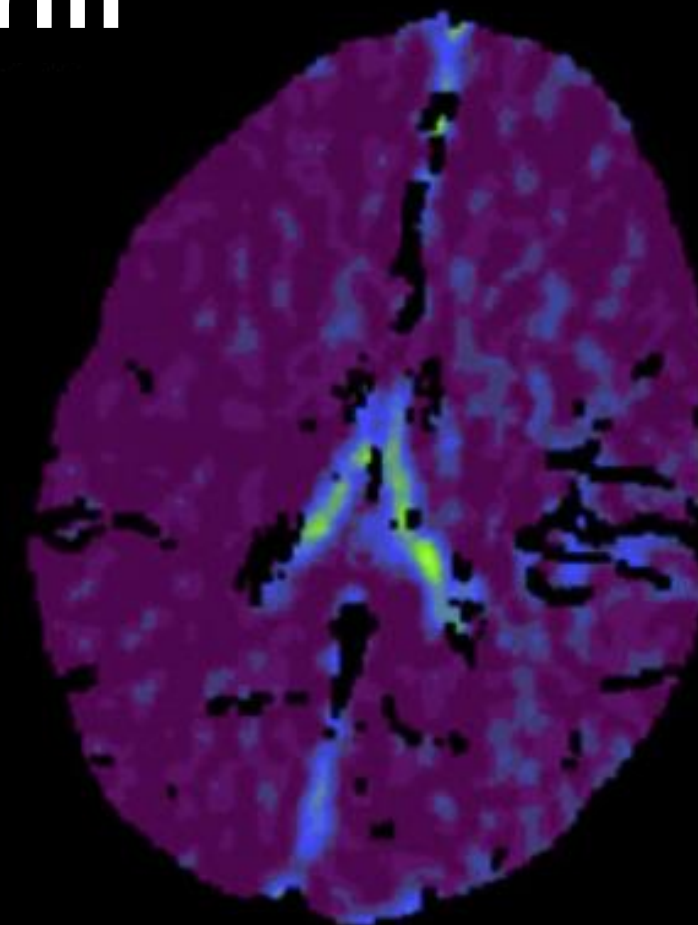


**TTD**



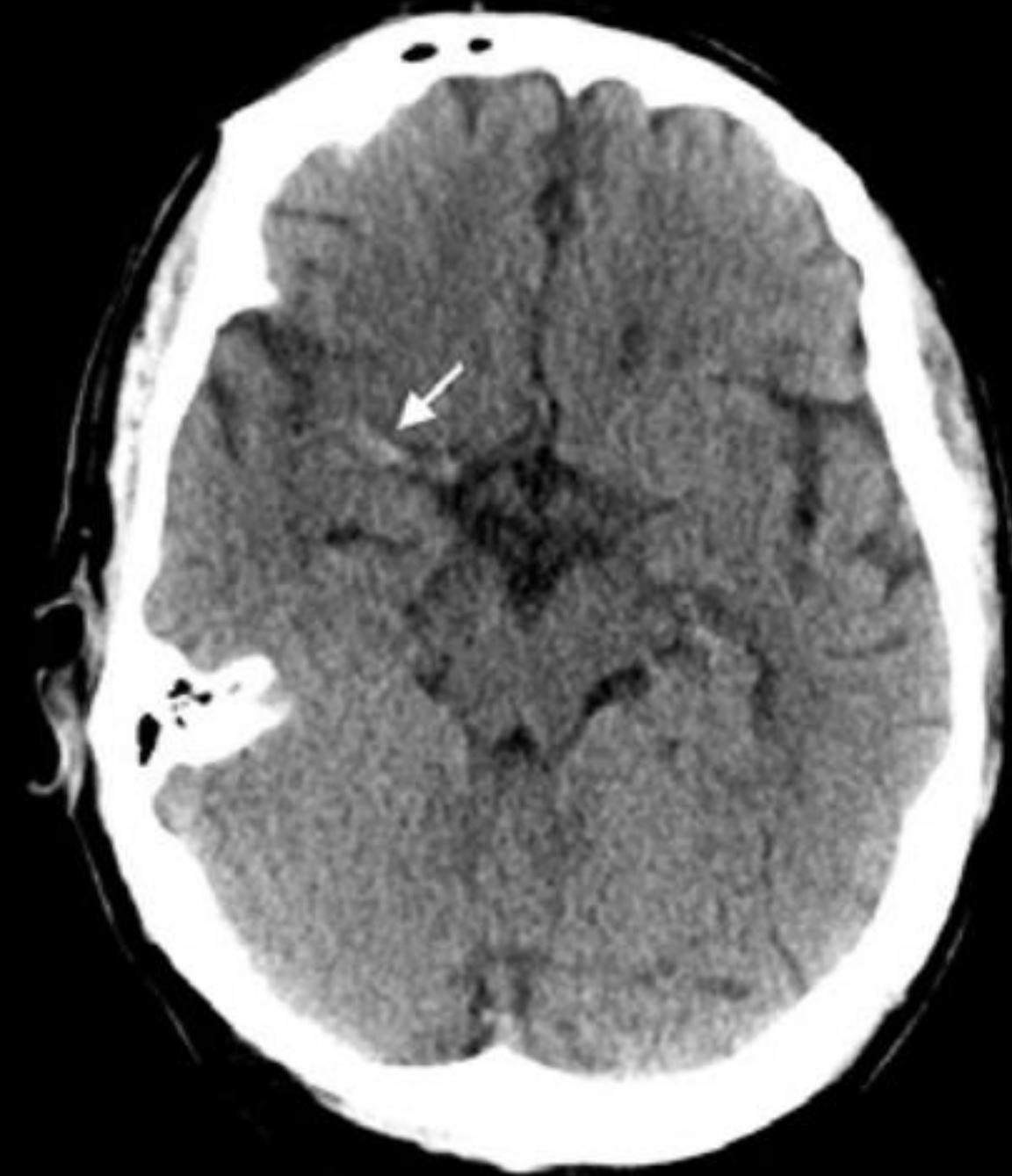
15.0

**Perm**



20.0

**NCCT**

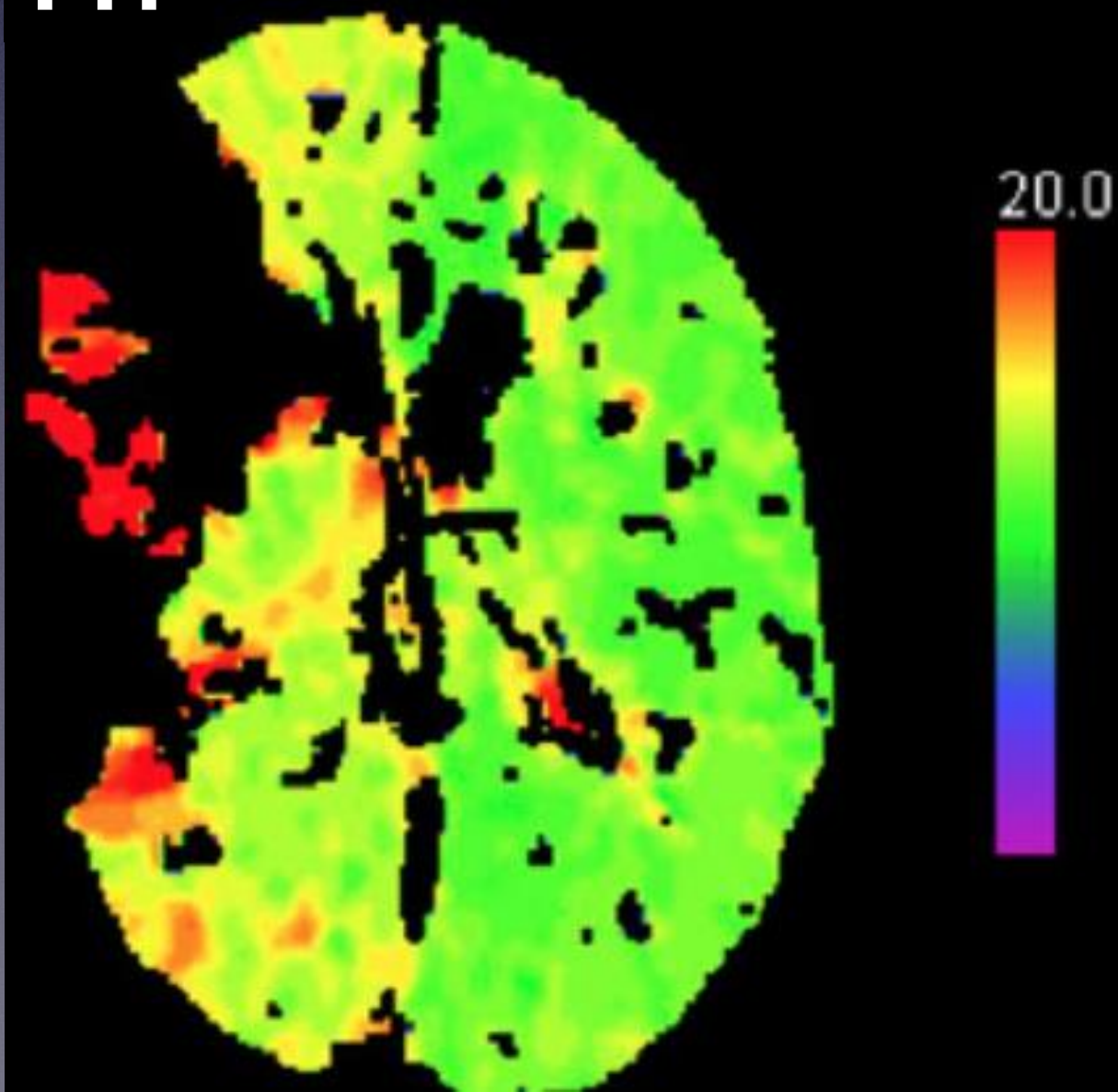


**Angio**

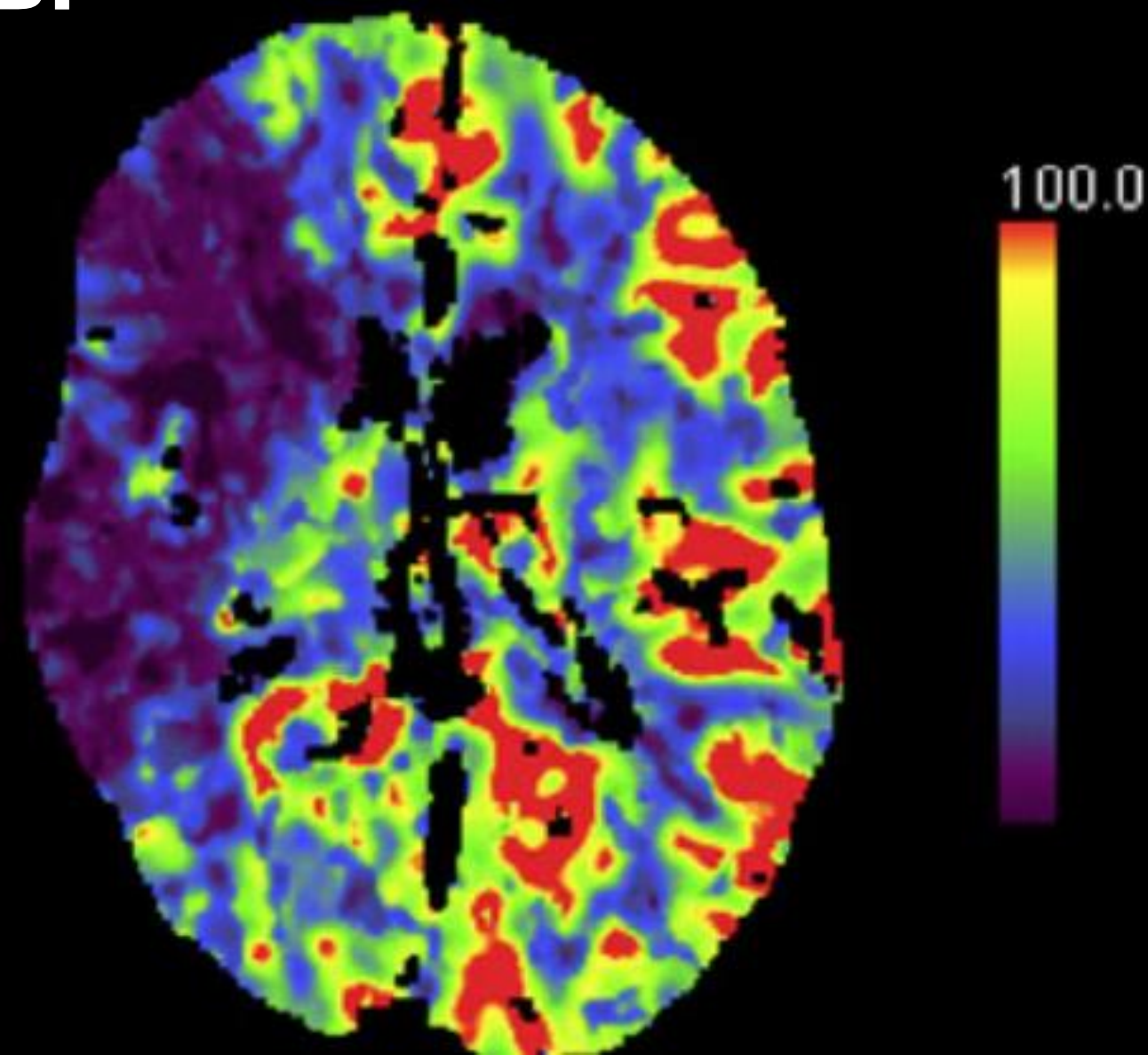


Wing, S. C. & Markus, H. S.  
Interpreting CT perfusion in stroke.  
*Pract Neurology* 19, 136 (2019).

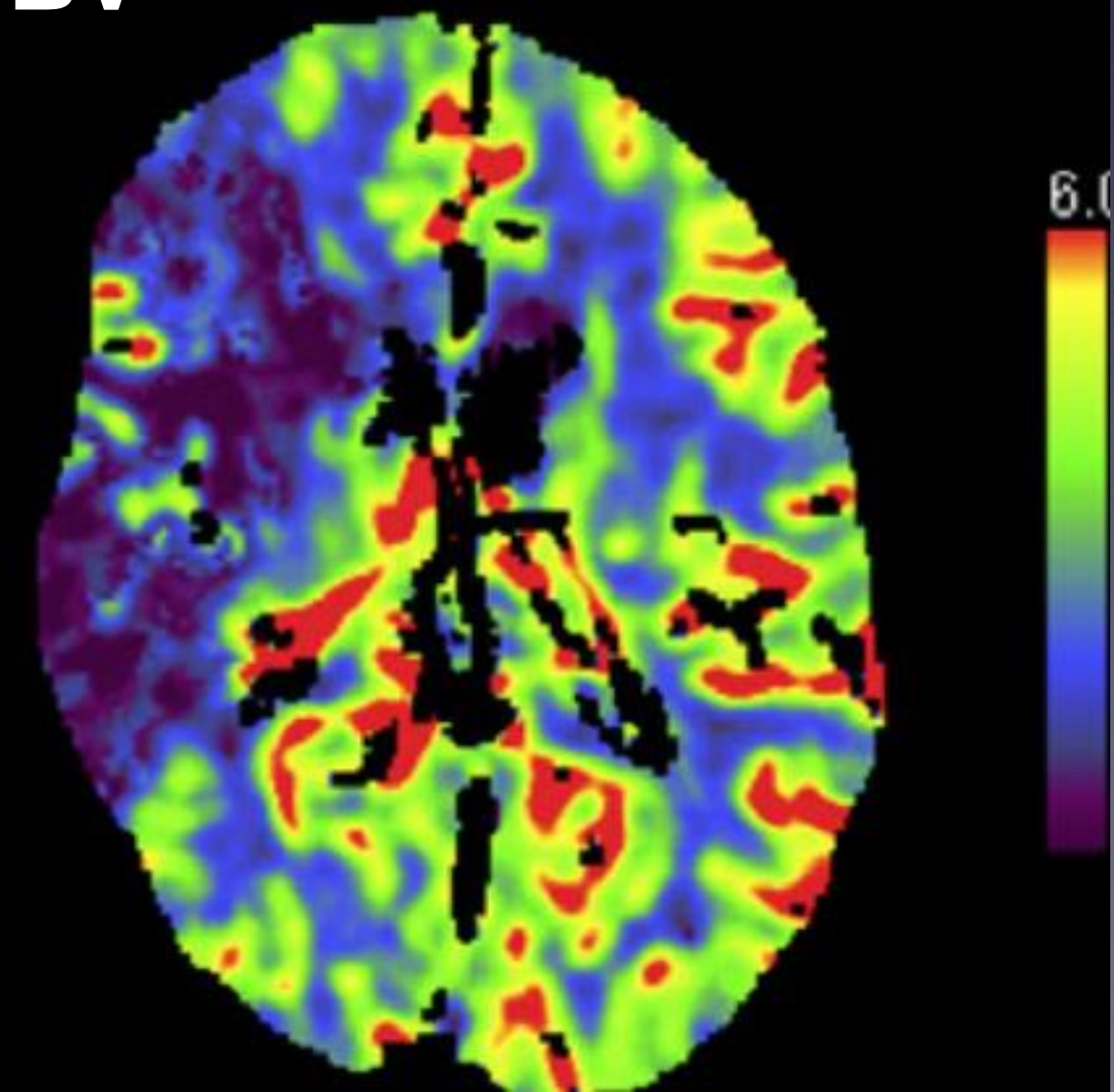
**TTP**



**CBF**



**CBV**

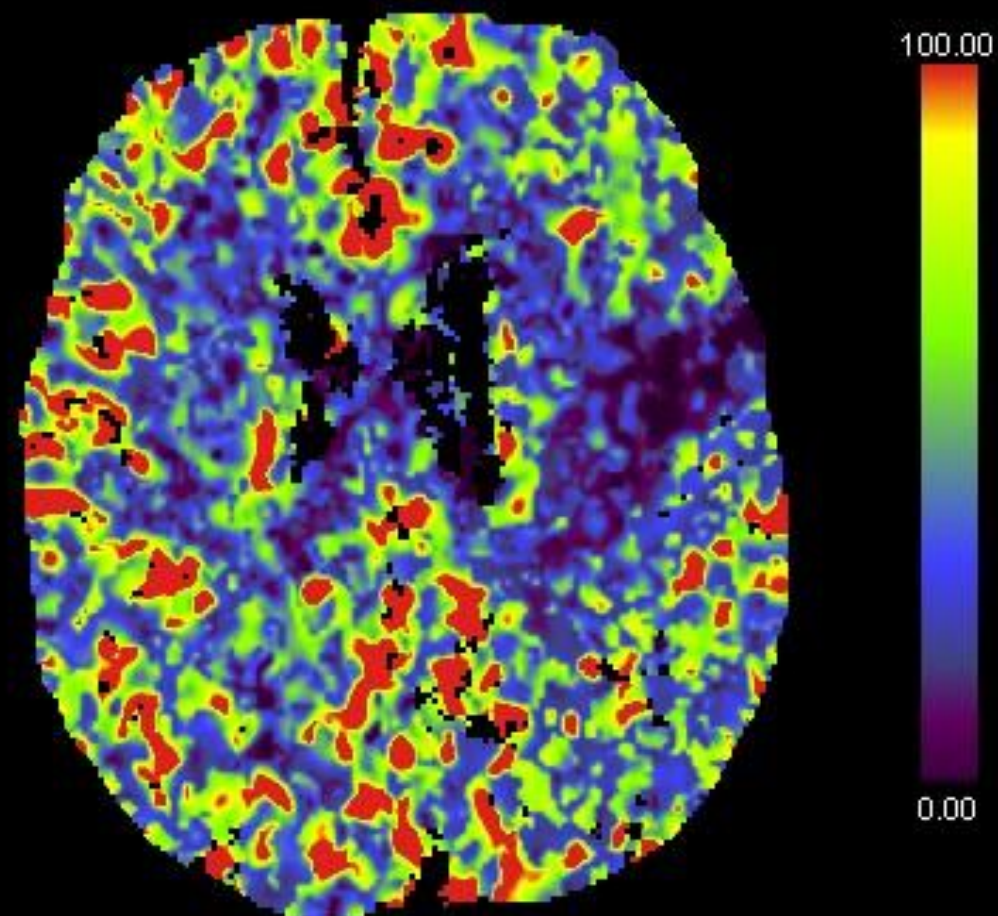


Automatically calculated results.  
Do not use without checking the quality control images.

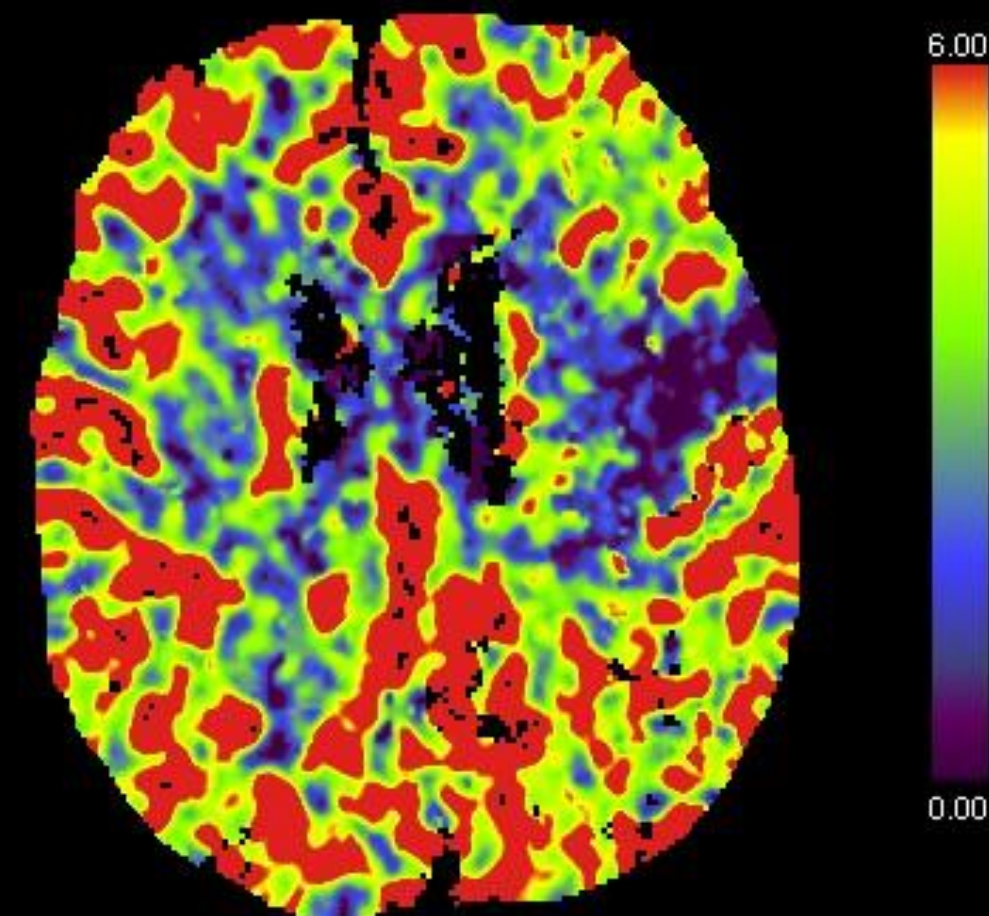
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**NCCT**



**CBF**



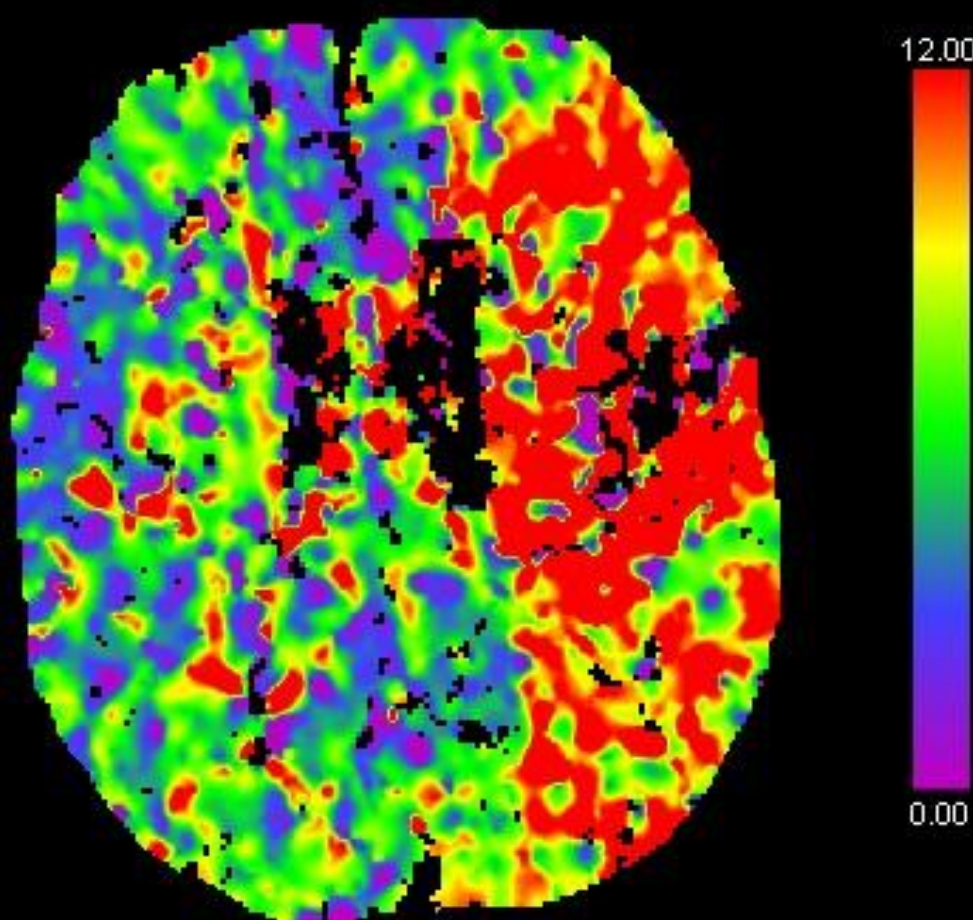
**CBV**



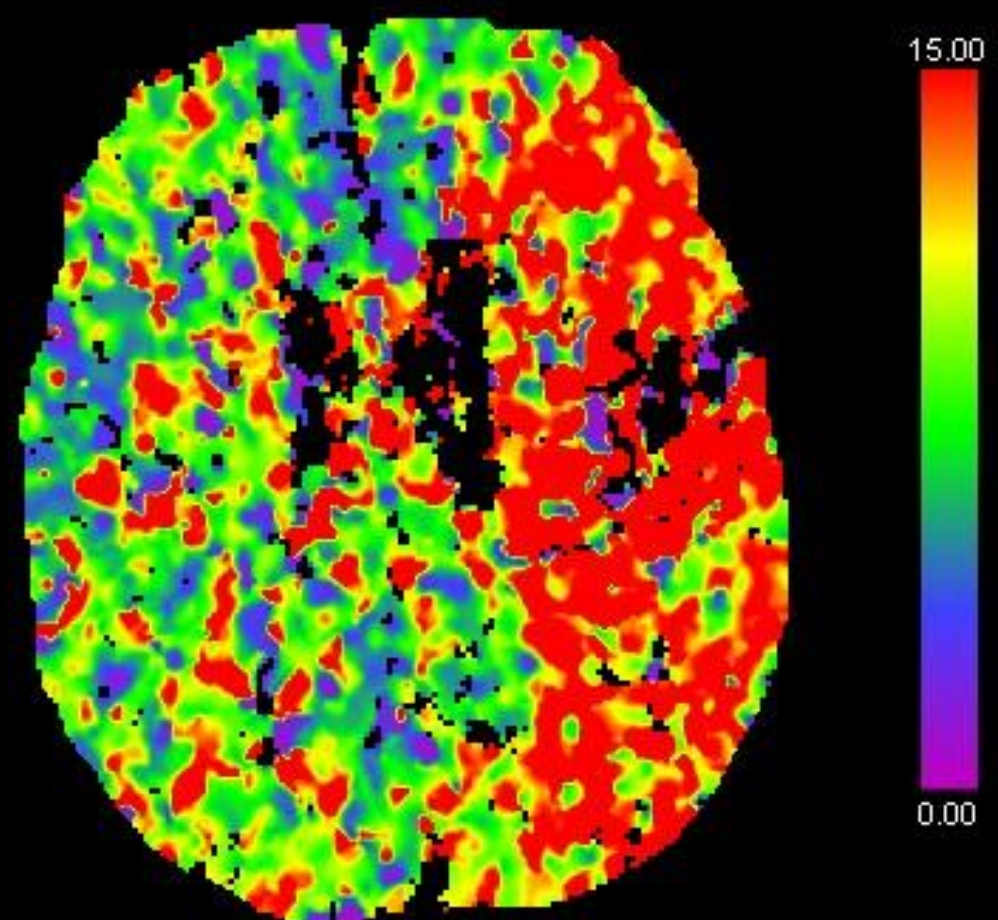
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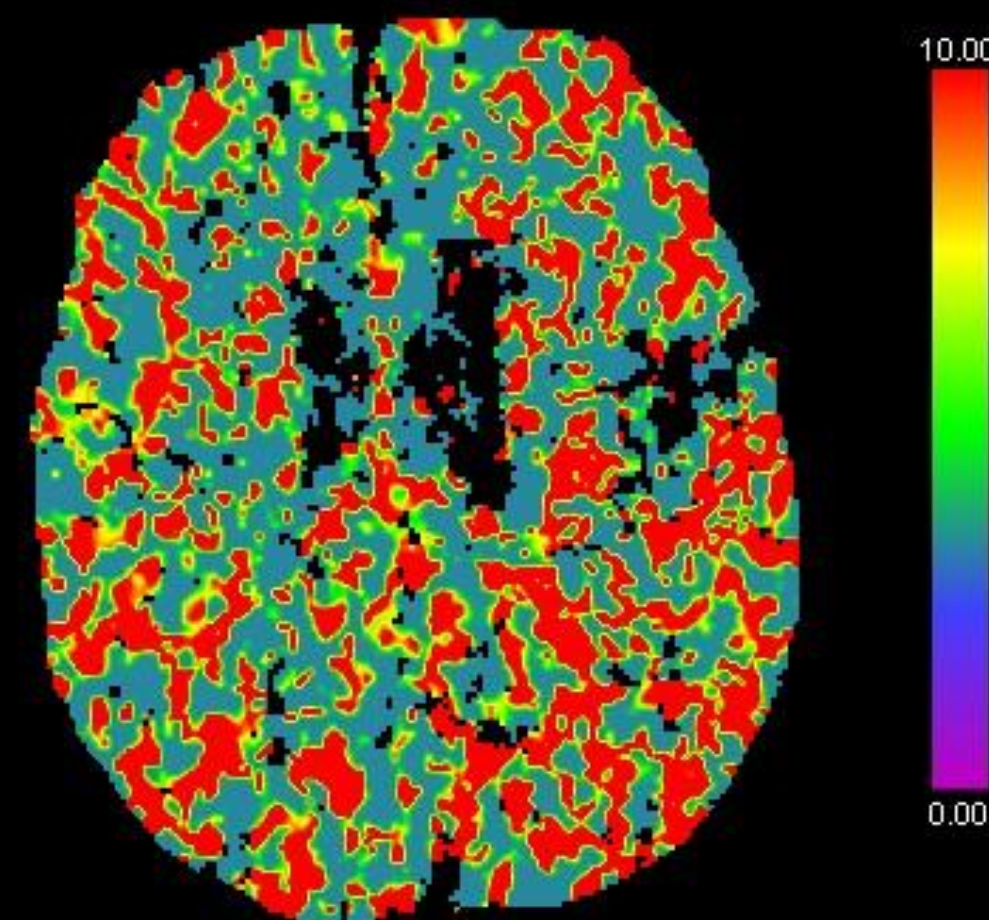
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Do not use without checking the quality control images.



**Tmax**



**TTD**



**MTT**





Automatically calculated results.  
Do not use without checking the quality control images.

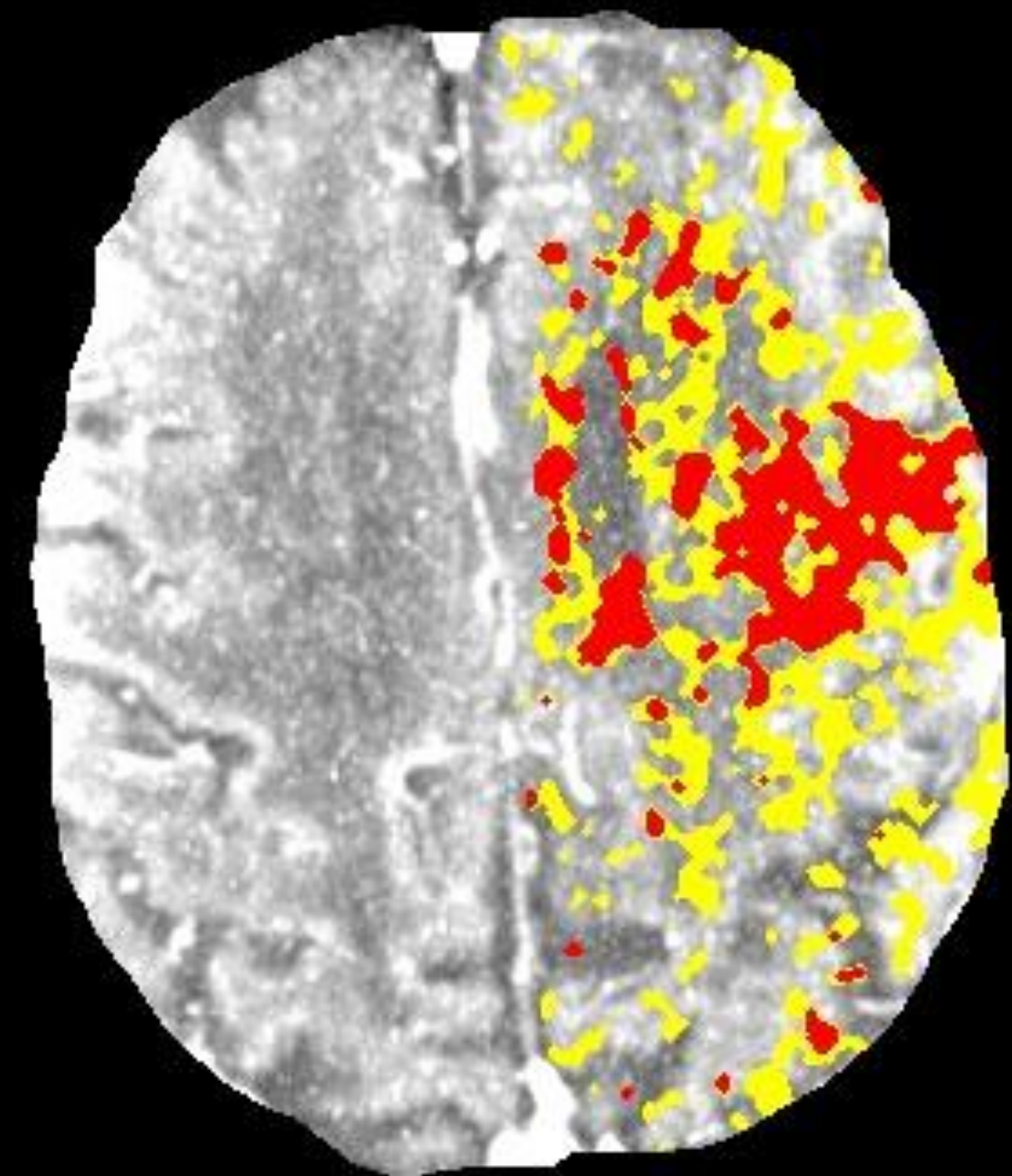


Relative

Region	Legend	Show TAC	Summary
Total	<span style="color: green;">—</span>	<input checked="" type="checkbox"/>	Hypoperfusion = 129.63cm <sup>3</sup> Infarct = 43.51cm <sup>3</sup>
TAR	<span style="color: yellow;">—</span>	<input checked="" type="checkbox"/>	Penumbra/Mismatch = 86.12cm <sup>3</sup>
NVT	<span style="color: red;">—</span>	<input checked="" type="checkbox"/>	Mismatch Ratio = 2.98
Rest	<span style="color: purple;">—</span>	<input checked="" type="checkbox"/>	PRR = 66.44 %

Calculated for left hemisphere.

Automatically calculated results.  
Do not use without checking the quality control images.

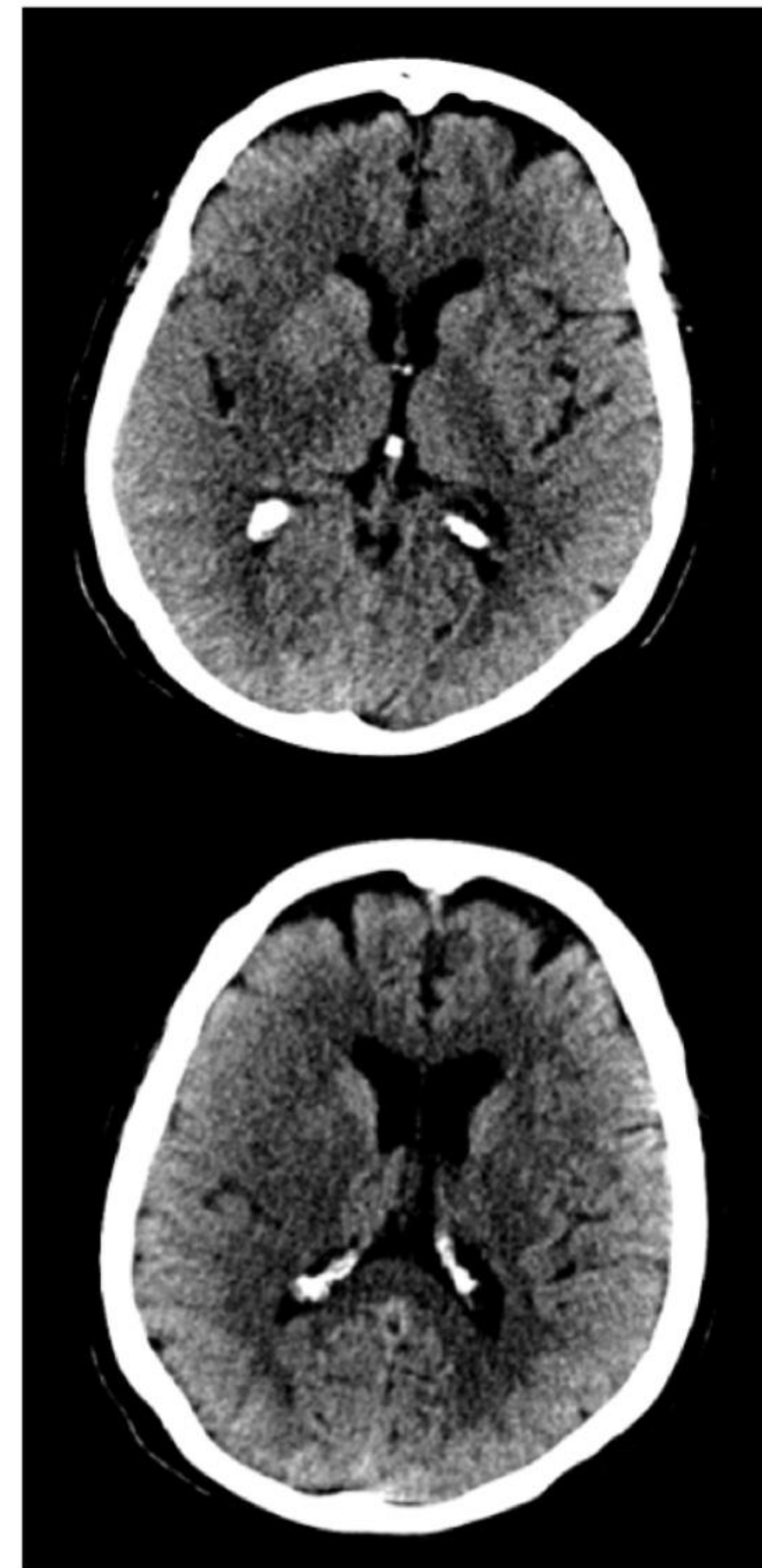
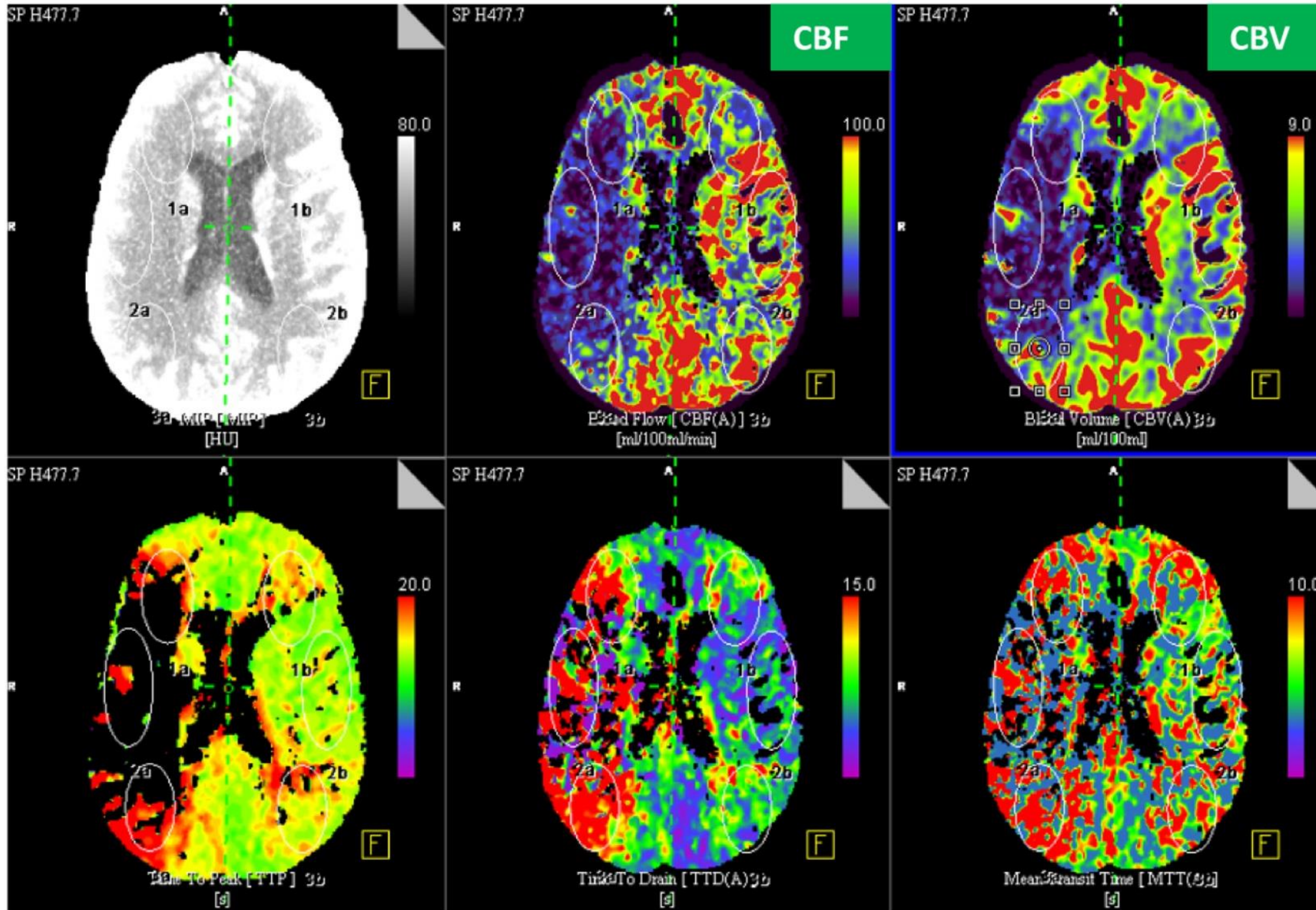


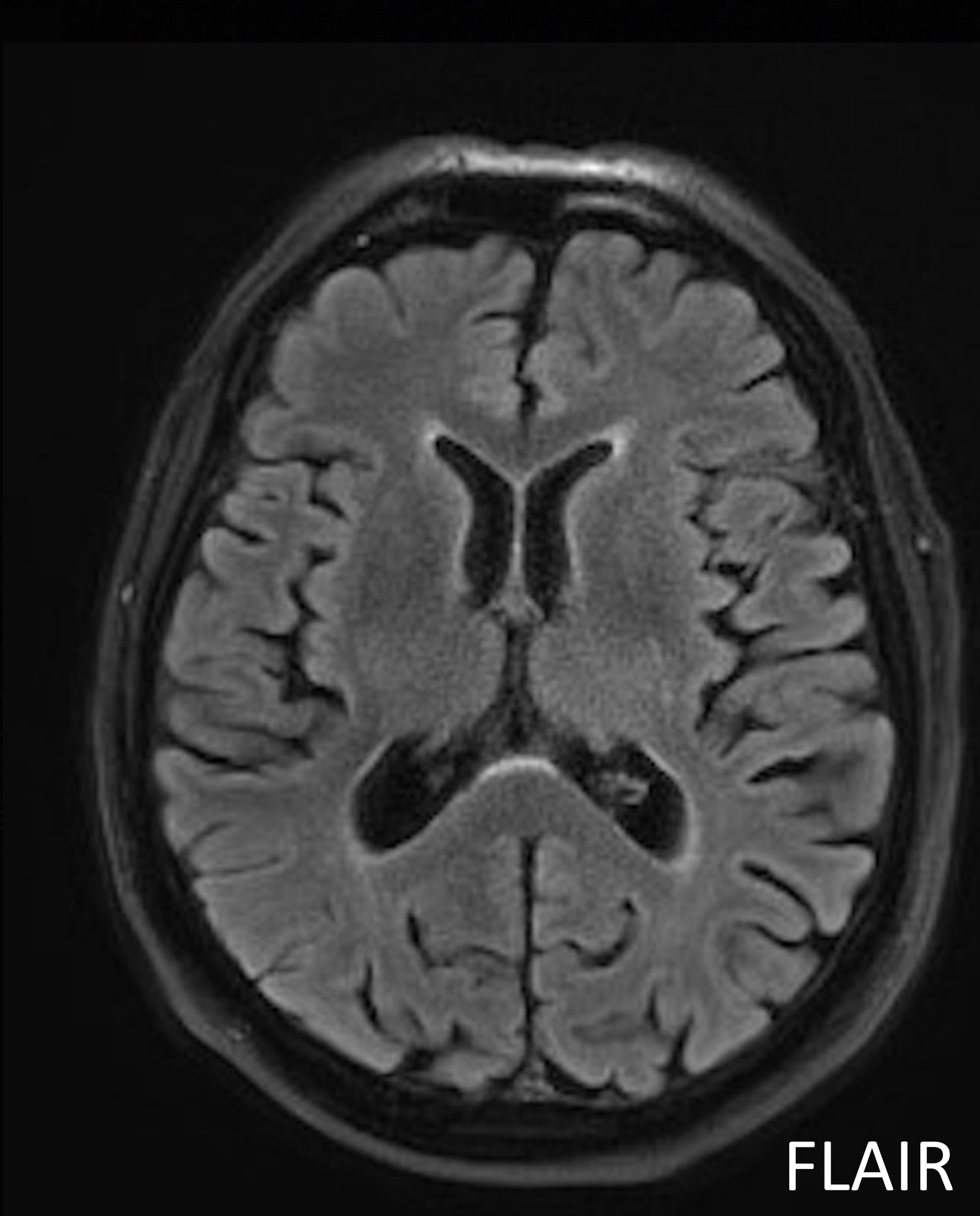
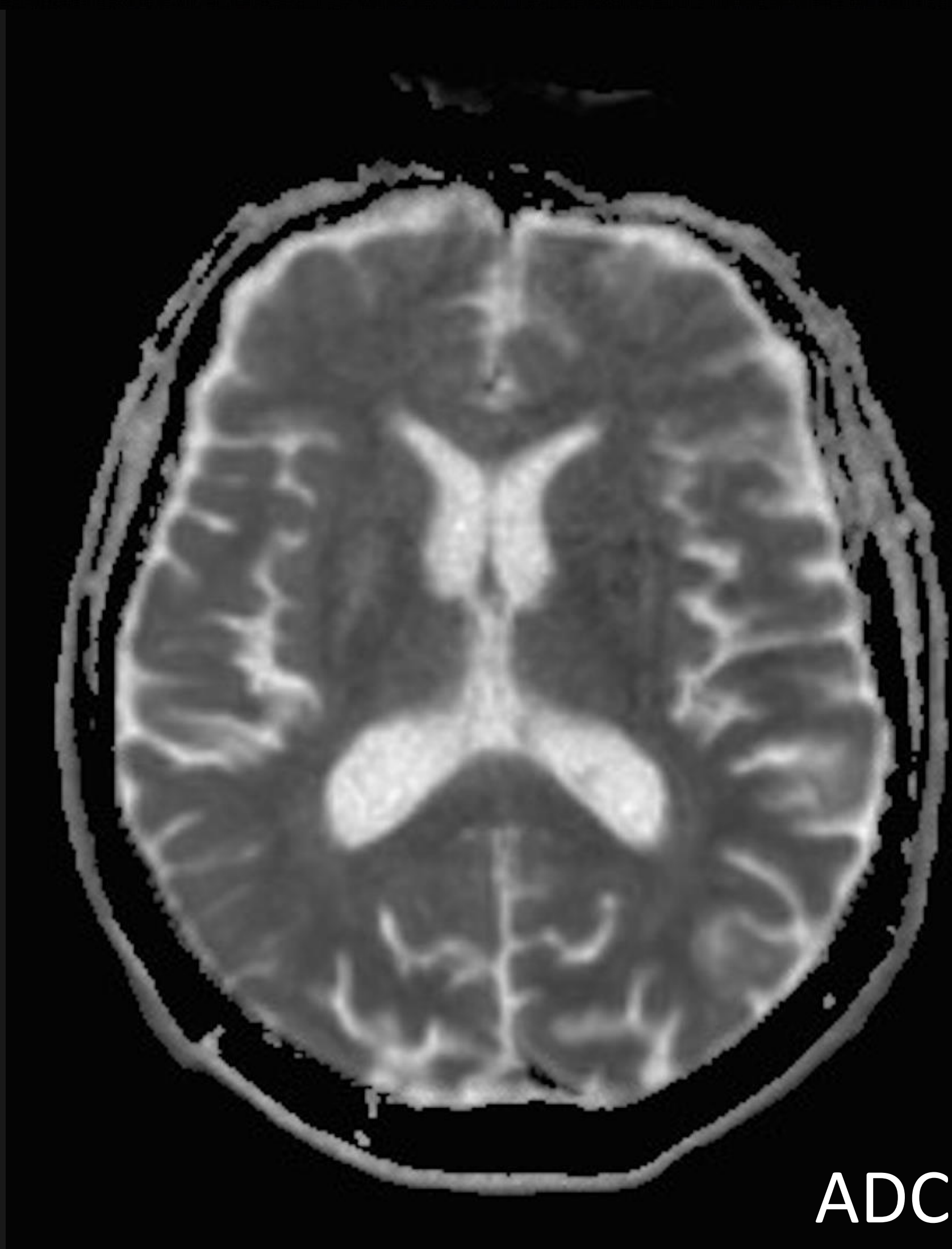
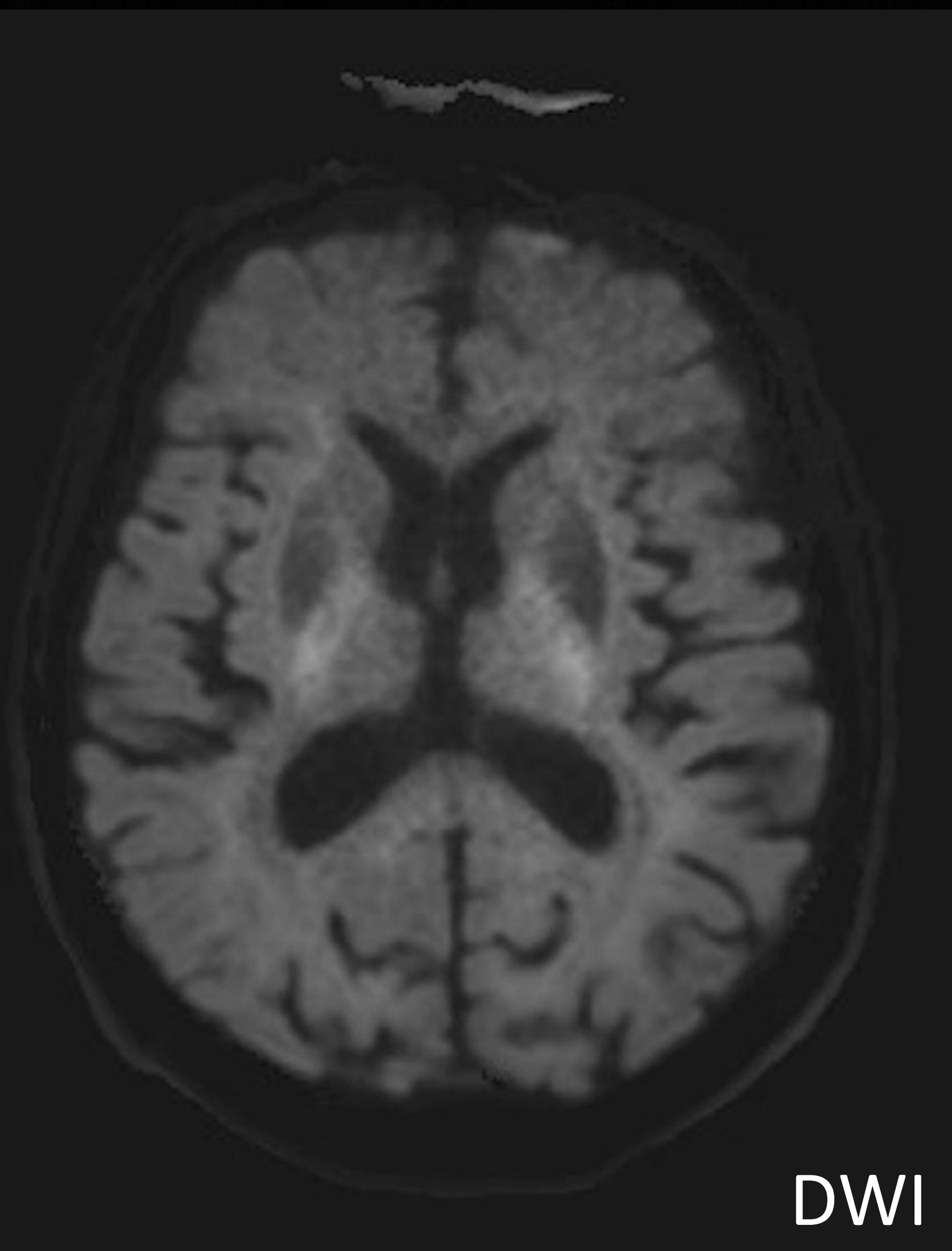
## Penumbra Map

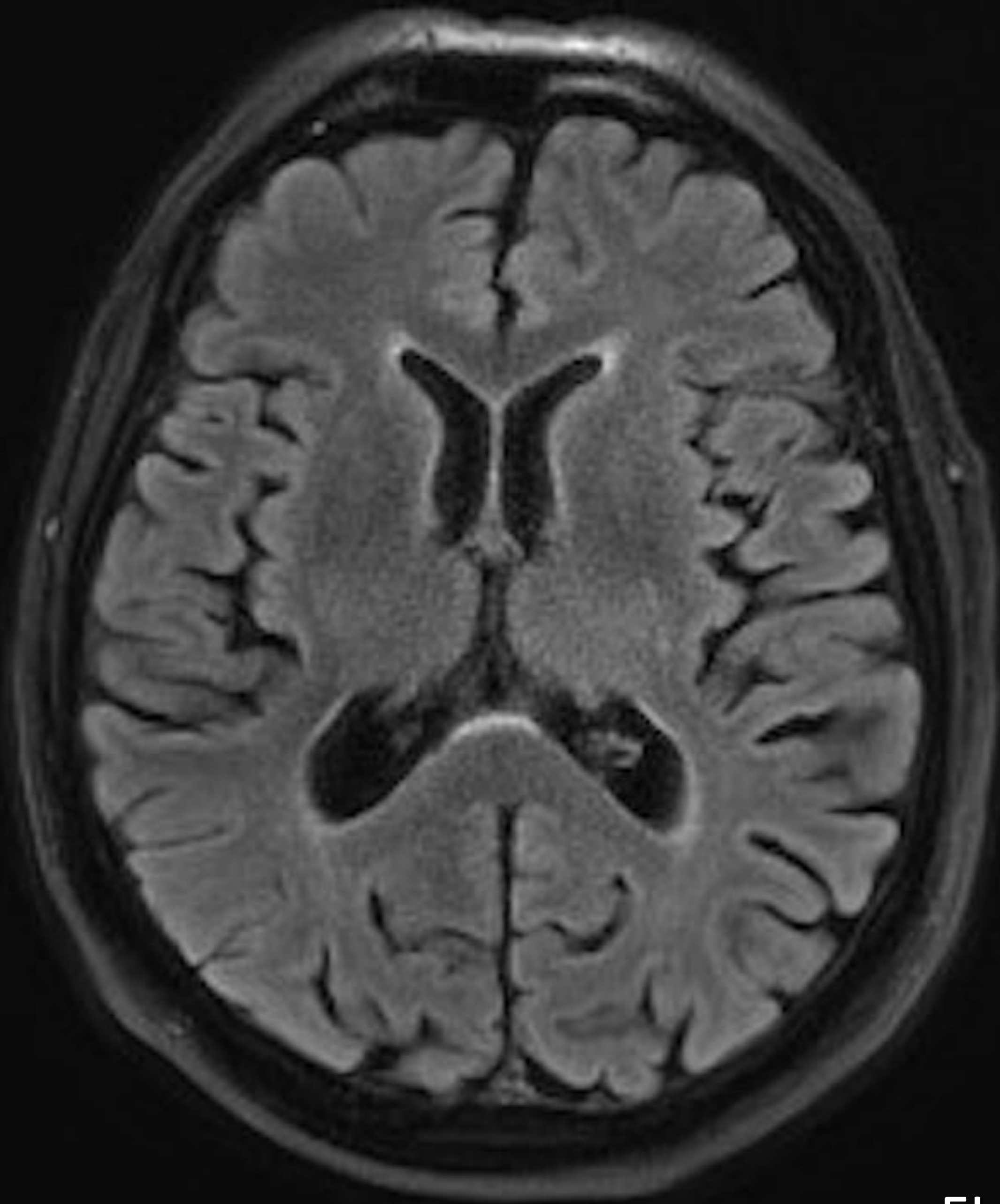
# Admission CTP

Boned, S. *et al.* Admission CT perfusion may overestimate initial infarct core: the ghost infarct core concept. *J Neurointerv Surg* 9, 66 (2017).

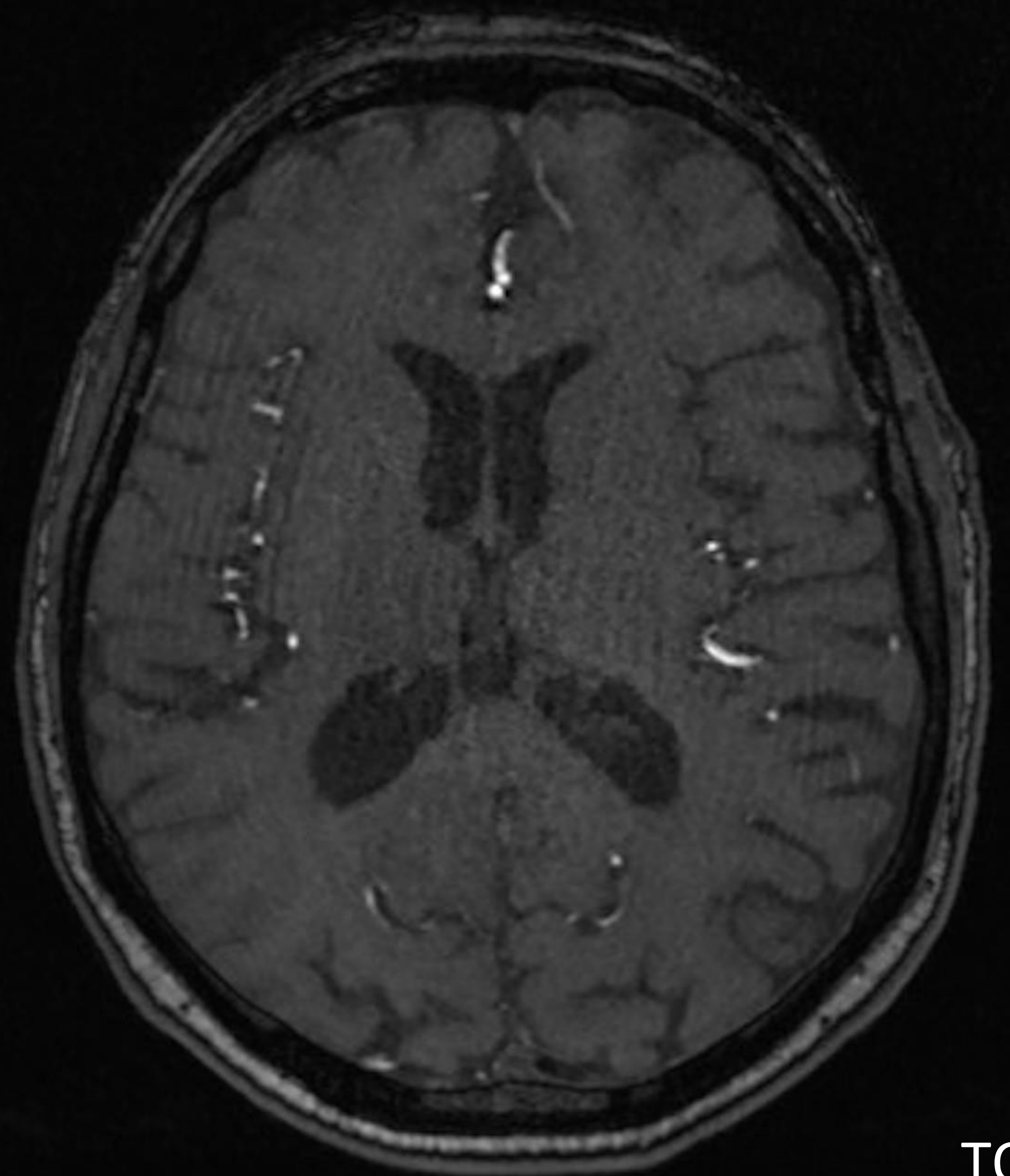
# 24h CT



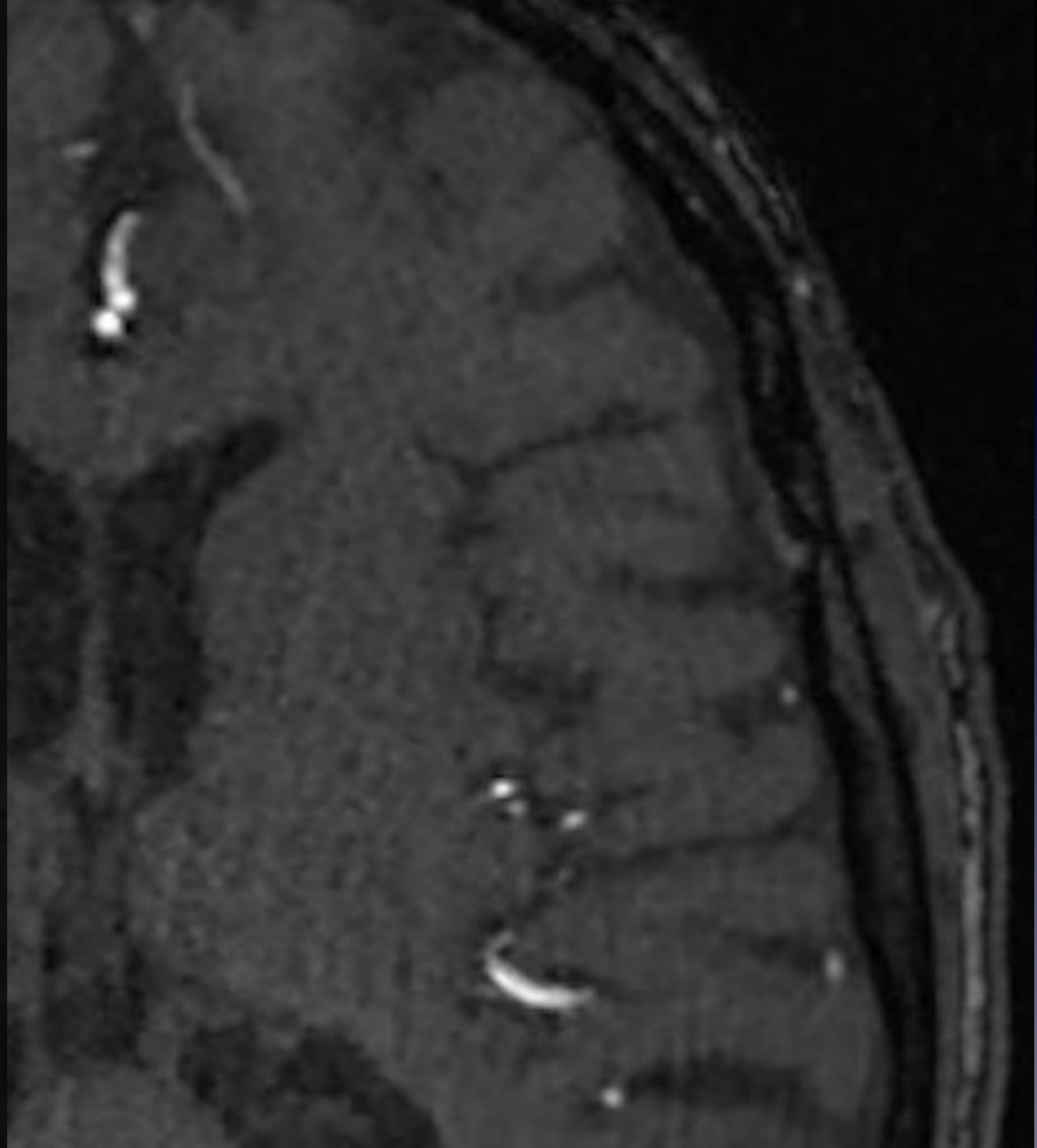
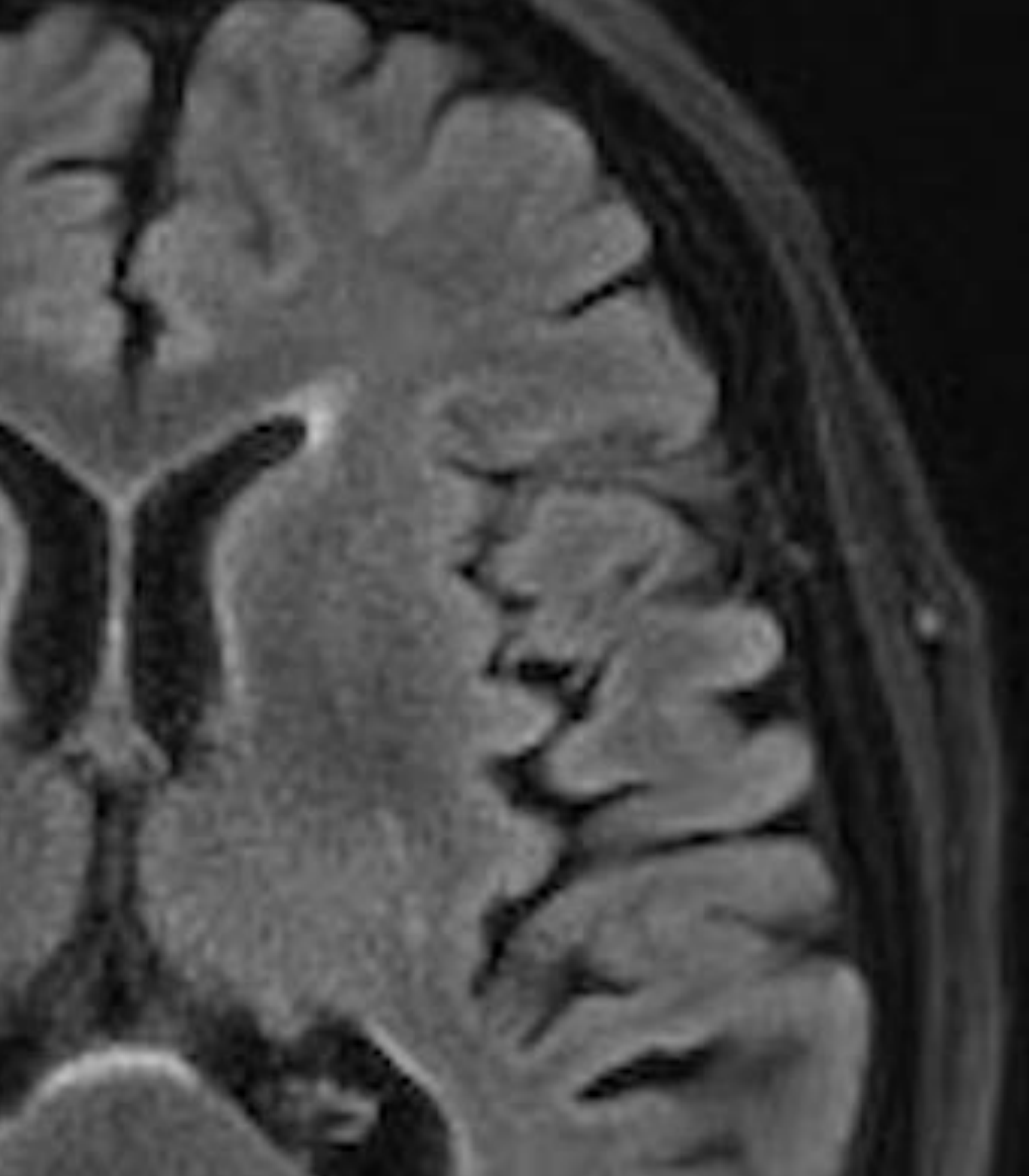


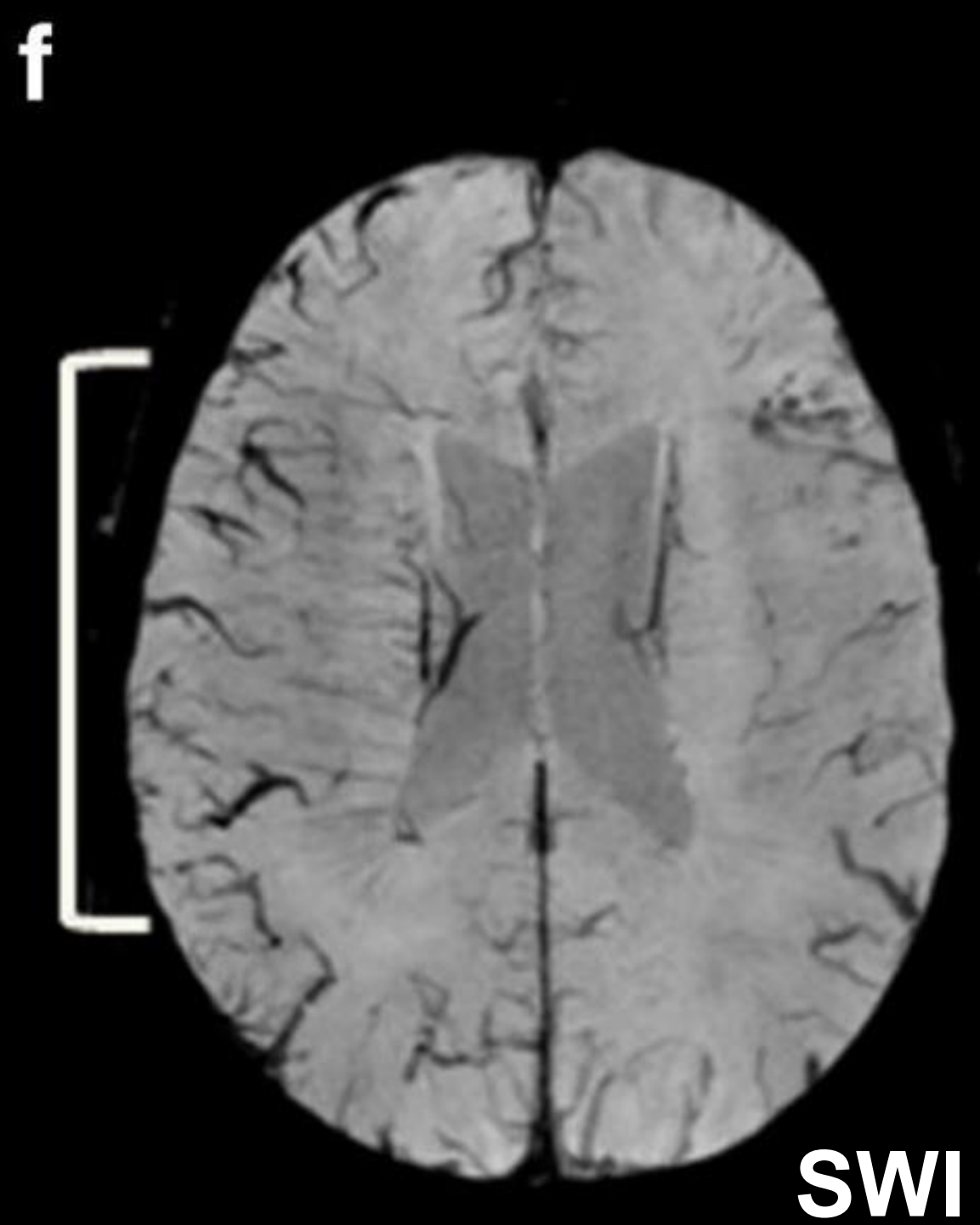
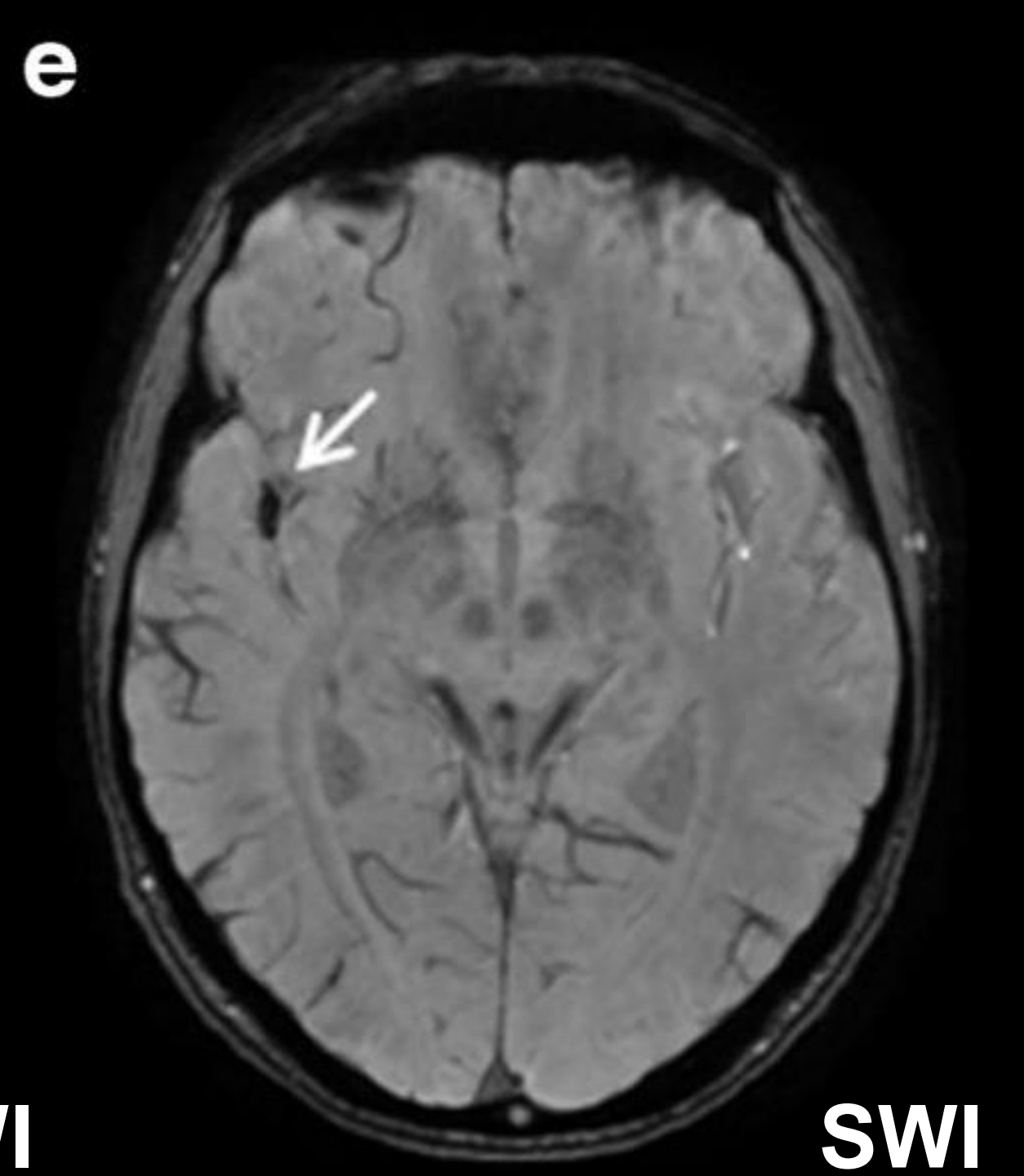
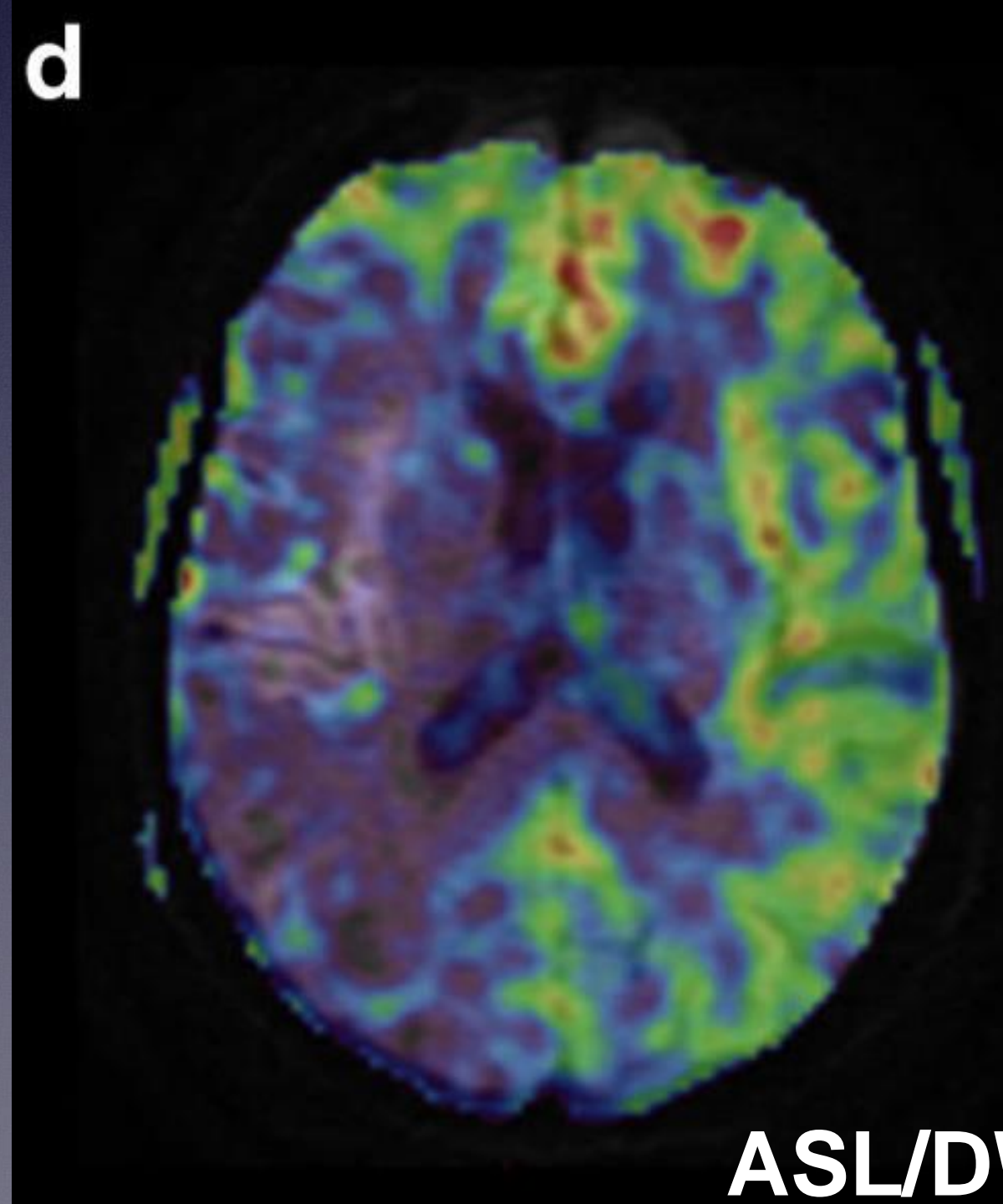
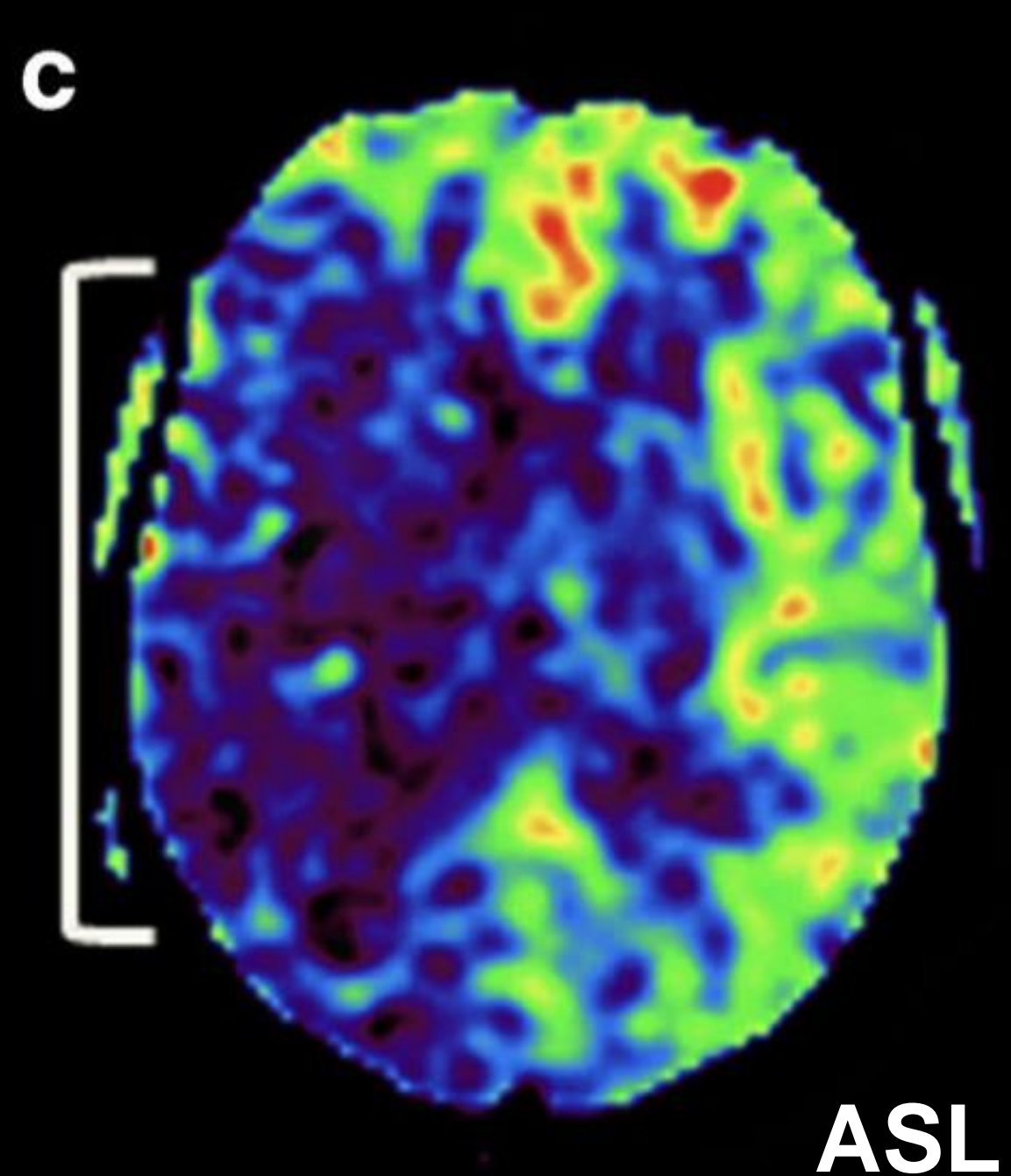
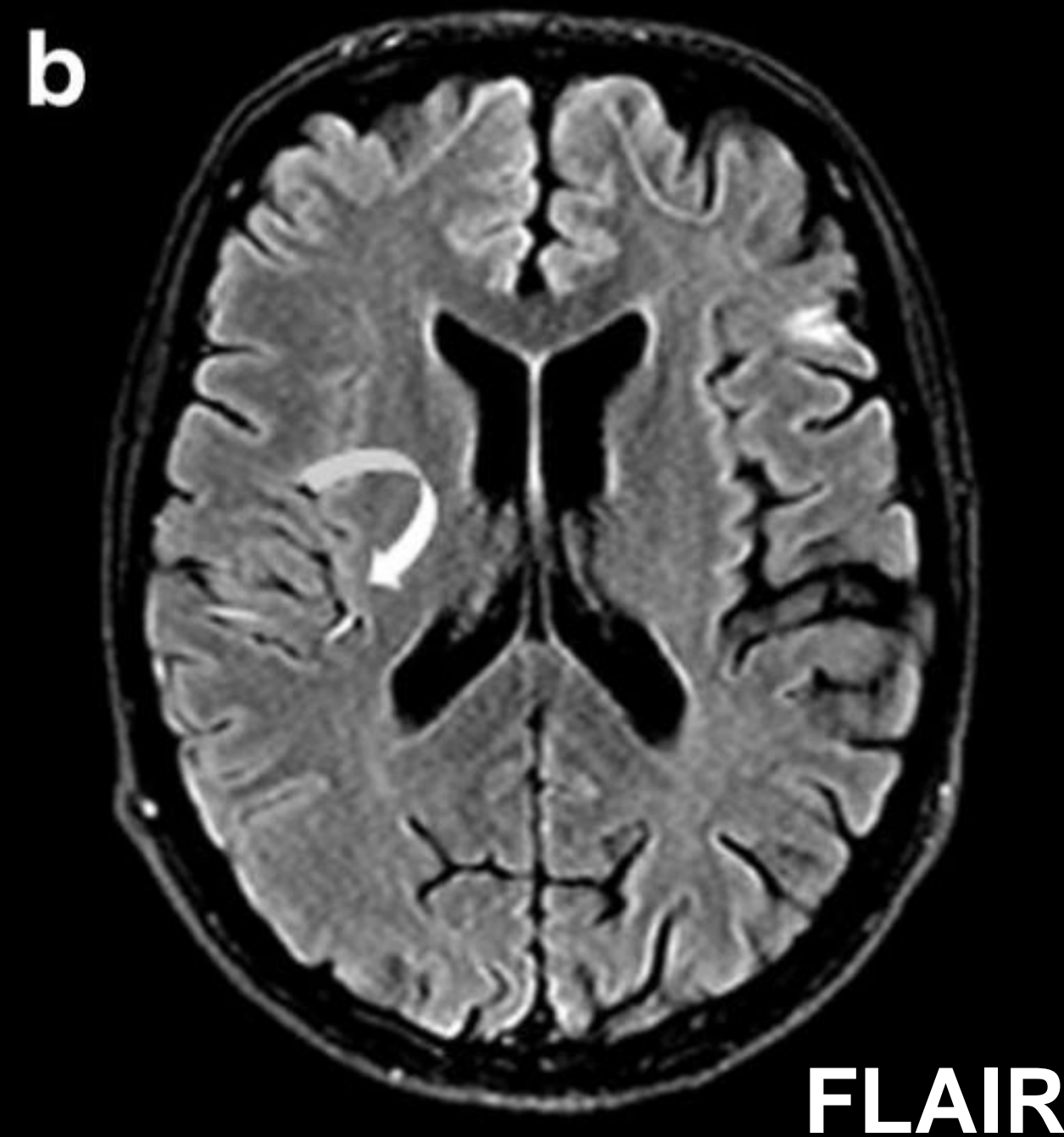
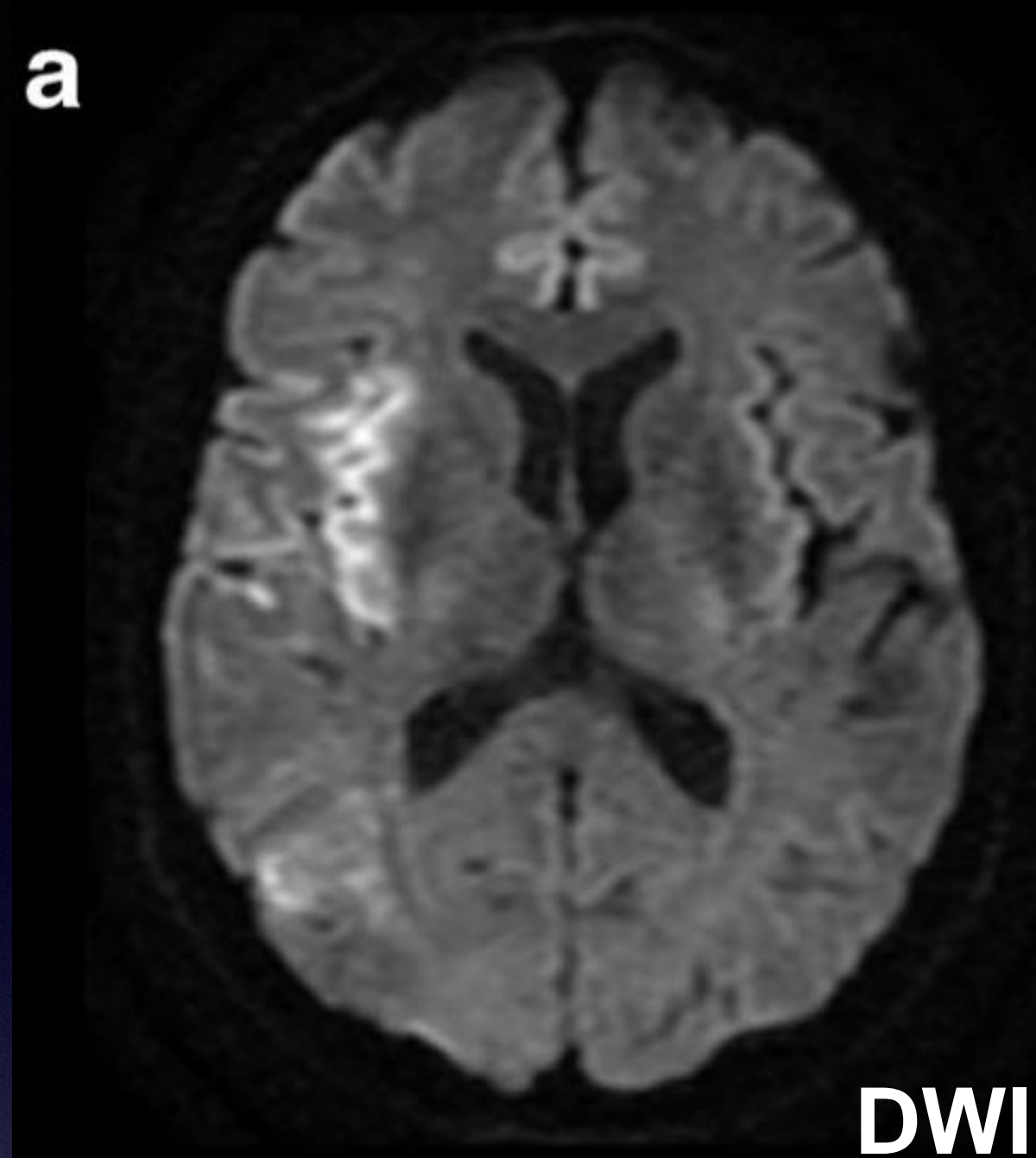


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TOF





Verclytte, S. *et al.*  
ASL and  
susceptibility-  
weighted imaging  
contribution to the  
management of  
acute ischaemic  
stroke. *Insights  
Imaging* 8, 91–100  
(2017).

# Take-Home

- Infarction can be detected momentarily on diffusion weighted MRI and after 4-6 hour on non-contrast CT
- VIM is a Dual Energy reconstruction which may help detect infarcts earlier on NCCT
- The penumbra can be visualised using perfusion imaging or by more indirect measures such as clinical symptoms, slow-flow on FLAIR og prominent veins on SWI

