Imaging of acute stroke patients: What is needed to make urgent decisions

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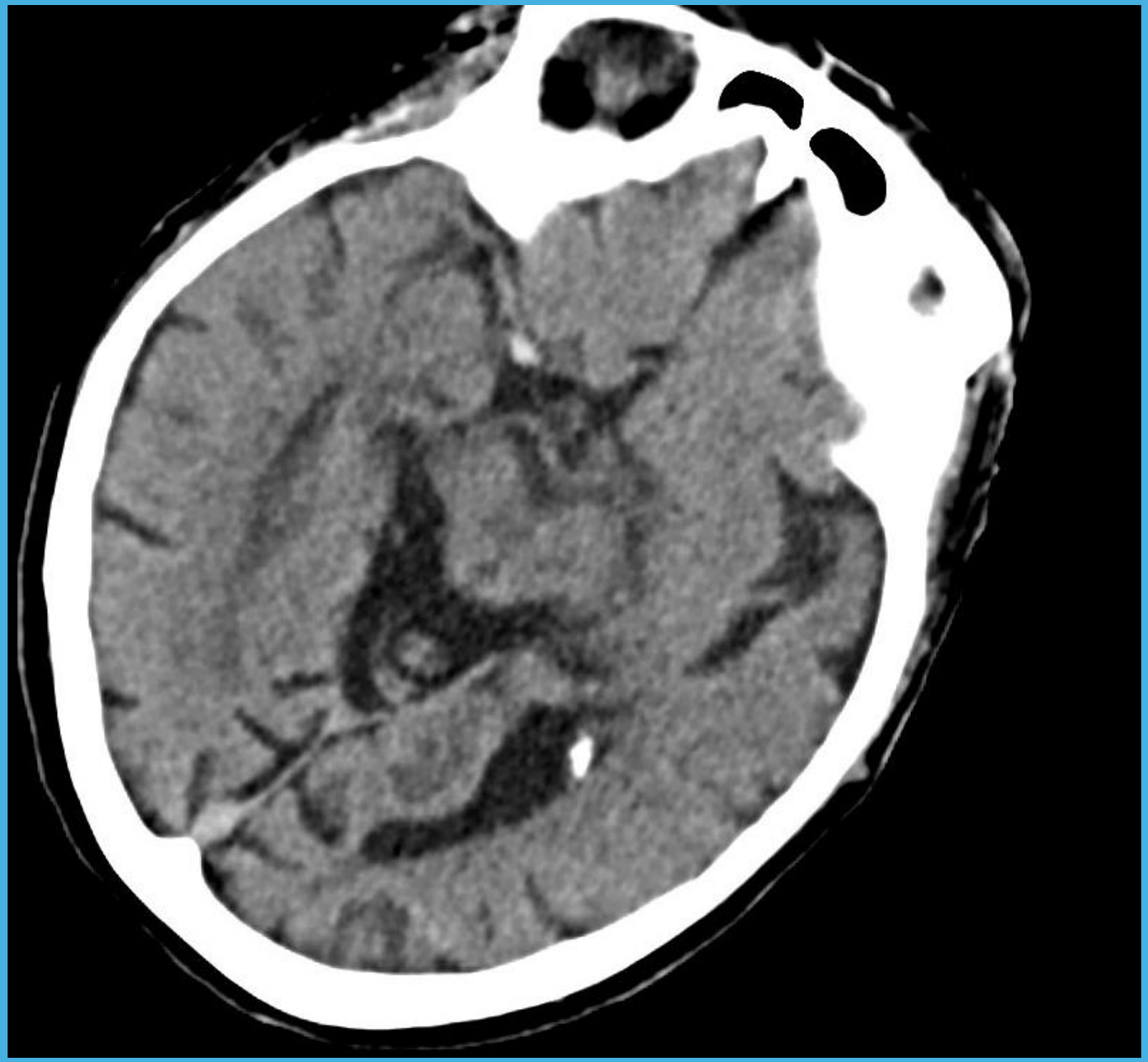
Disclosures

- None

Goals of imaging

- Identify presence of hemorrhage
- Determine the presence of a Large vessel occlusion-LVO
- Assess proximal anatomy and patency
- Assess collateral flow in the affected territory
- Assess extent/volume of completed infarct
- Identify salvageable penumbra (CT perfusion or MRI DWI/FLAIR)
- Determine pattern of injury

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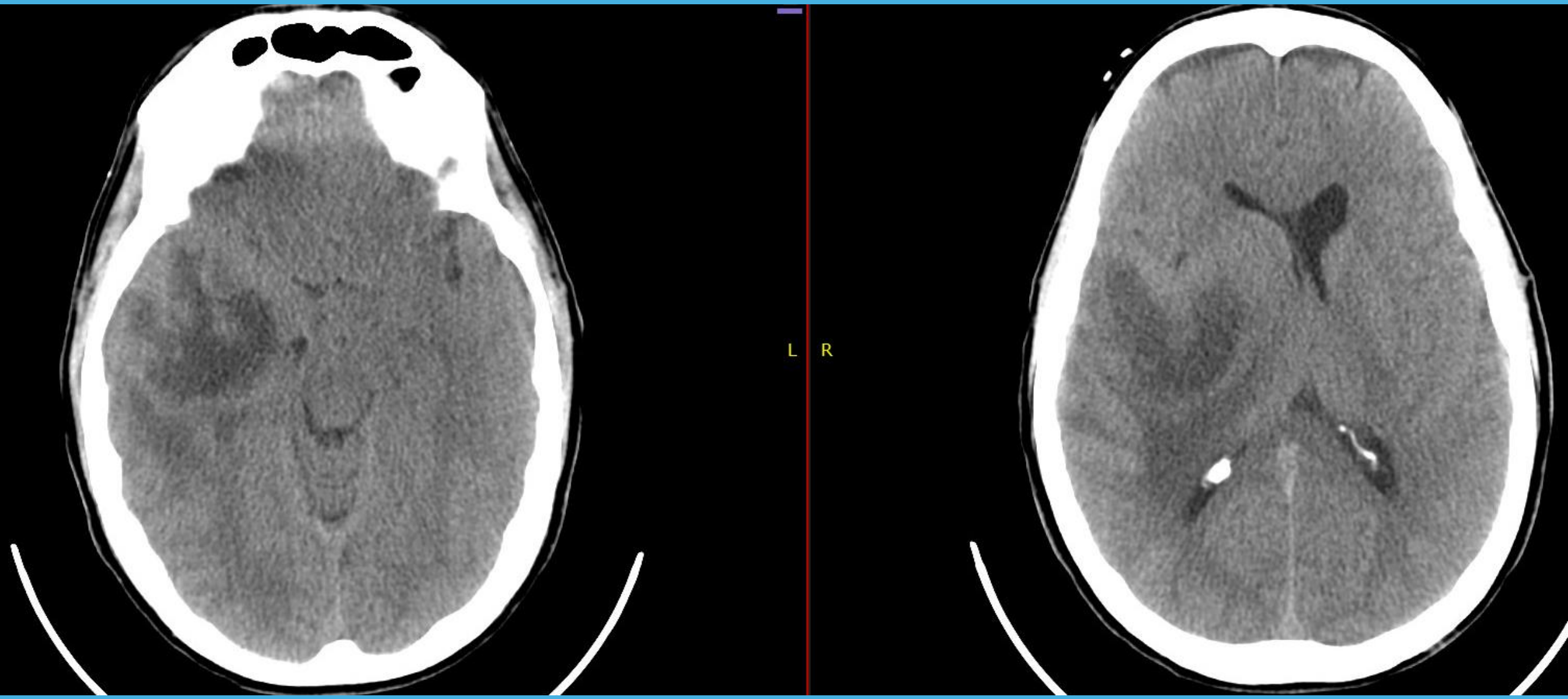
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- Imaging algorithm that we follow
- NCCT
- CTA Head and Neck
- CTP if stroke onset >4.5hrs
- Urgent MRI in selected patients: posterior circulation
- Intraop/ Post Op CT on table
- Post op NCCT
- MRI typically next day

- Alberta Stroke Program Early CT Score (ASPECTS)
- Reproducible grading system to assess early ischemic changes in anterior circulation strokes
- can predict poor functional outcome with increased risk of parenchymal hemorrhage for IV thrombolysis alone or in combination with endovascular therapy (score ≤7)

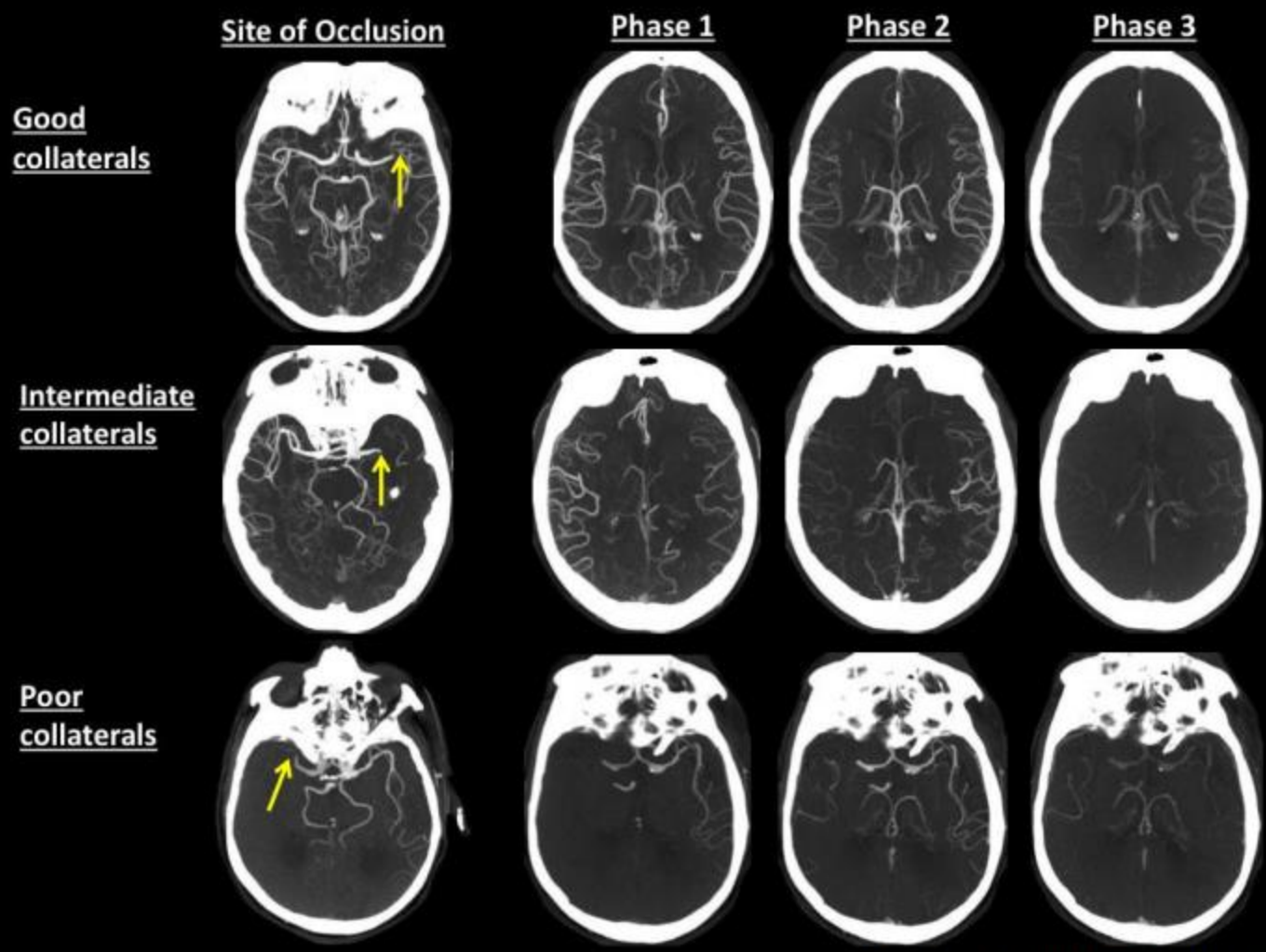
CTA - Collateral Vessel Scoring

- CT-Angiography is performed concurrently with the non contrast head CT and gives information about:
- - site of occlusion
- - clot length –
- presence of leptomeningeal collaterals
- Regional Leptomeningeal Collateral Score (rLMC)

Alberta stroke programme early computed tomographic score and Regional Leptomeningeal Collateral scores evaluated on computed tomography angiography

Aspects		**rLMC scrore**	
Caudate	/1	Sylvian sulcus	/4
Lentiform	/1	Basal ganglia	/2
Internal capsule	/1	M1	/2
Insula	/1	M2	/2
M1	/1	M3	/2
M2	/1	M4	/2
M3	/1	M5	/2
M4	/1	M6	/2
M5	/1	ACA	/2
M6	/1		
Total	/10		/20

CTA - Collateral Vessel Scoring



! Leptomeningeal collateral scoring systems based on CT-Angiography have been shown to correlate with and predict clinical outcome

ASPECTS and Collateral Vessel Scoring

Estimation of Infarct Core

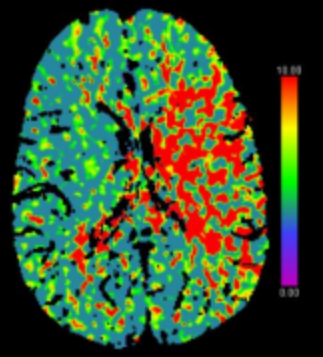
	Large	Medium	Small
Non-contrast CT ASPECTS	0-4	5-7	8-10
CT-Angiography Collaterals	Poor	Intermediate	Good
CT Perfusion	>70 mL	20-70 mL	<20 mL
DWI Lesion Volume	>70 mL	20-70 mL	<20 mL

CTP

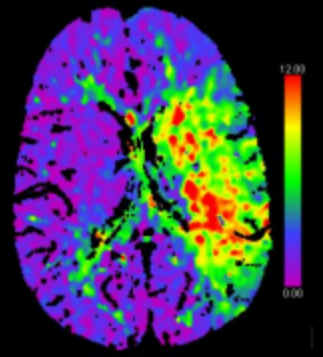
- Perfusion source data are a 4-dimensional data set (3-dimensional volumes captured over time).
- Multiple software products that produce perfusion maps and estimate volumes of ischemic core and tissue at risk are available. Perfusion processing is a nonstandard domain and substantial differences exist between vendors. Frequently, CBF, cerebral blood volume, and Tmax are calculated differently and are, therefore, not comparable between packages.
- A rCBF threshold of <30% has been extensively validated for ischemic core
- The DEFUSE 2 study redefined the mismatch definition for EVT-eligible patients: MMR >1.8, penumbra >15 mL, DWI volume <70 mL, and Tmax >10 seconds volume <100 mL

- Units of Measurements
- Cerebral blood vol – ml/100g/min
- Cerebral blood flow-ml/100g/min
- Mean Transit Time-secs
- Time to peak-seconds

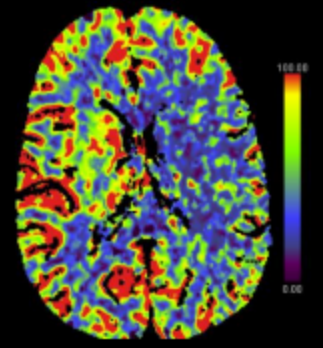
CT PERFUSION - PARAMETERS



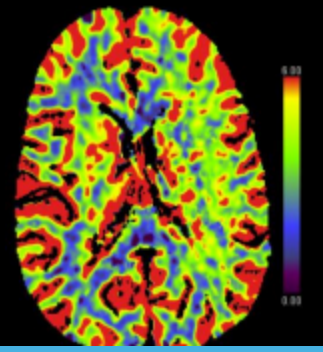
- MTT – MEAN TRANSIT TIME: - AVERAGE AMOUNT OF TIME THAT BLOOD TAKES TO TRANSIT THROUGH THE CAPILLARY VESSELS
  - INCREASED MTT = VASODILATORY RESPONSE TO <u>REDUCED FLOW</u>



- TMAX/TTP – TIME TO PEAK: - RELATIVE TIME TO PEAK ENHANCEMENT FOR BRAIN TISSUE VOXELS
  - IDENTIFIES <u>DELAYED FLOW</u> (STENOSIS OR OCCLUSION)



- CBF – CEREBRAL BLOOD FLOW: - BLOOD FLOW RUNNING THROUGH CAPILLARY BLOOD VESSELS PER UNIT TIME AND BRAIN TISSUE
  - IDENTIFIES <u>LOW BLOOD FLOW</u>



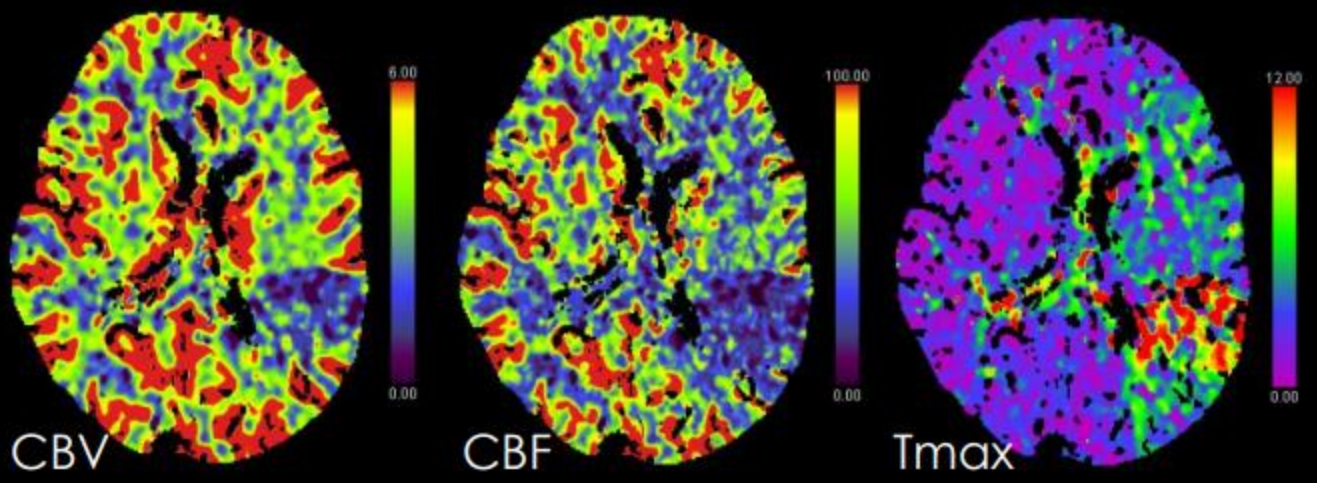
- CBV – CEREBRAL BLOOD VOLUME: - DISTRIBUTION OF BLOOD PER UNIT BRAIN TISSUE
  - EVALUATION OF <u>AUTOREGULATION/COLLATERALIZATION</u>

DIFFERENT CT PERFUSION SOFTWARES

Calculations not always the same – need to be careful – may overestimate core…

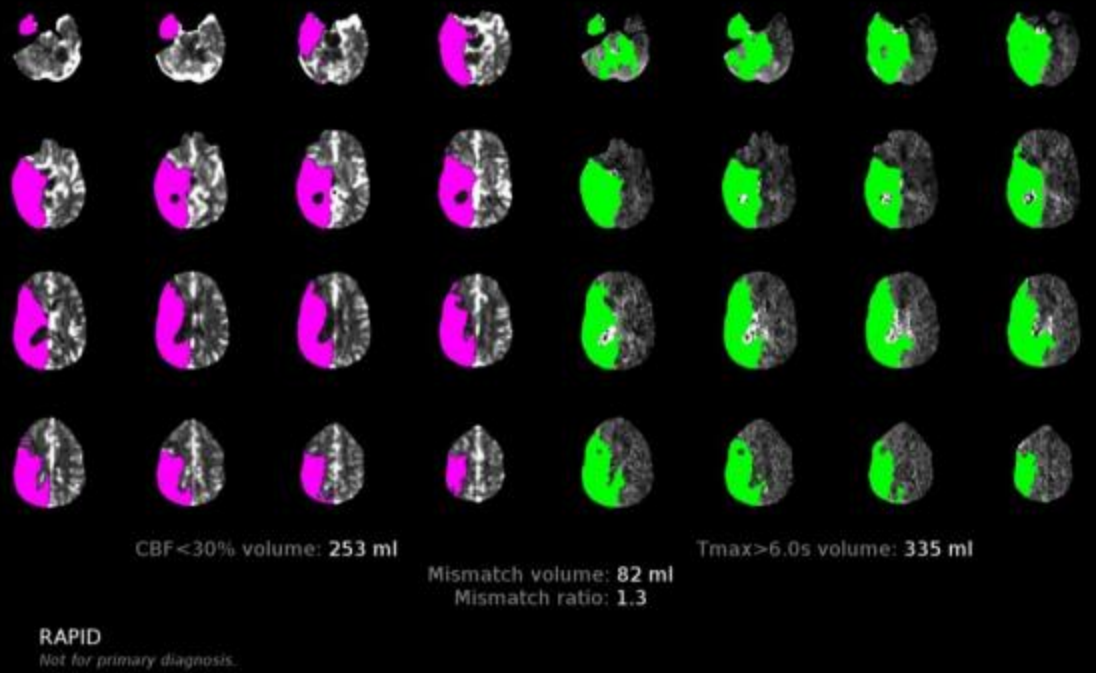
UMASS:

CBV = core
CBF/Tmax=penumbra



RAPID Software:

CBF=core Tmax=penumbra



CT PERFUSION – POSTPROCESSING OF PERFUSION IMAGES

- Perfusion source data:
  - 4-dimensional data set (3D volumes captured over time)
  - Generation of the perfusion maps = relationship between bolus shape in feeding vasculature, arterial input function, contrast passage in each voxel

- Software Packages
  - perfusion processing is a nonstandard domain
  - substantial difference between vendors exists
  - CBF, CBV, Tmax often calculated differently – not comparable between packages

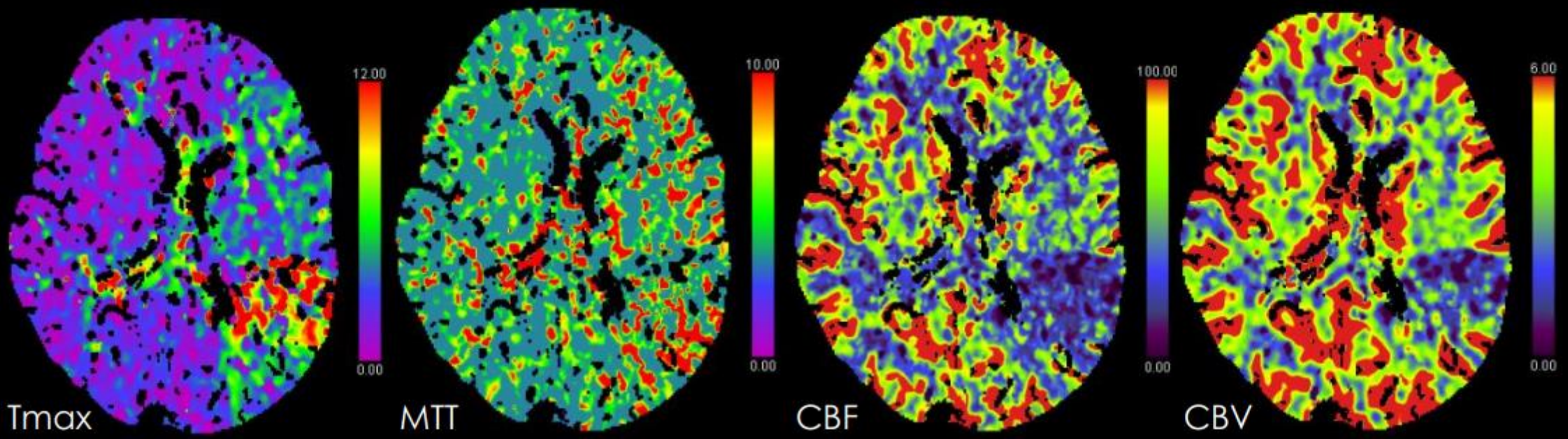
IMAGING APPEARANCE - UMASS

INFARCT CORE

- PROLONGED MTT OR TMAX,
- MARKEDLY DECREASED CBF
- MARKEDLY REDUCED CBV

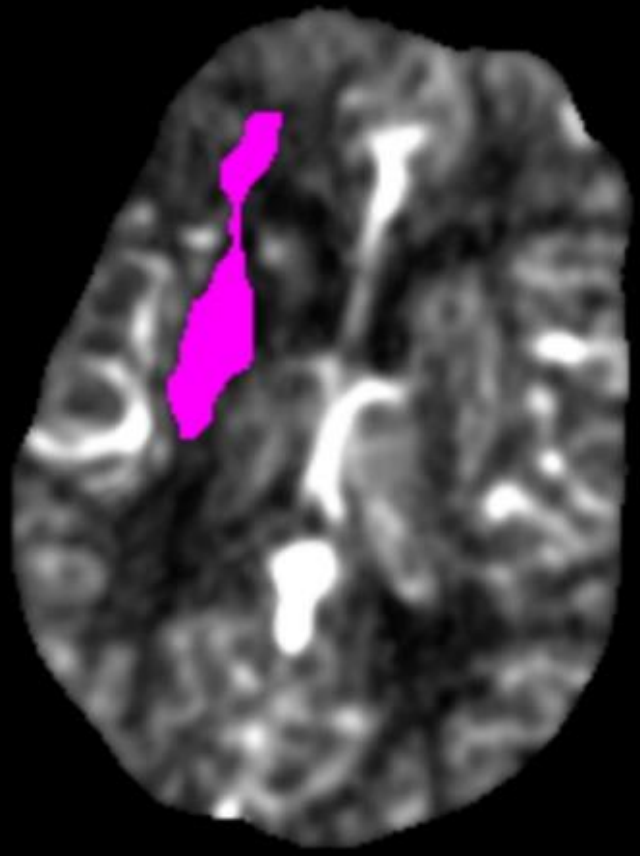
PENUMBRA

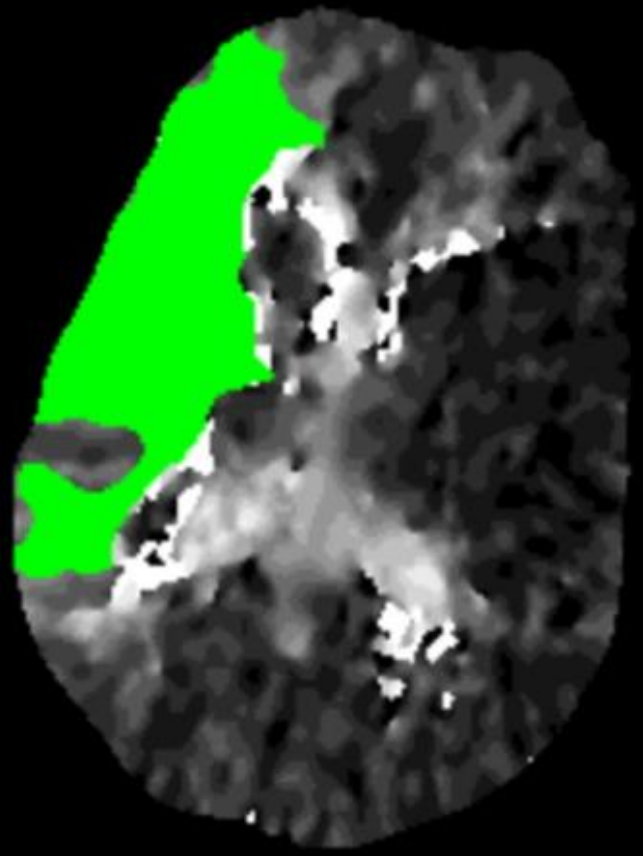
- PROLONGED MTT OR TMAX
- MODERATELY REDUCED CBF
- NEAR-NORMAL OR EVEN INCREASED CBV



CBF

Tmax





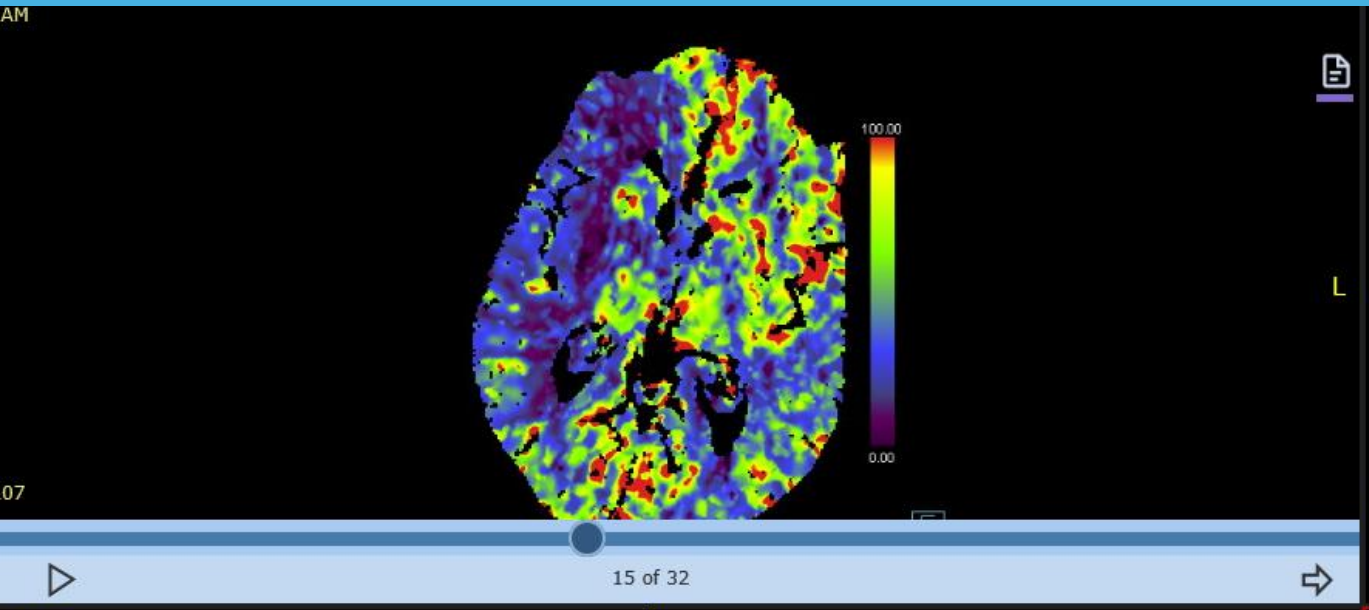
● CBF<30%: 23 ml

● Hypodensity ≥5 and ≤12 HU

● Tmax>6.0s: 165 ml

Mismatch volume: 142 ml

Mismatch ratio: 7.2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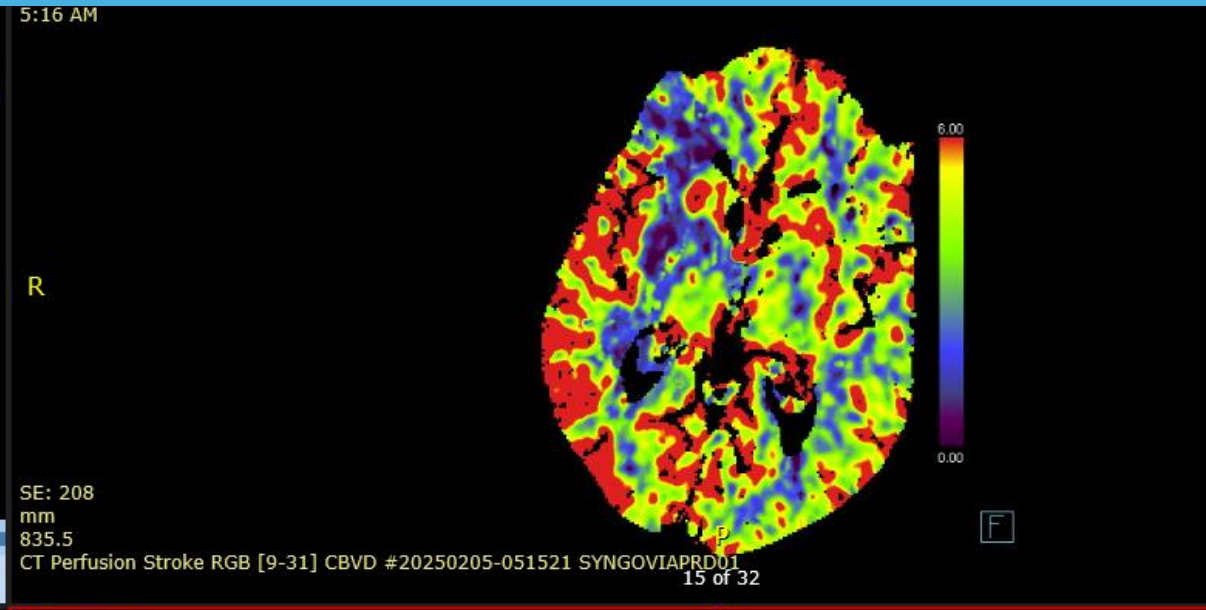
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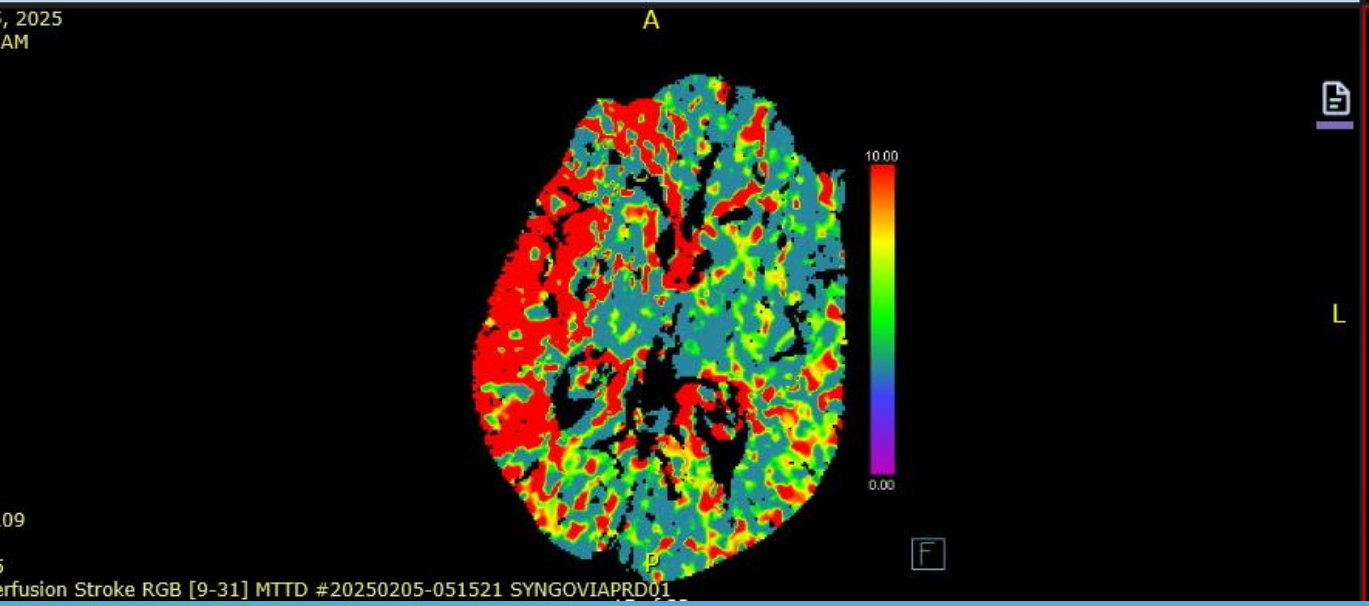
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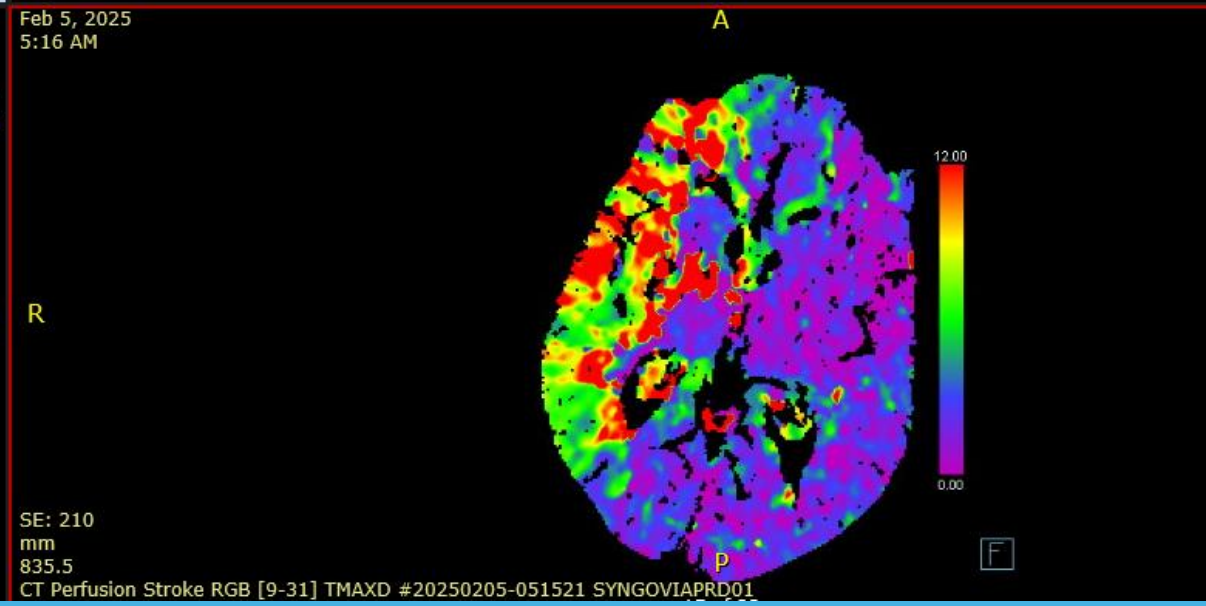
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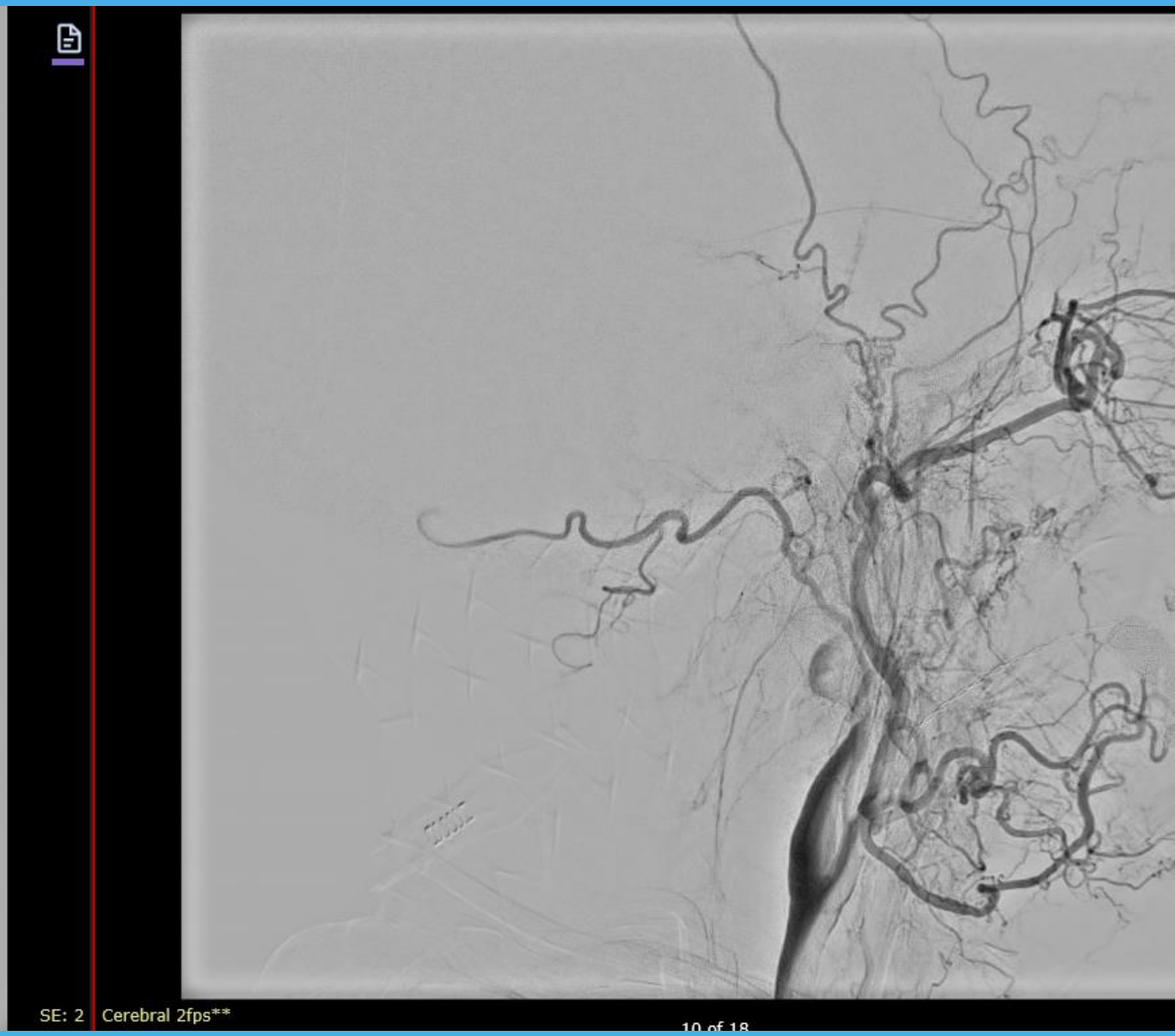
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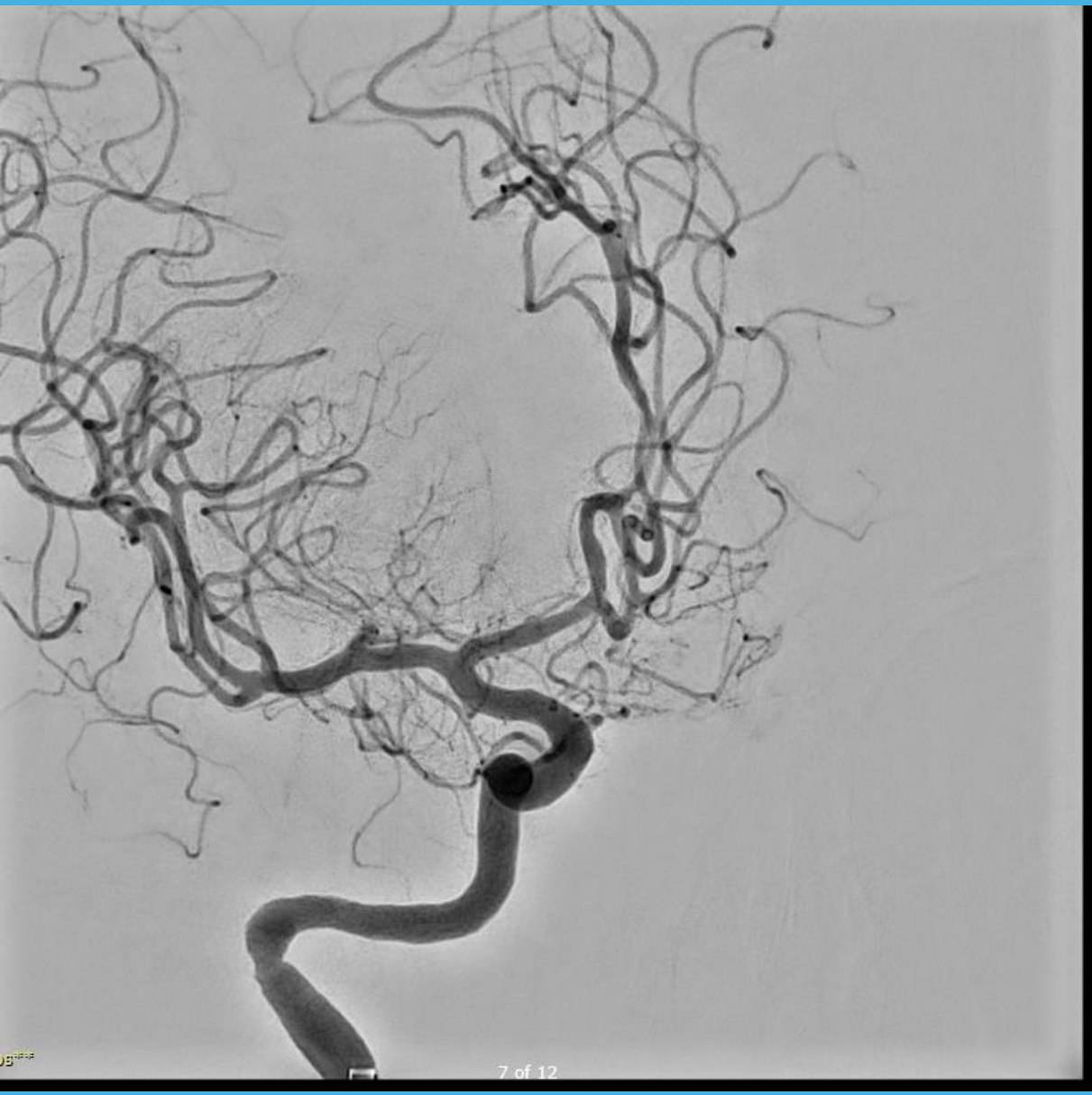

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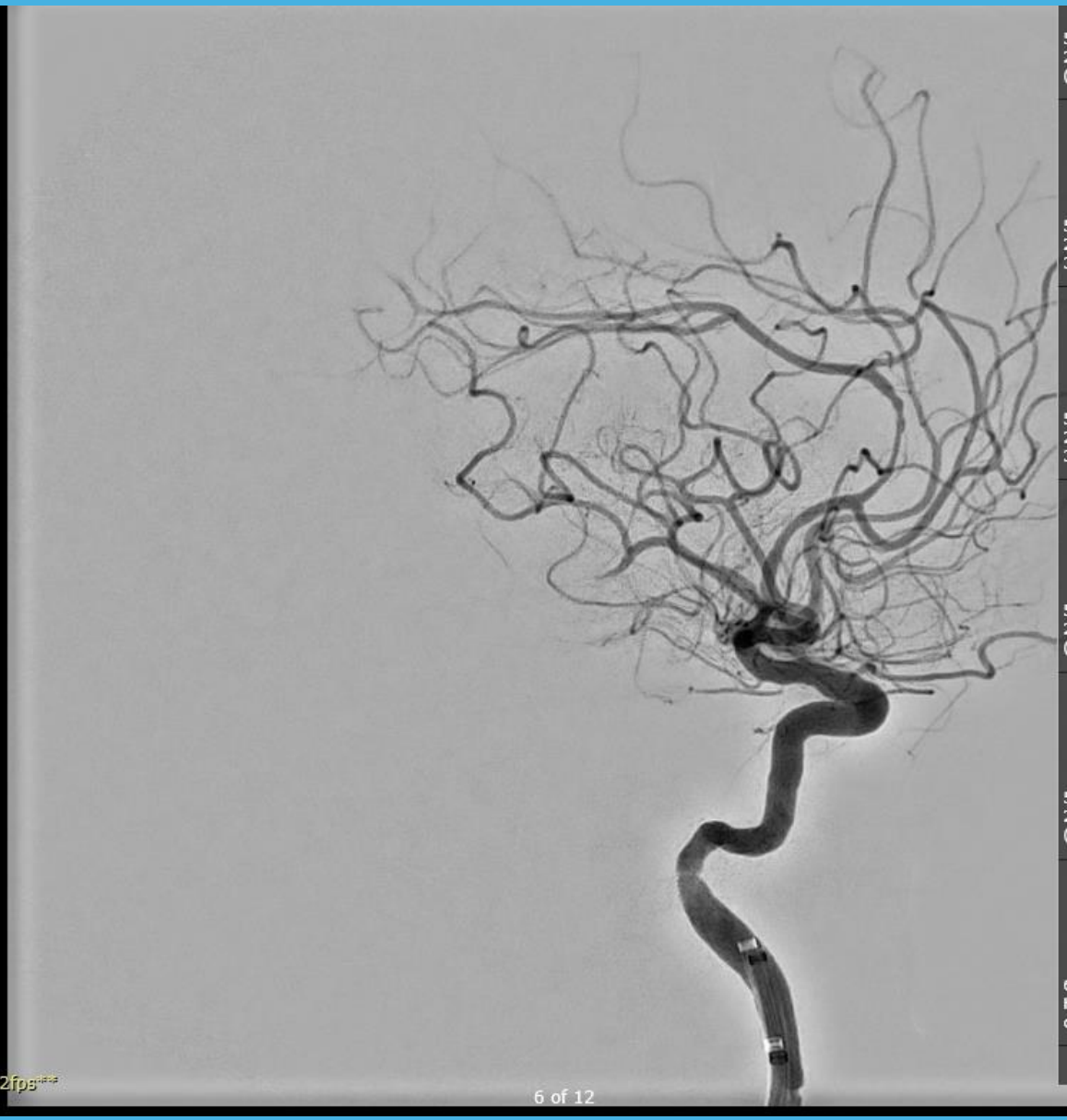
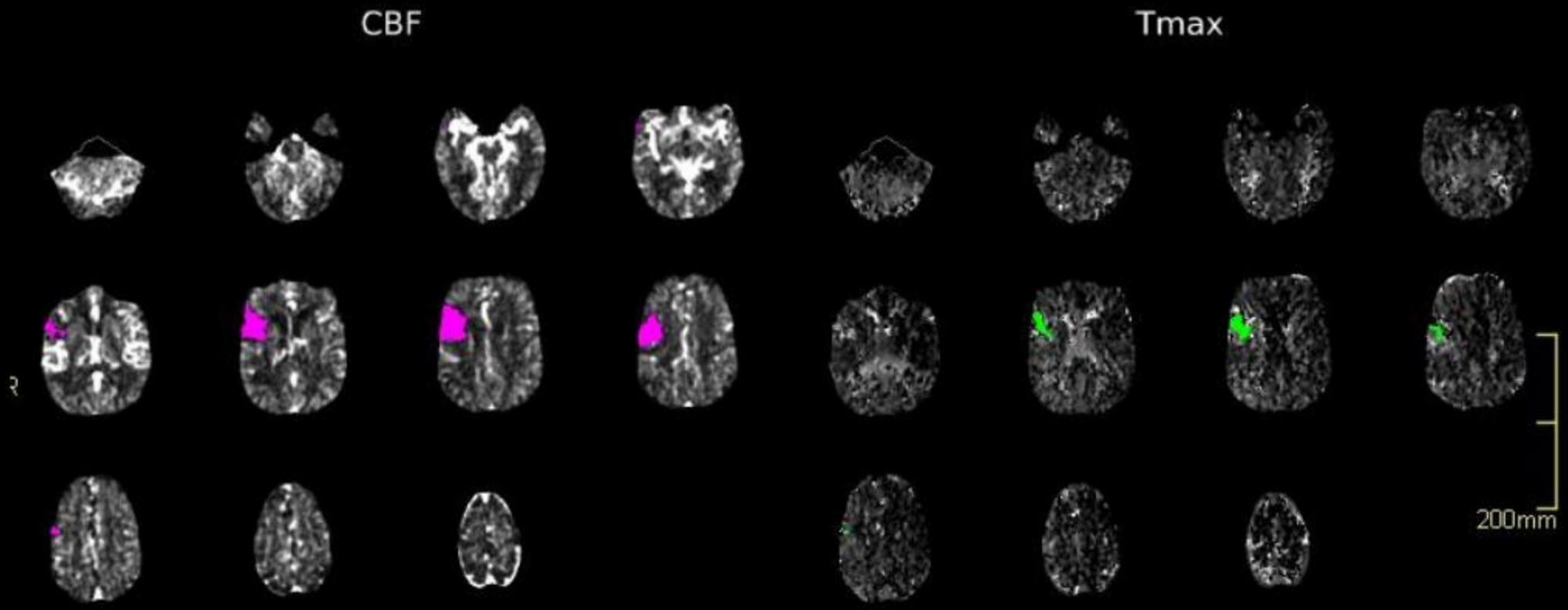


IMAGING APPEARANCE - RAPID



● CBF<30%: **25 ml**

= marker of infarct core

Mismatch volume: **-18 ml**
Mismatch ratio: **0.3**

● Tmax>6.0s: **7 ml**

= critical hypoperfusion

RAPID

Mismatch ratio >1.8
Patient may benefit from mechanical thrombectomy

CONSIDERATIONS

>> IN PATIENTS WITH UNFAVORABLE PERFUSION IMAGING PROFILE IN EARLY TIME WINDOW, DECISIONS BASED ON CTP ESTIMATIONS SHOULD BE CAREFULLY TAKEN <<

- CT PERFUSION REFLECTS A HEMODYNAMIC STATE AND MEASURES CONTRAST FLOW/TRANSIT!

↓

POOR COLLATERAL STATUS = LOW BRAIN PERFUSION AND LOW CONTRAST FLOW/TRANSIT

↓

SYMPTOM ONSET TO IMAGING TIME <8HRS = OVERESTIMATION OF CORE INFARCT

SYMPTOM ONSET TO IMAGING TIME >8HRS = MORE APPROPRIATE ESTIMATION OF CORE INFARCT

Subtypes of ischemic strokes

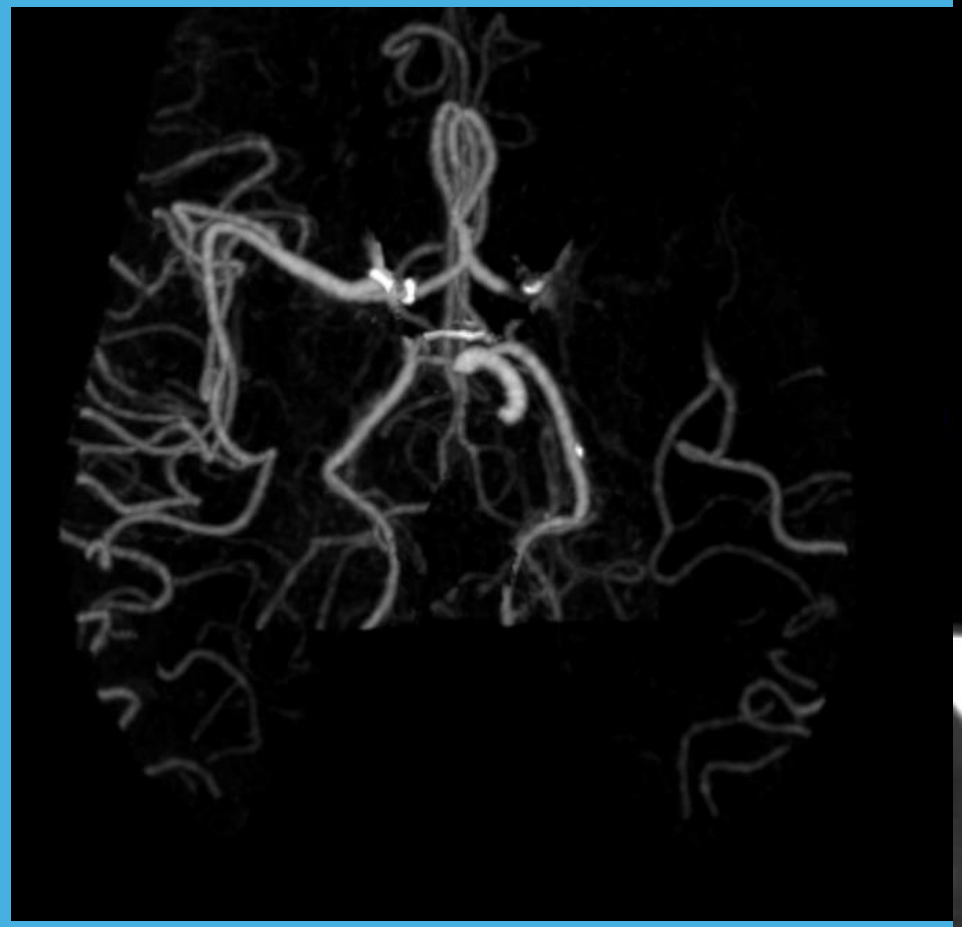
Box 1
Trial of Org 10172 in acute stroke treatment classification

- Large artery atherosclerosis (embolus or thrombosis)
- Cardioembolic
- Small vessel occlusion (lacune)
- Stroke of other determined cause, or unusual cause
- Stroke of undetermined cause
    - Two or more causes identified
    - Negative evaluation
    - Incomplete evaluation

The TOAST classification was developed to categorize causes of acute ischemic stroke. It is a useful way to categorize stroke in order to guide management decisions.

Large Artery Atherosclerosis

- Infarctions larger than 15 to 20 mm, involving the cortex, cerebellum, brainstem, and subcortical regions, are usually caused by large vessel disease arising from atherosclerosis of cervical or proximal intracranial vessels
- 30-43% of all strokes
- The mechanism of infarction secondary to atherosclerosis of the extracranial vasculature is a combination of low-flow states and artery-to-artery emboli, with the latter thought to be the greater contributing factor

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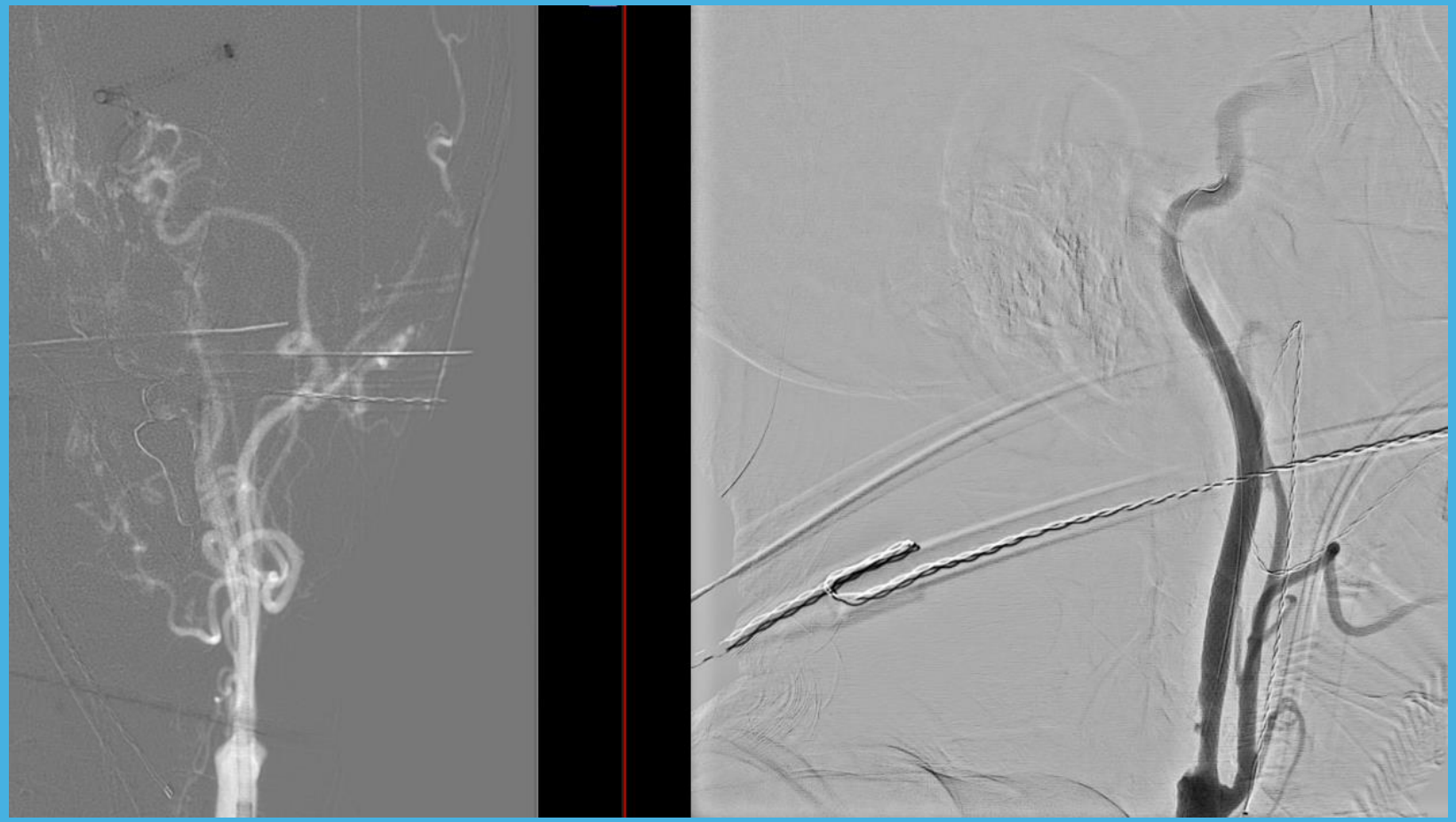


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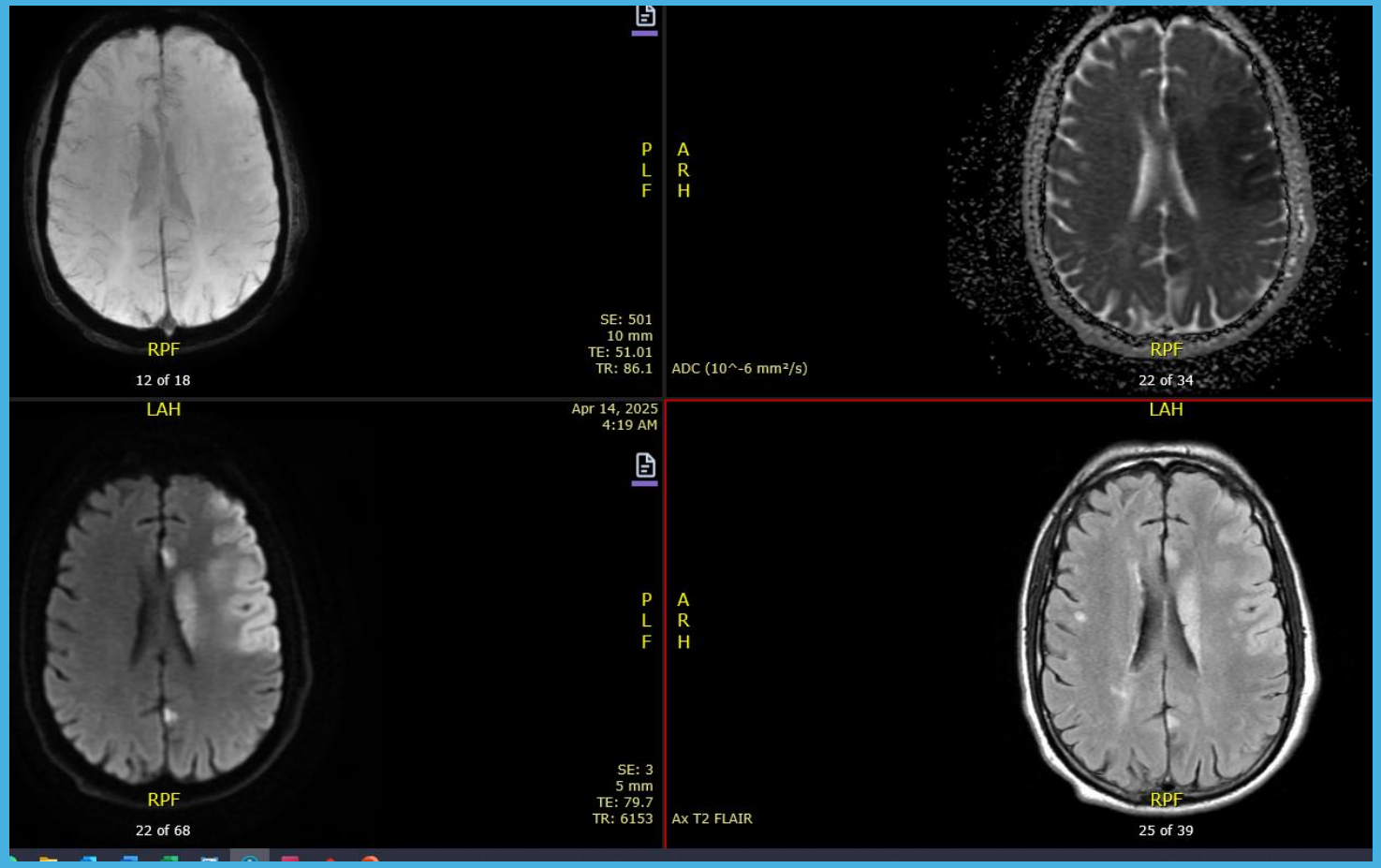
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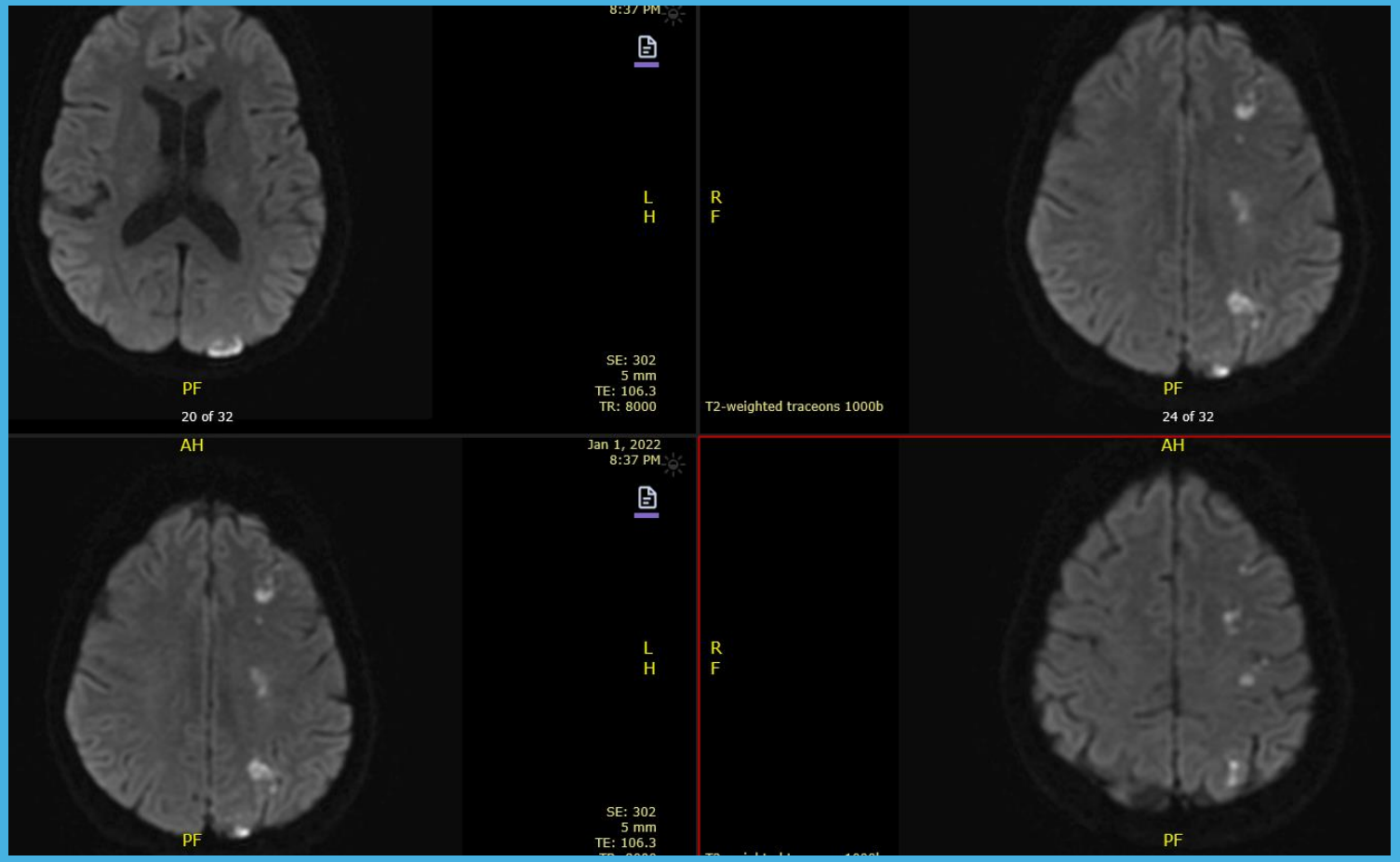
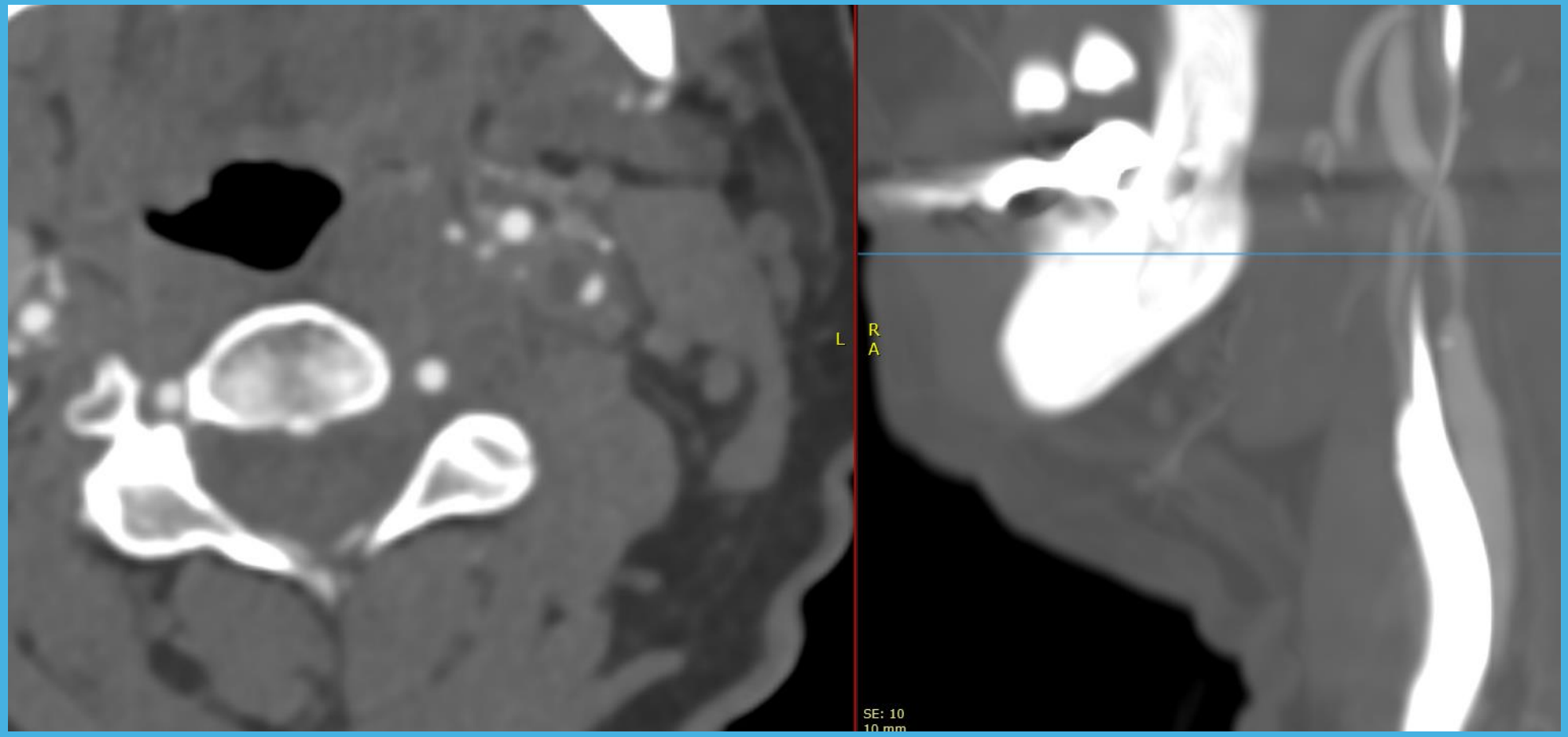
External Border zone infarcts

- Cortical infarcts that occur at the zones between the anterior, middle, and posterior cerebral artery (PCA) territories. Although the cause of these infarcts is not well understood, the prevailing theory is that they result from a combination of embolic phenomena and hypoperfusion

64-year-old female who presented to the ED developed slurred speech and right hand weakness two days ago. She further reported the slurred speech resolved but she continued to have difficulty grasping things with her right hand.

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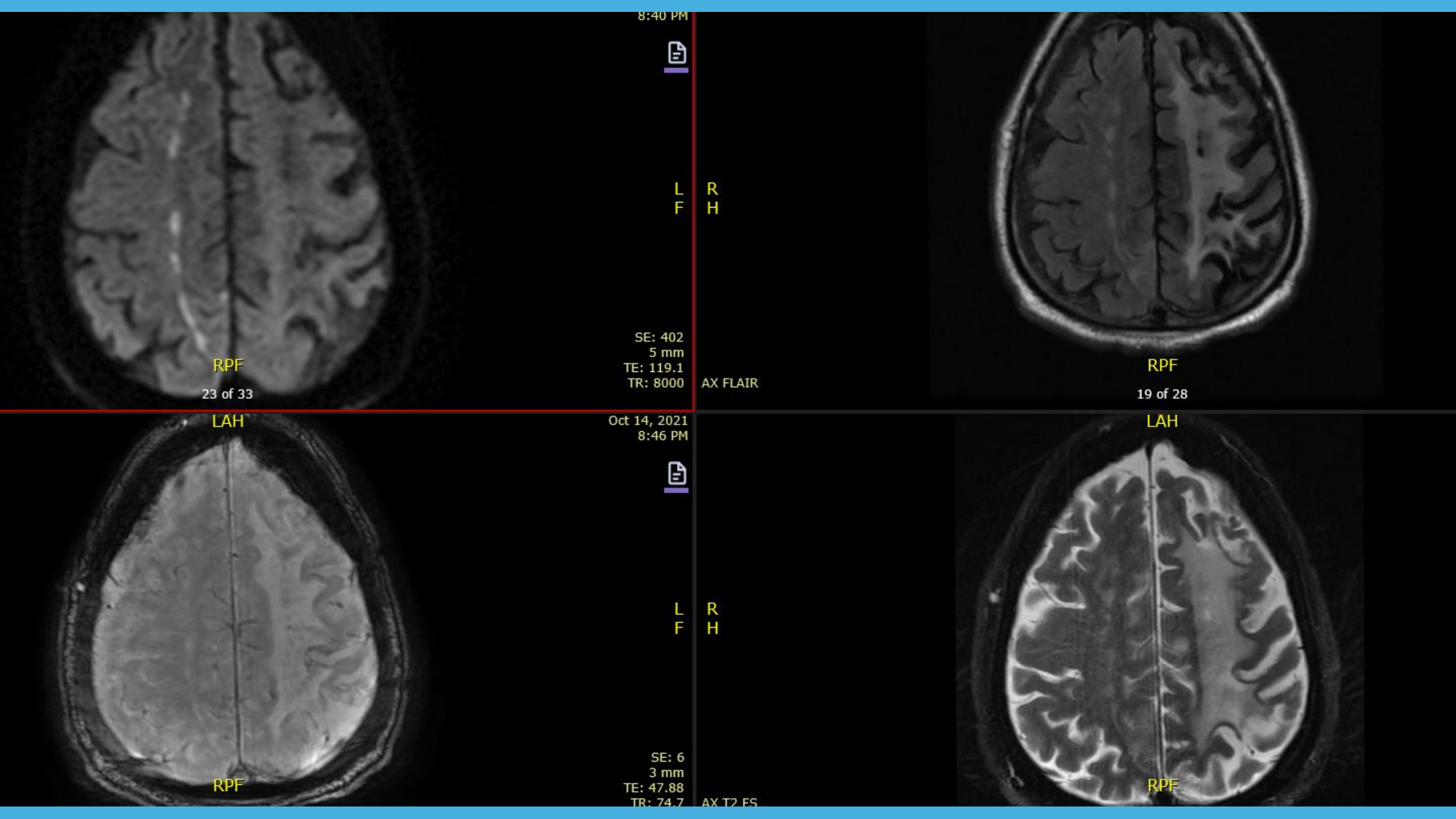
64 y.o. male with PMH of LICA (MCA/ACA territories) CVA, recent right SAH, right posterior cingulate gyrus and L cerebellar subacute infarction, significant intracranial stenoses, IDDM, HTN, HLD, Hypothyroid, Psoriasis/psoriatic arthritis on Humira who presented from rehab for AMS/inability to follow commands after an episode of hypotension. CODE STROKE activated. Initial NIHSS 18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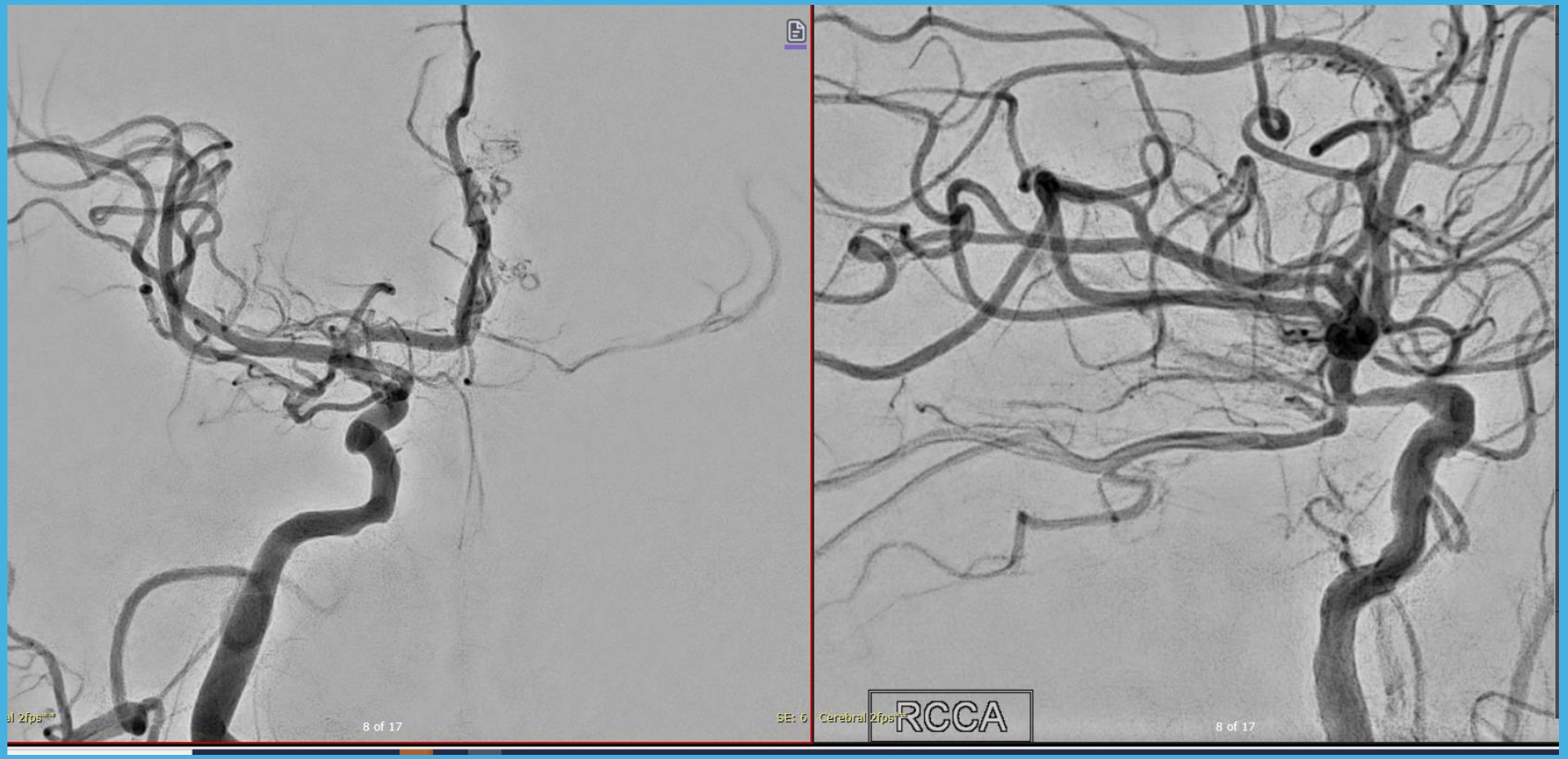
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SE: 6 Cerebral 2fps**
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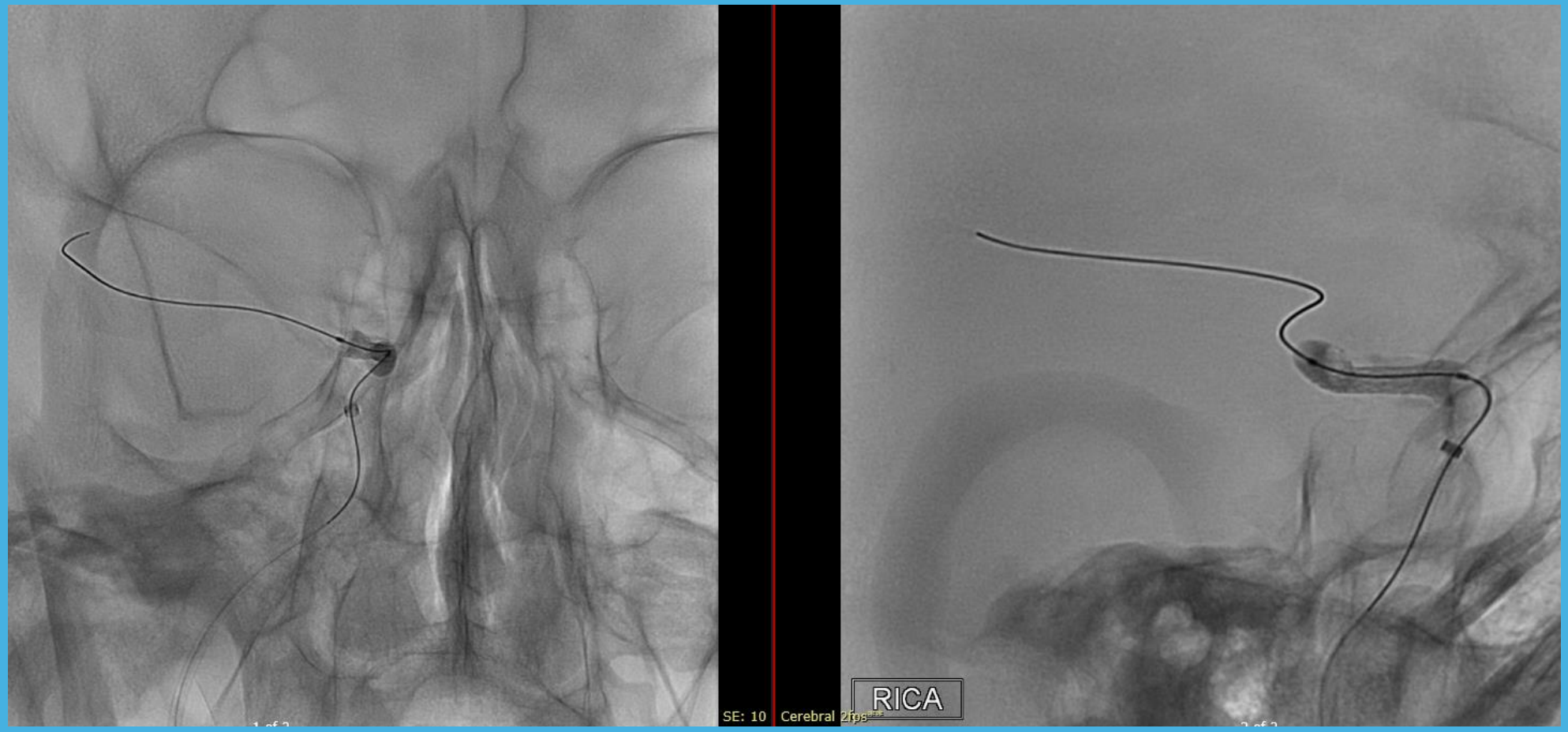
8 of 17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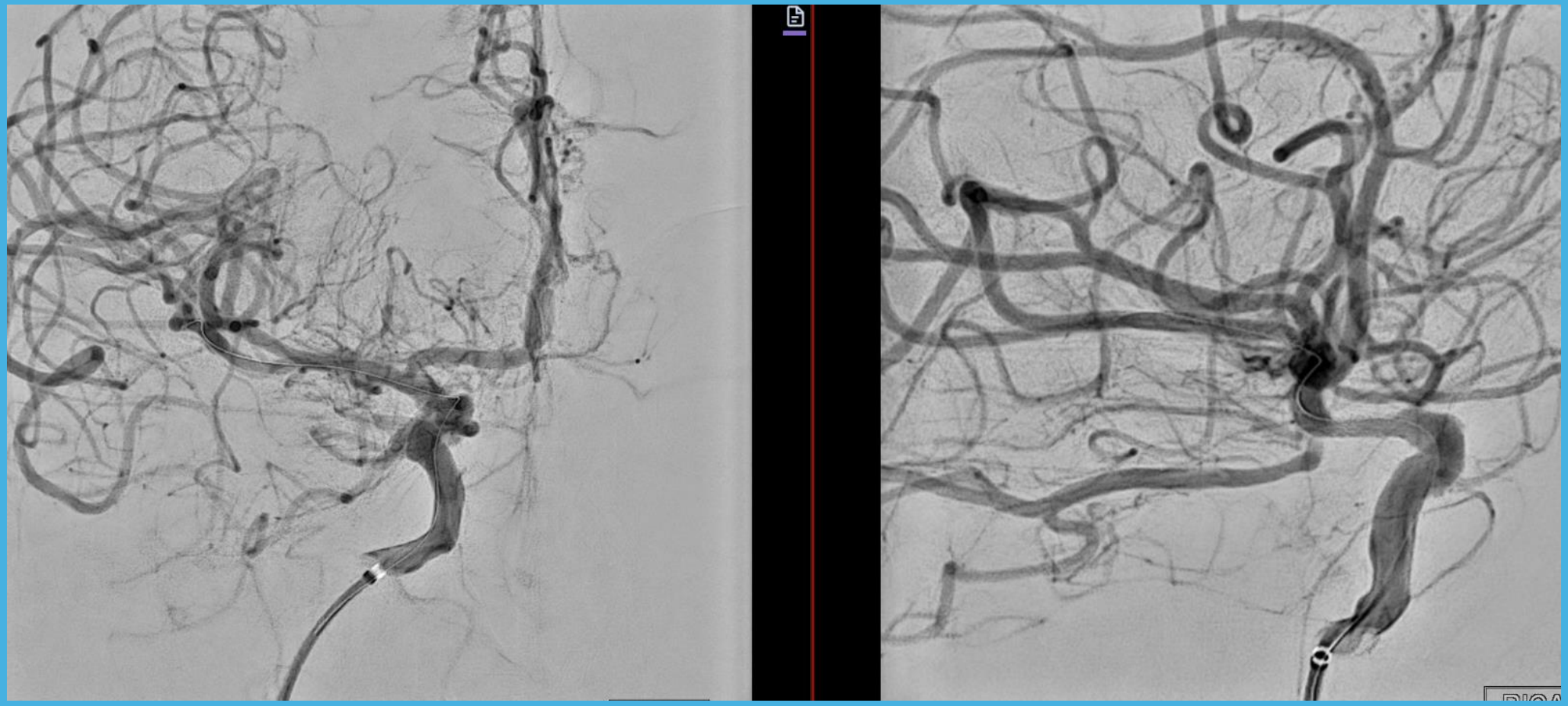
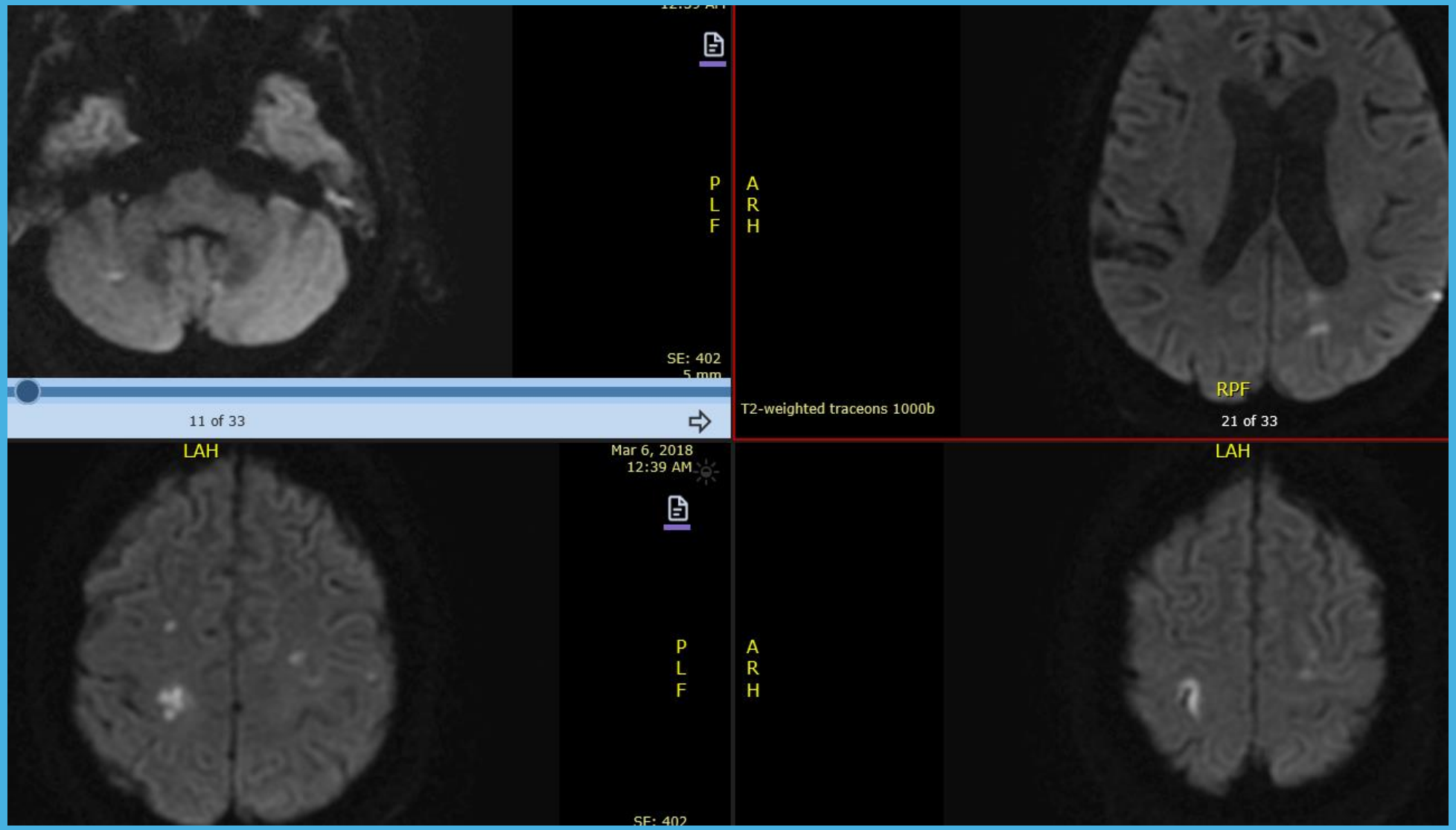
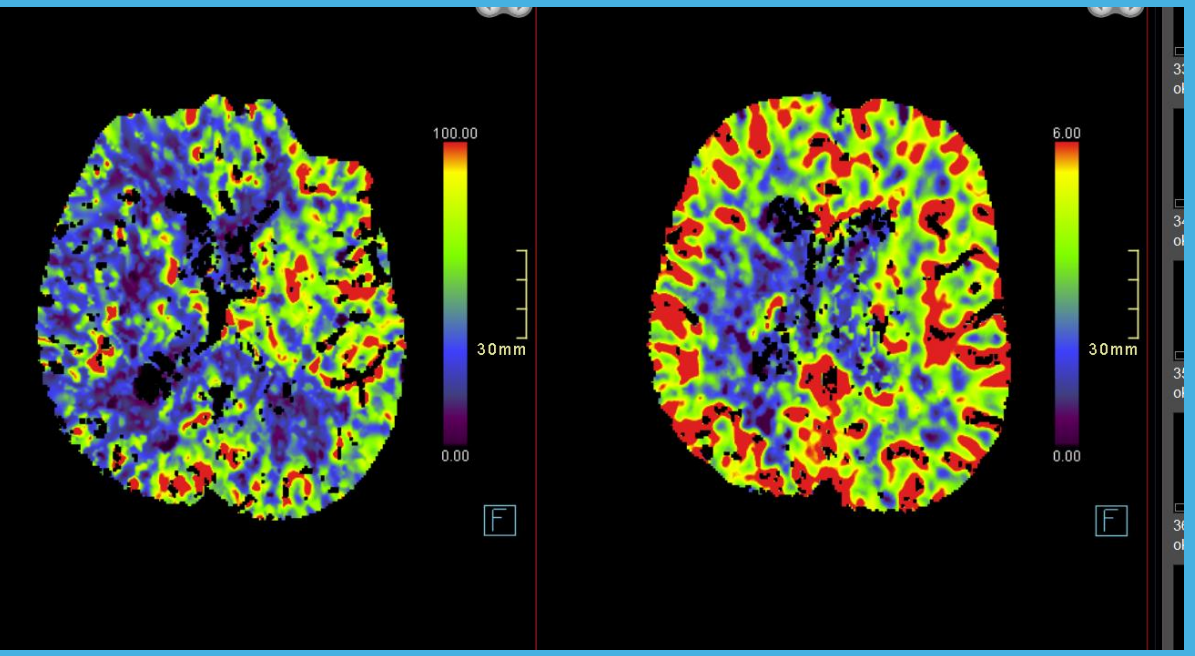


Cardioembolic infarcts



- Found to have endocarditis with vegetations

- 67 y.o.female with past medical history HTN, HLD, Obesity, OSA, DMII, and a prior right subclavian to carotid graft who presented this morning to outside hospital with new onset with L sided weakness and speech difficulties. LKW 7am per neurology. Her NIHSS on arrival to outside hospital was 8.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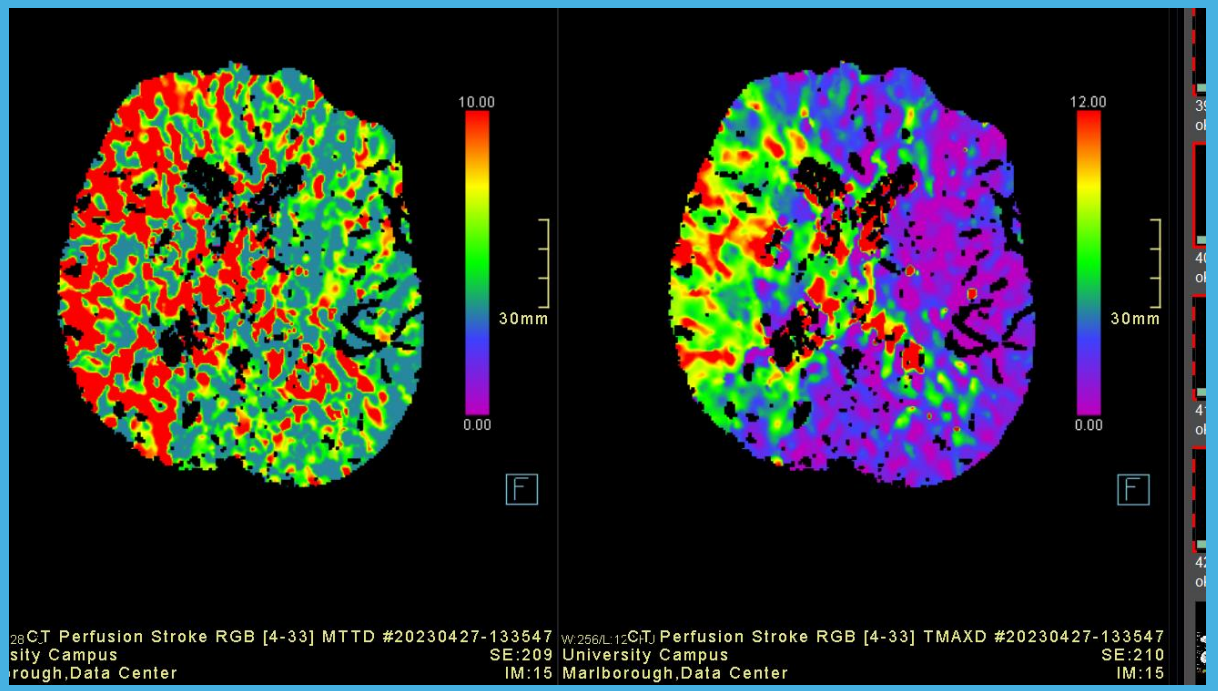
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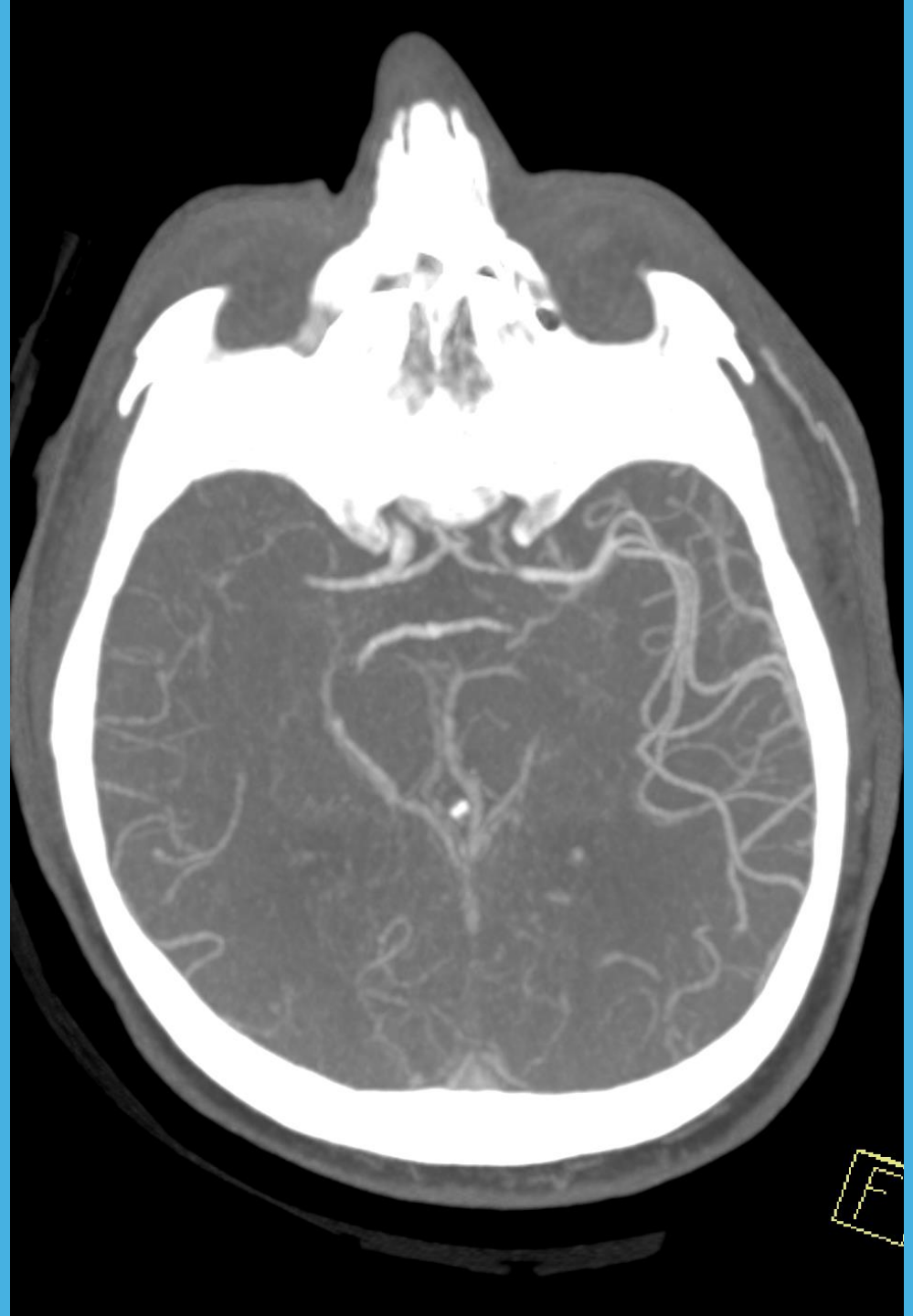

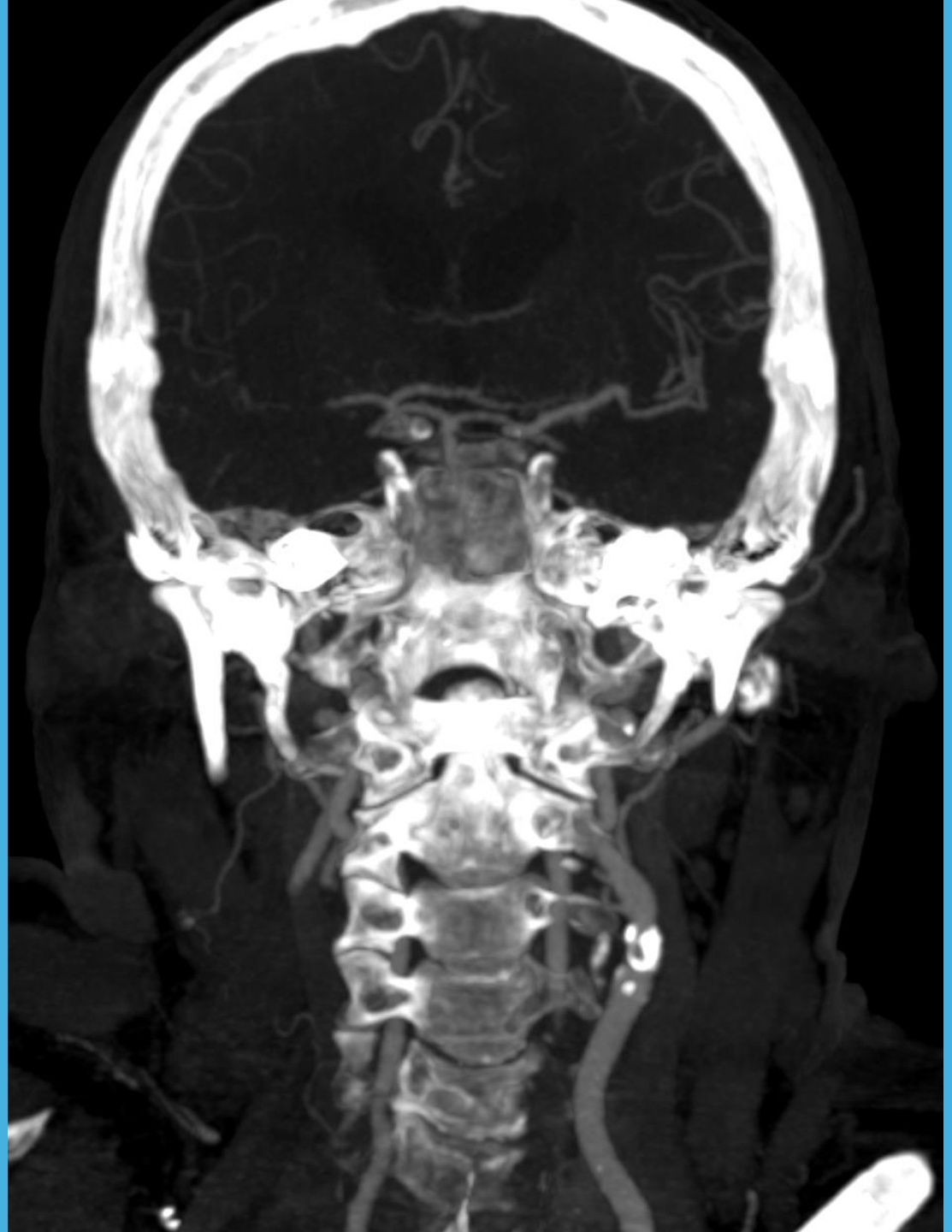

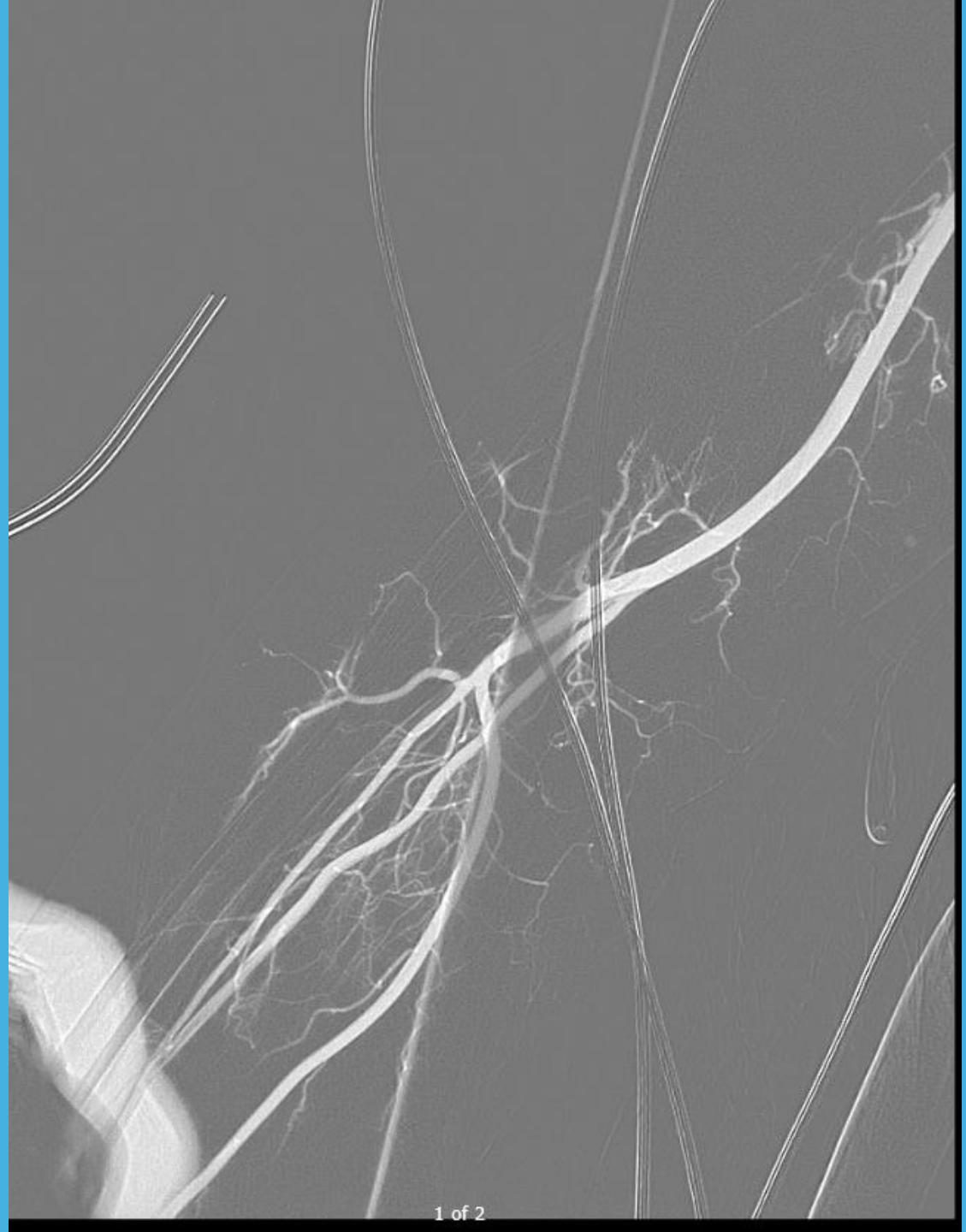
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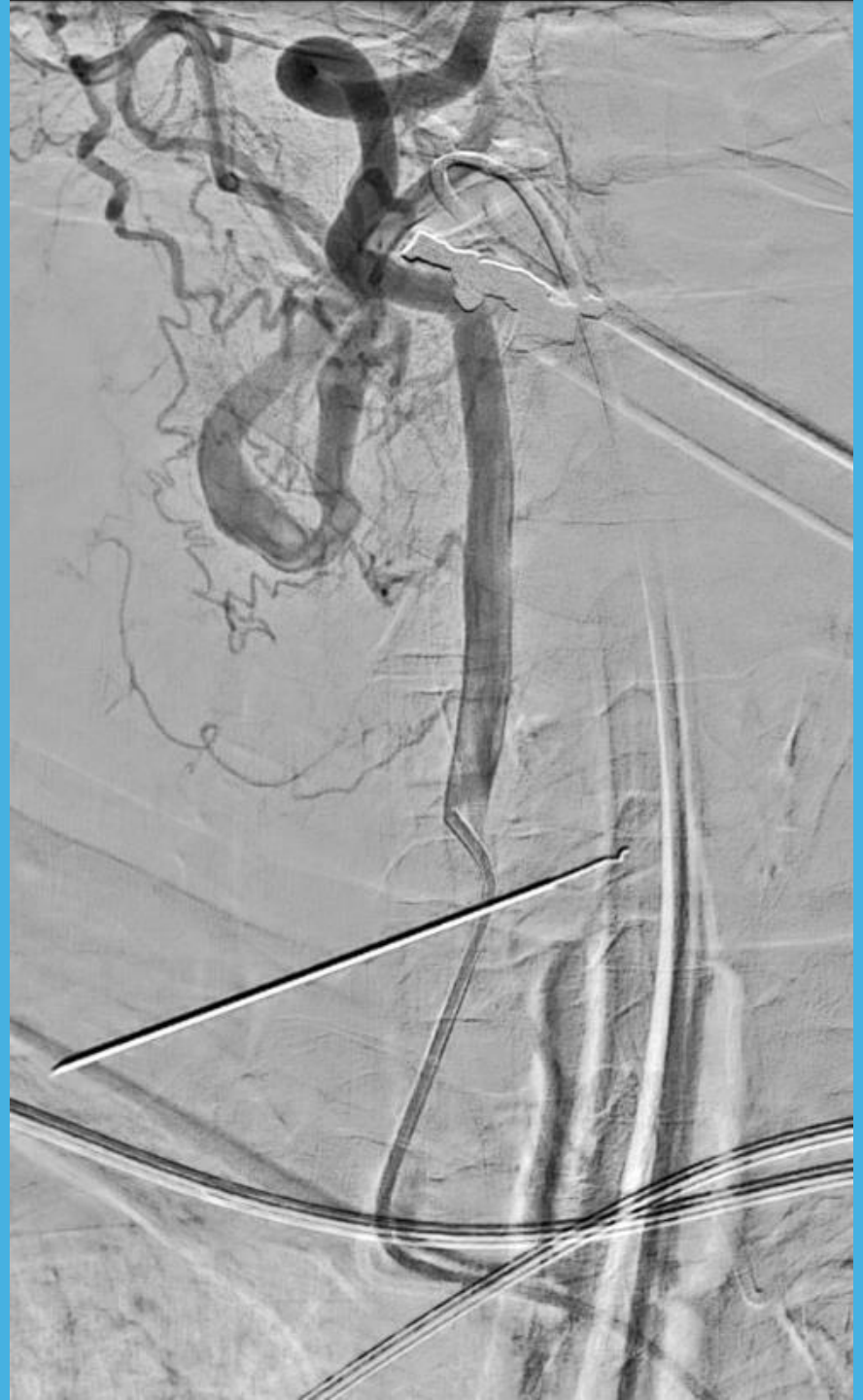

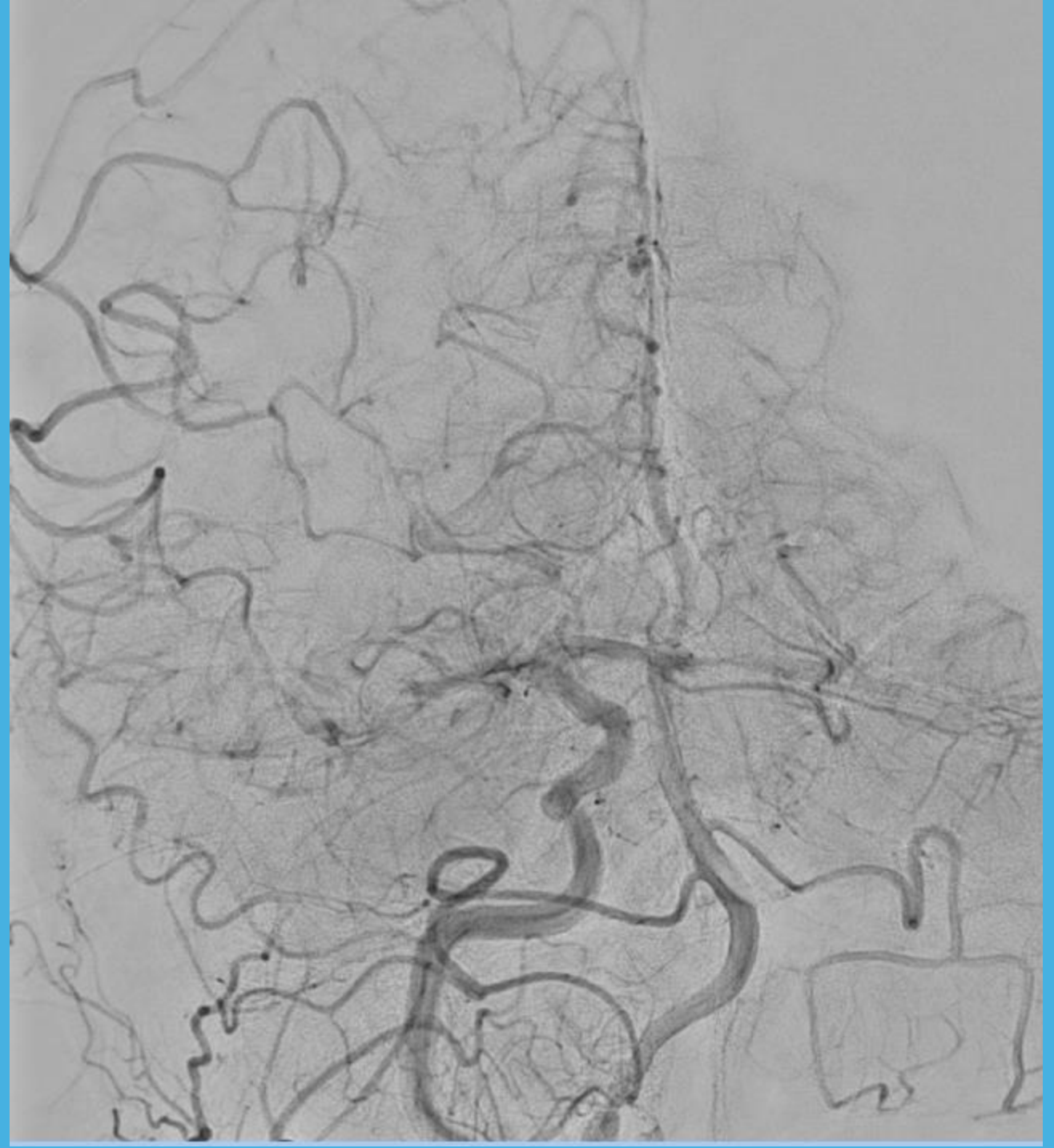


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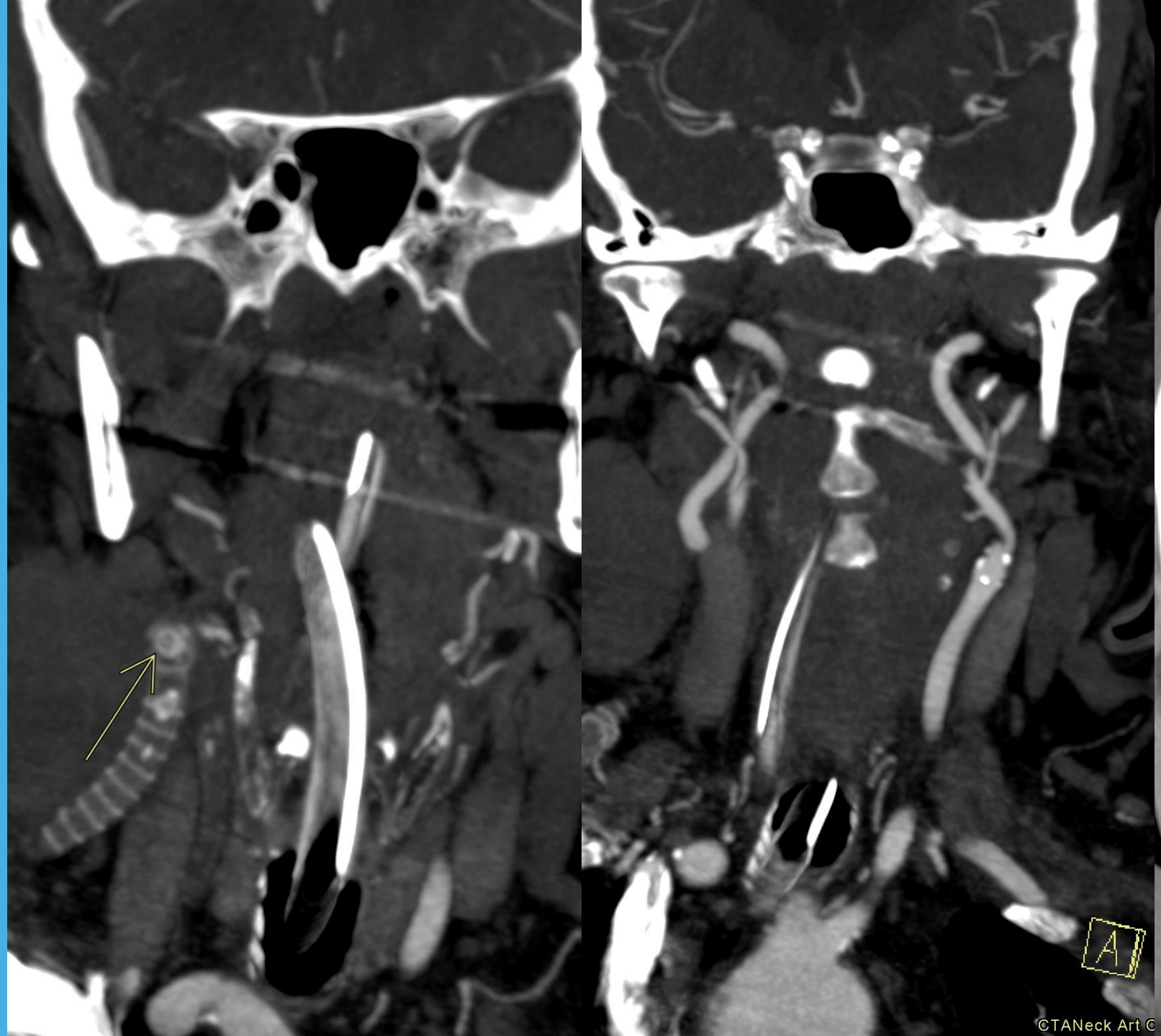
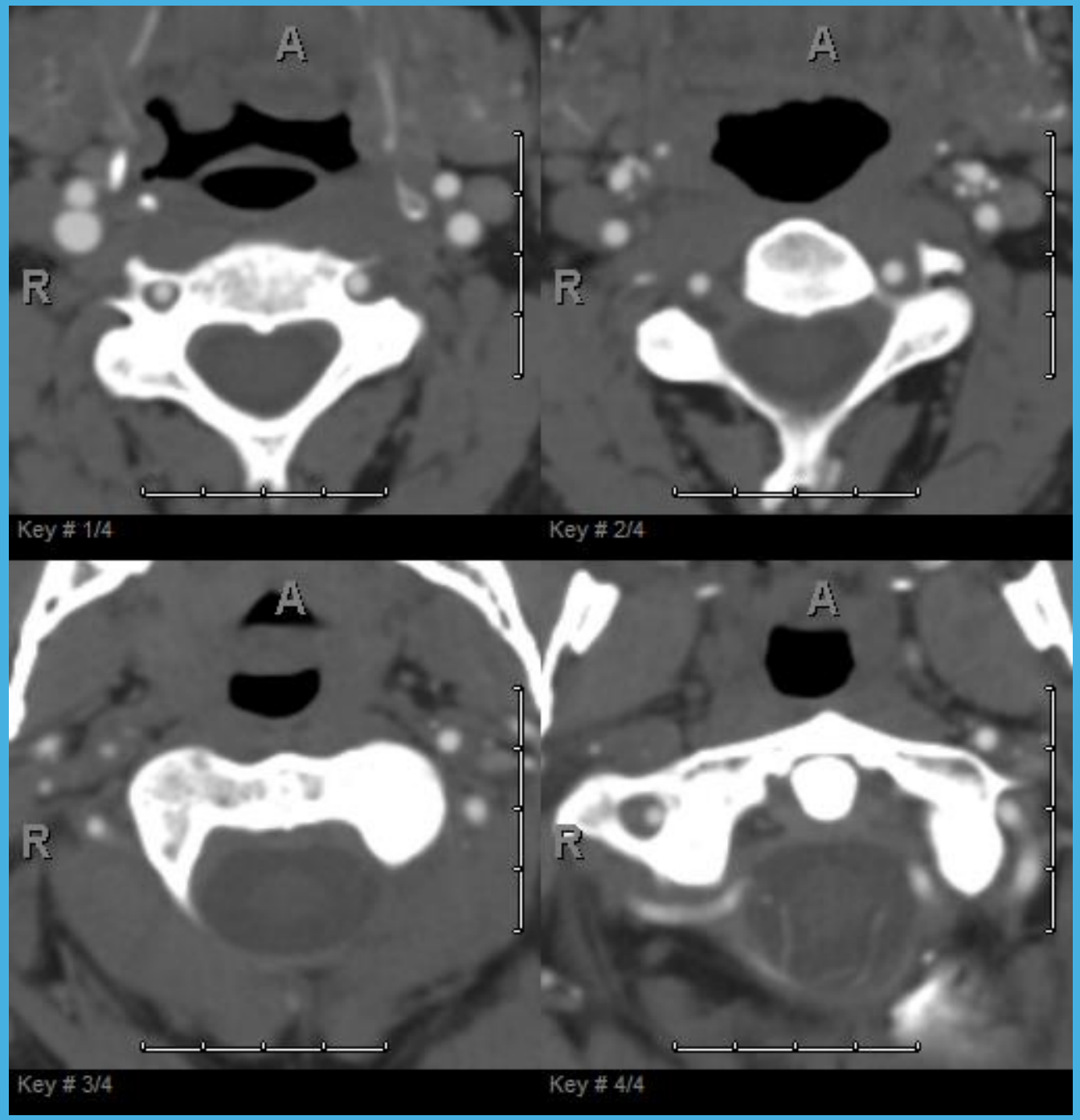
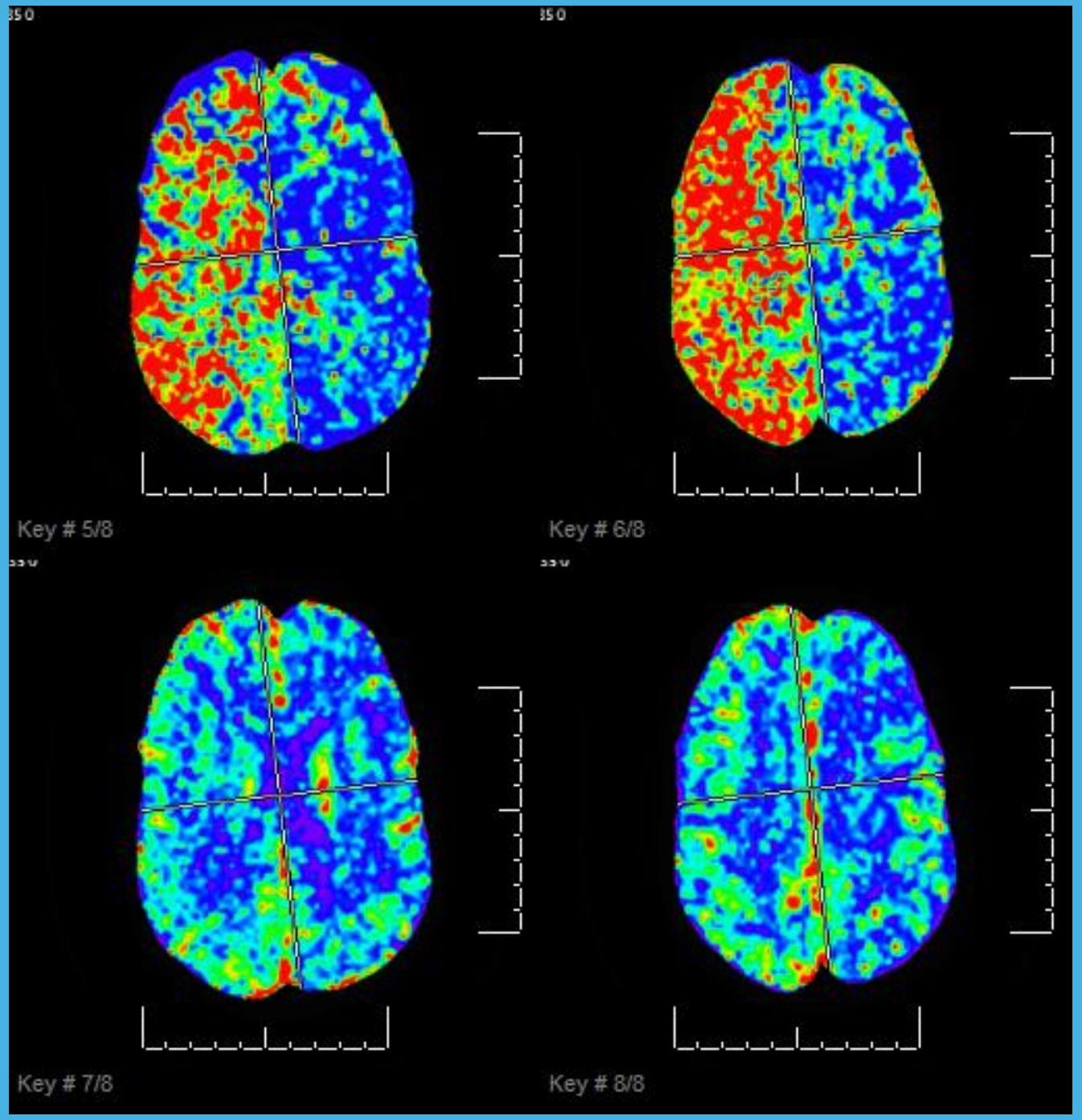
[proj]


RICA


A
©TANeck Art ©

- 49 y old; right sided headache with radiation to neck for a week.
- Acute onset left hemiplegia
- NIHHS stroke scale 35. Airlifted to Wake


A
R
Key # 1/4
A
R
Key # 2/4
A
R
Key # 3/4
A
R
Key # 4/4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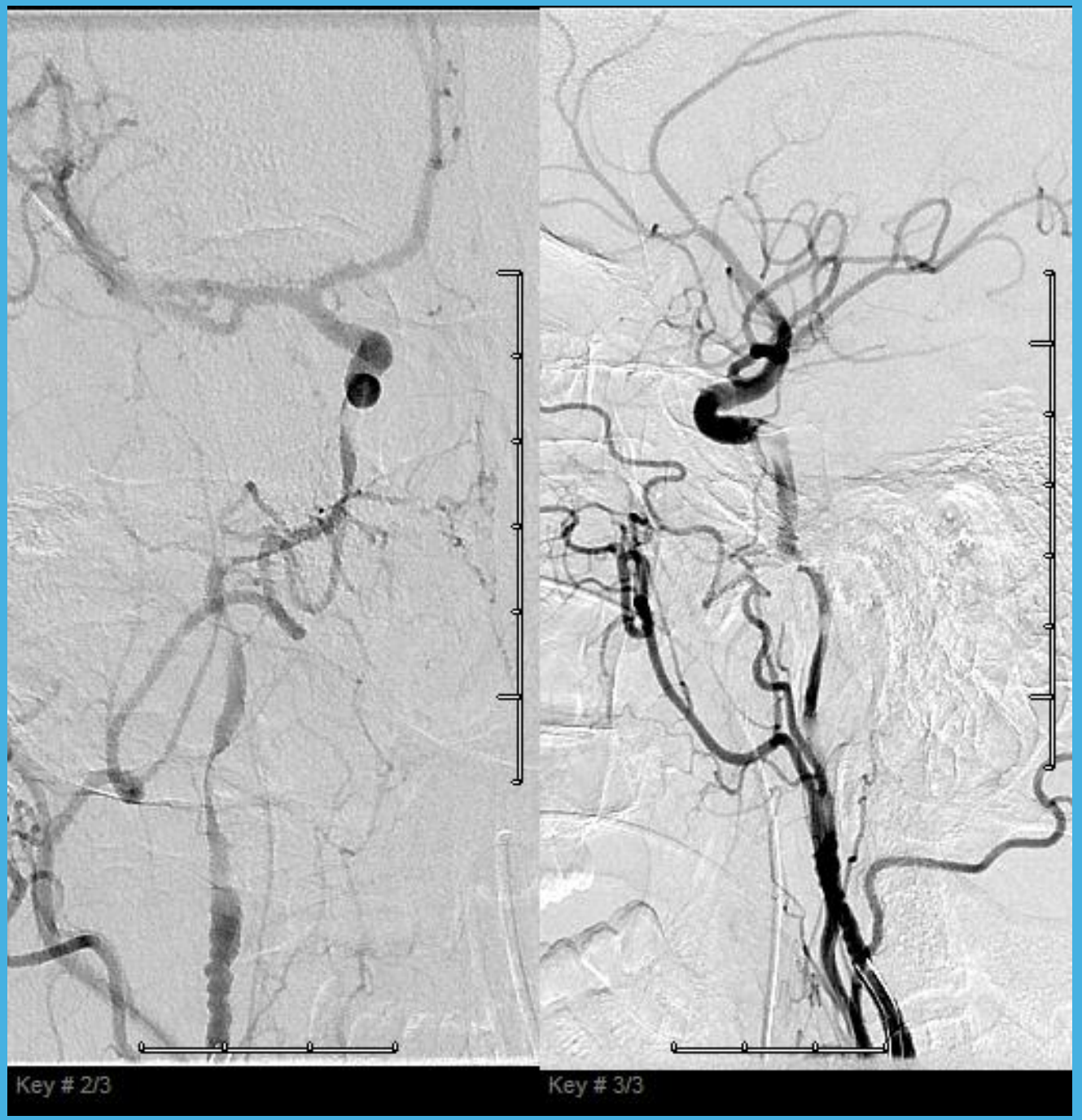
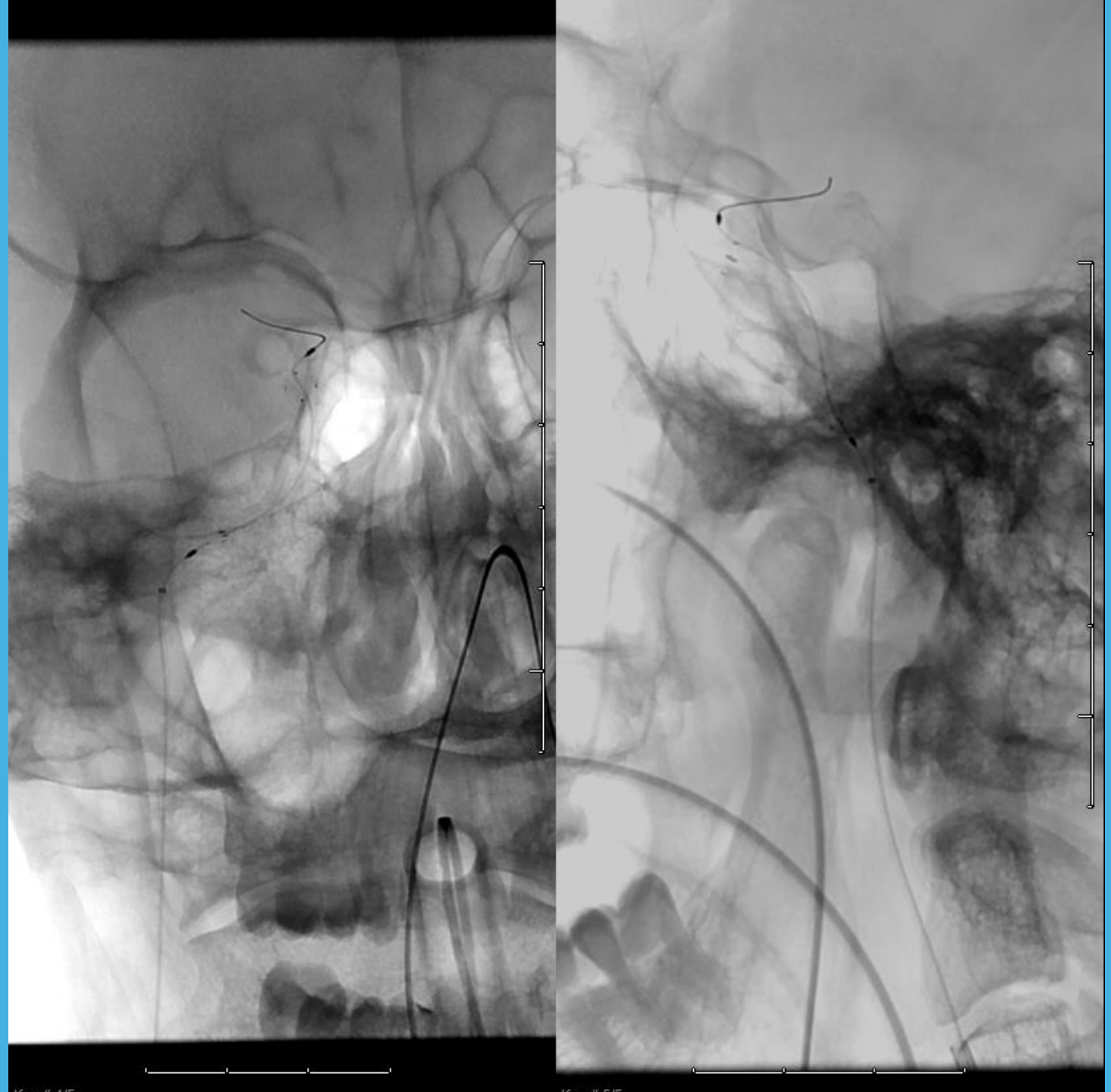
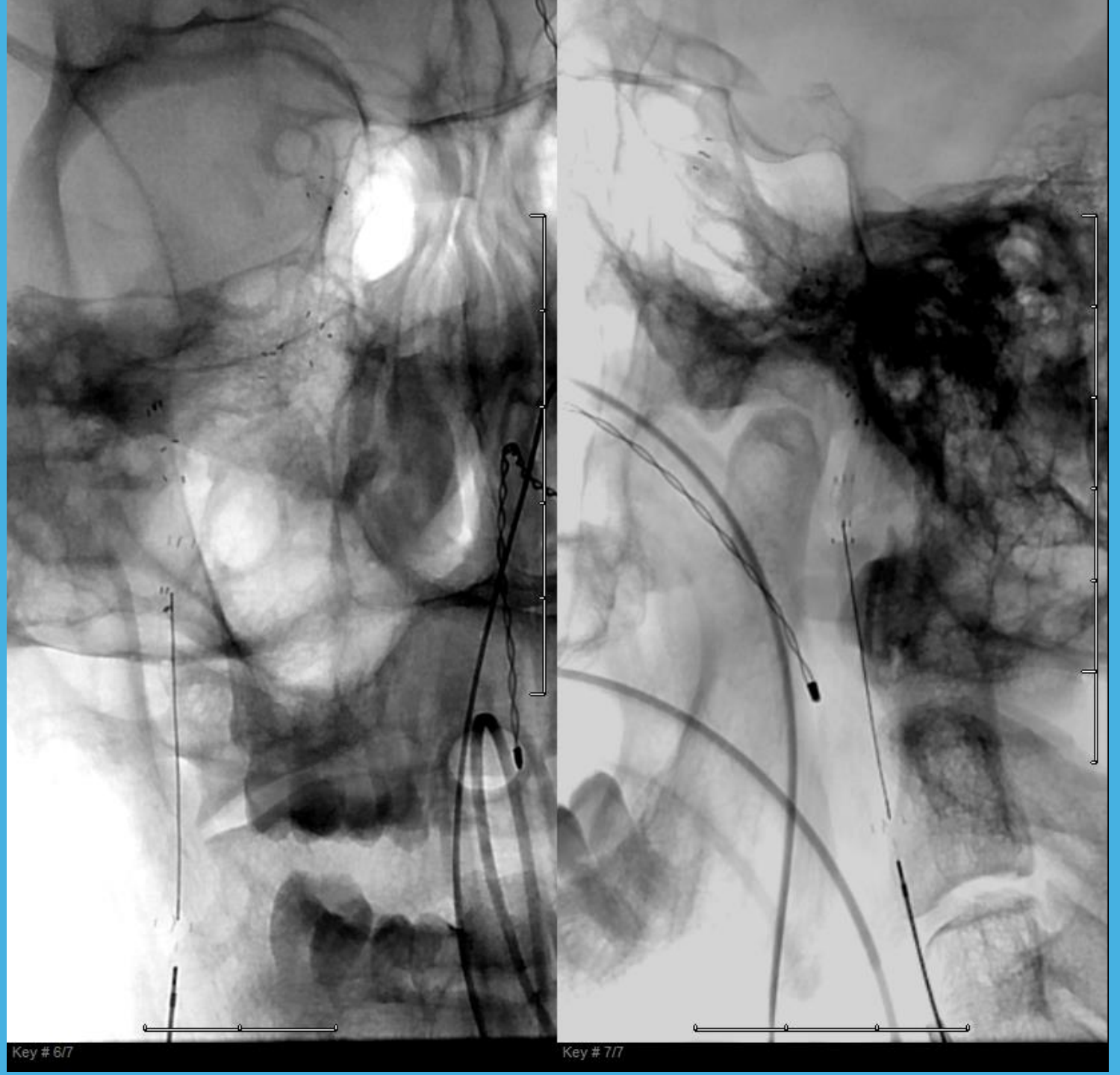
Key # 6/8
Key # 7/8
Key # 8/8


Key # 2/3
Key # 3/3

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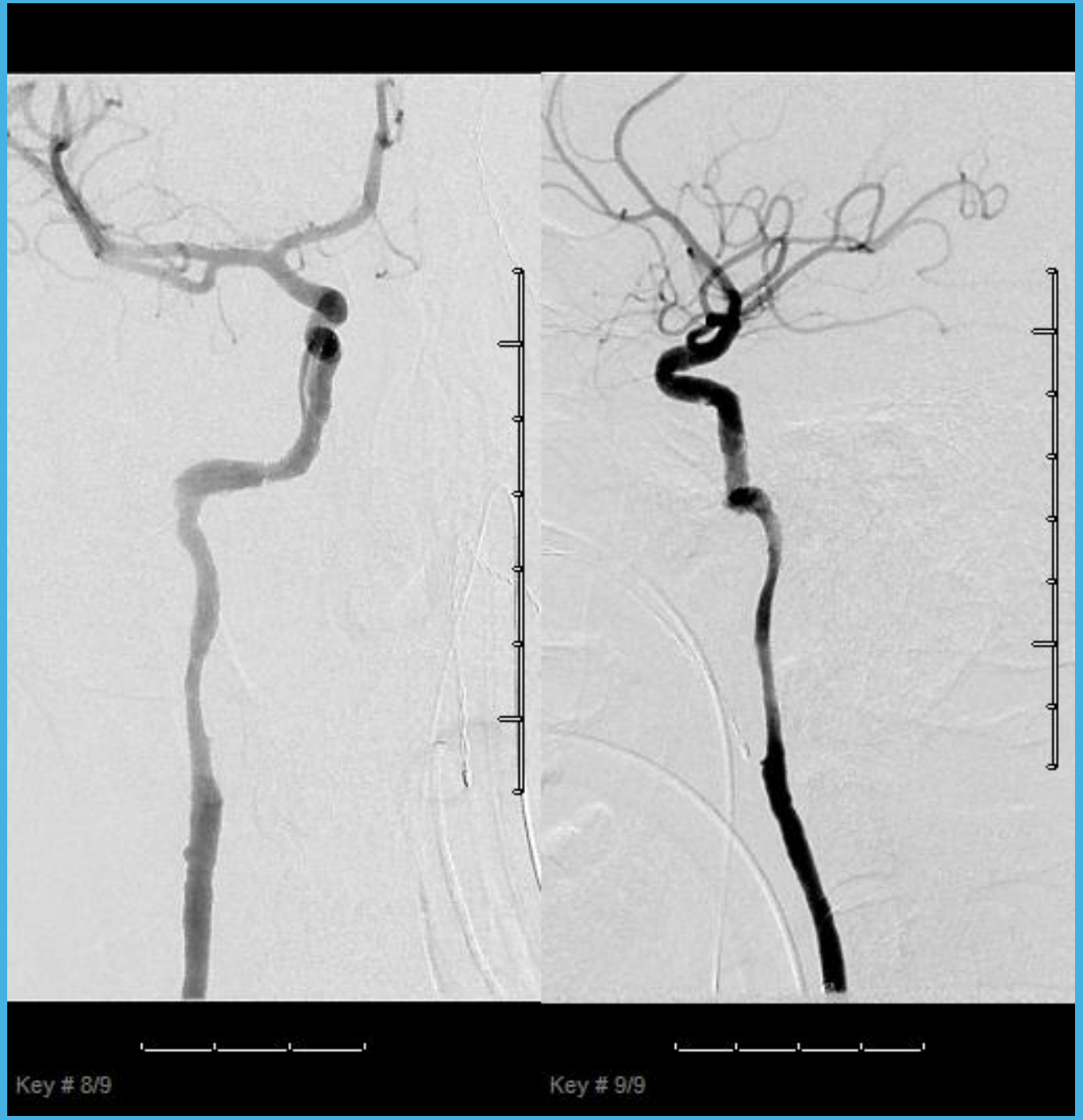
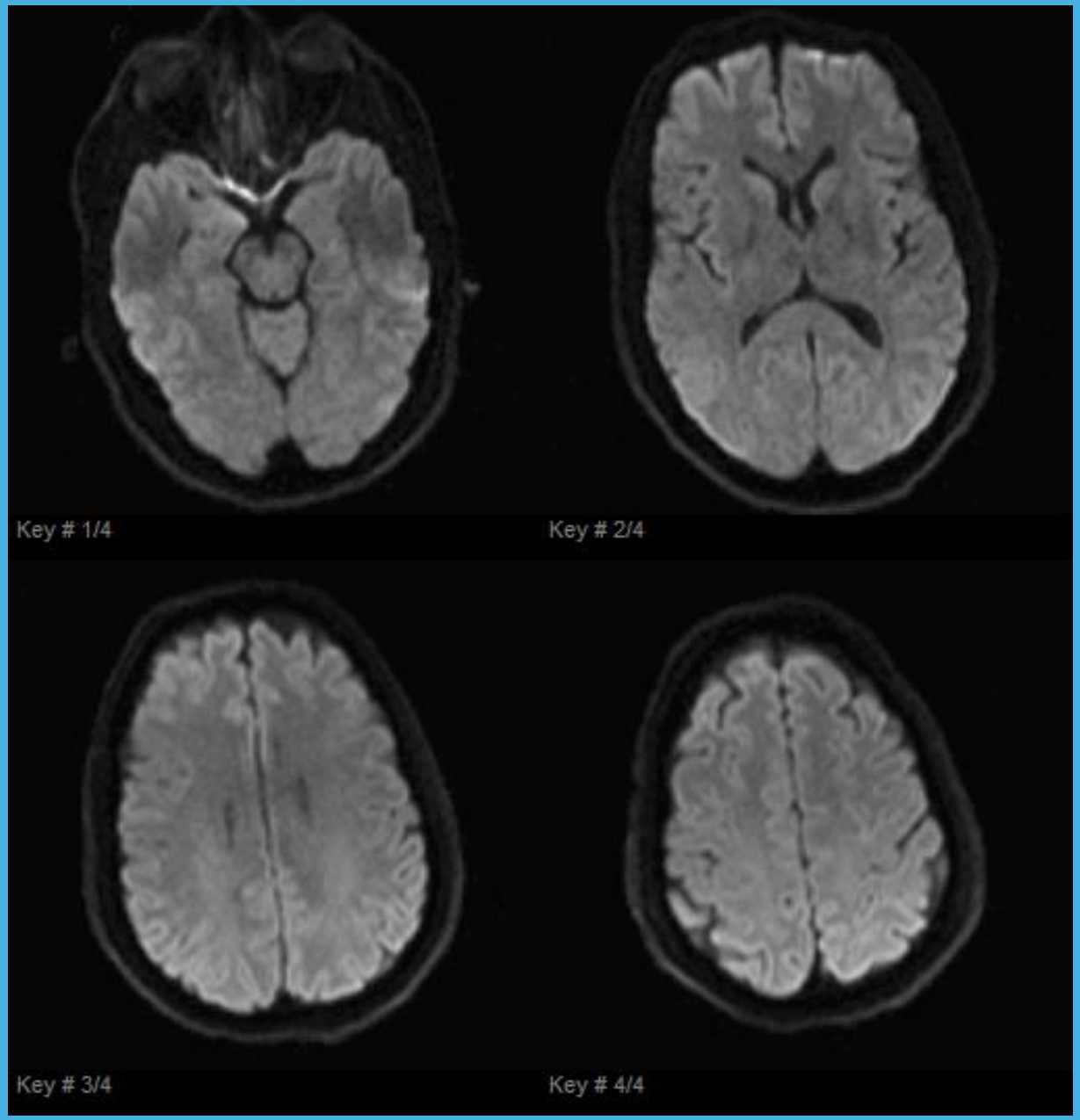
Key # 7/7

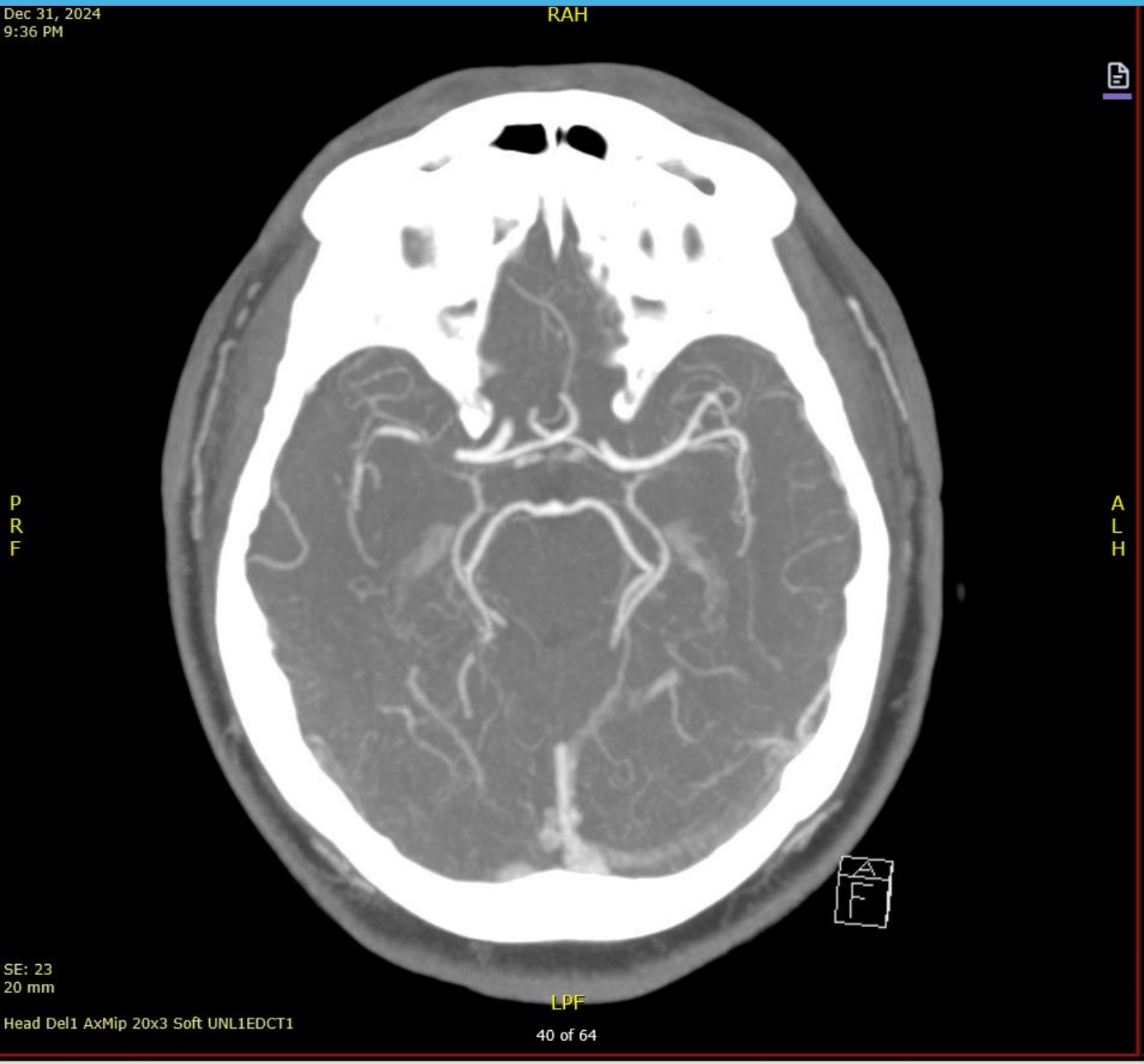

Key # 8/9
Key # 9/9

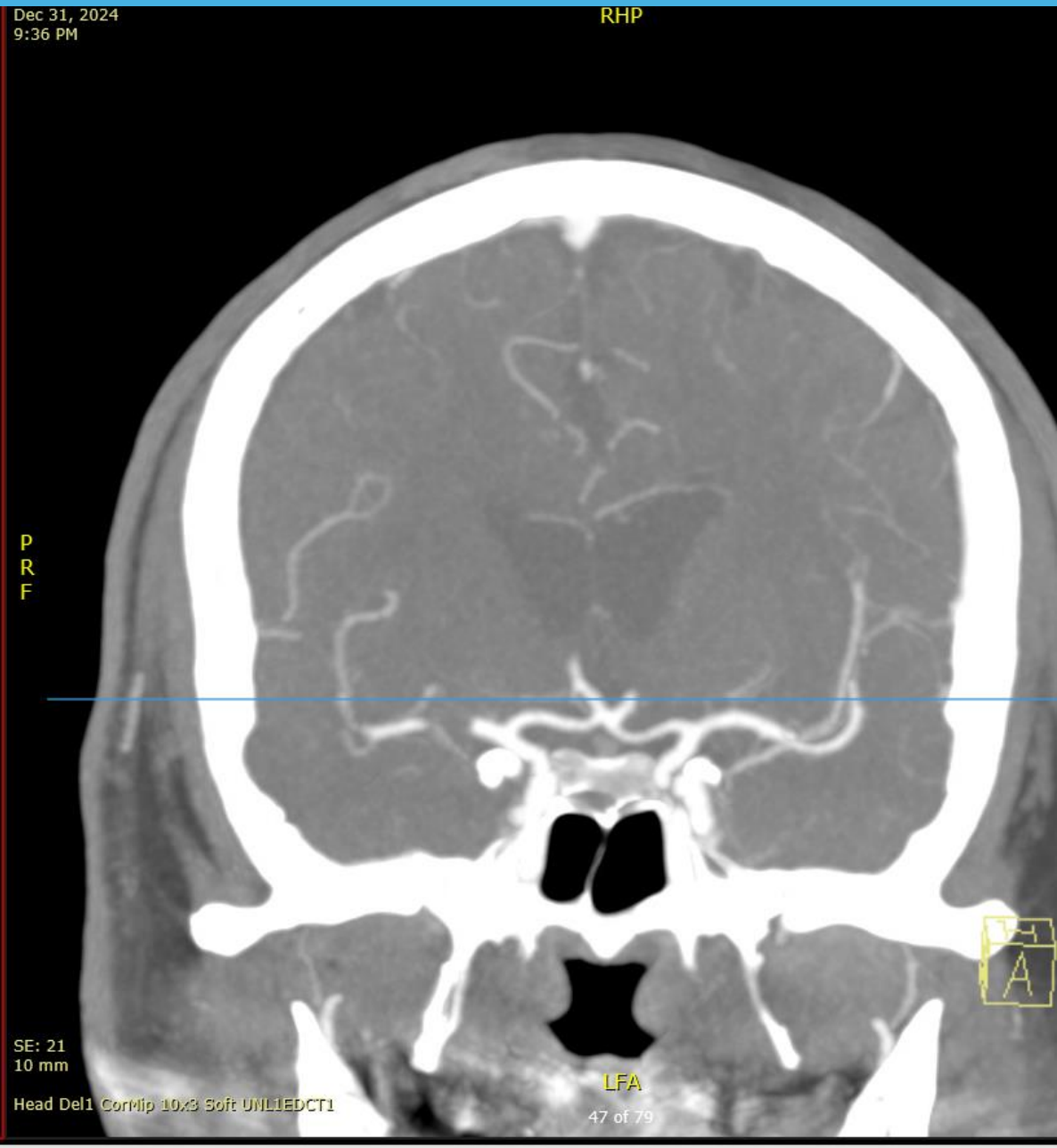

Key # 10/11
Key # 11/11


Key # 1/4
Key # 2/4
Key # 3/4
Key # 4/4


Key # 1/2
Key # 2/2

74 y.o. with a PMH of aortic dissection s/p repair 2008 , A-fib on apixaban, multiple past strokes, seizures (last seizure in 2023 on keppra and lamictal), who presented to the ER 12/31 with left arm weakness, left facial droop, and dysarthria. He reported around 2100 he was getting into the shower and slipped. No HS. Symptoms noted at that time. Not a TNK candidate given apixaban use. NIHSS 11

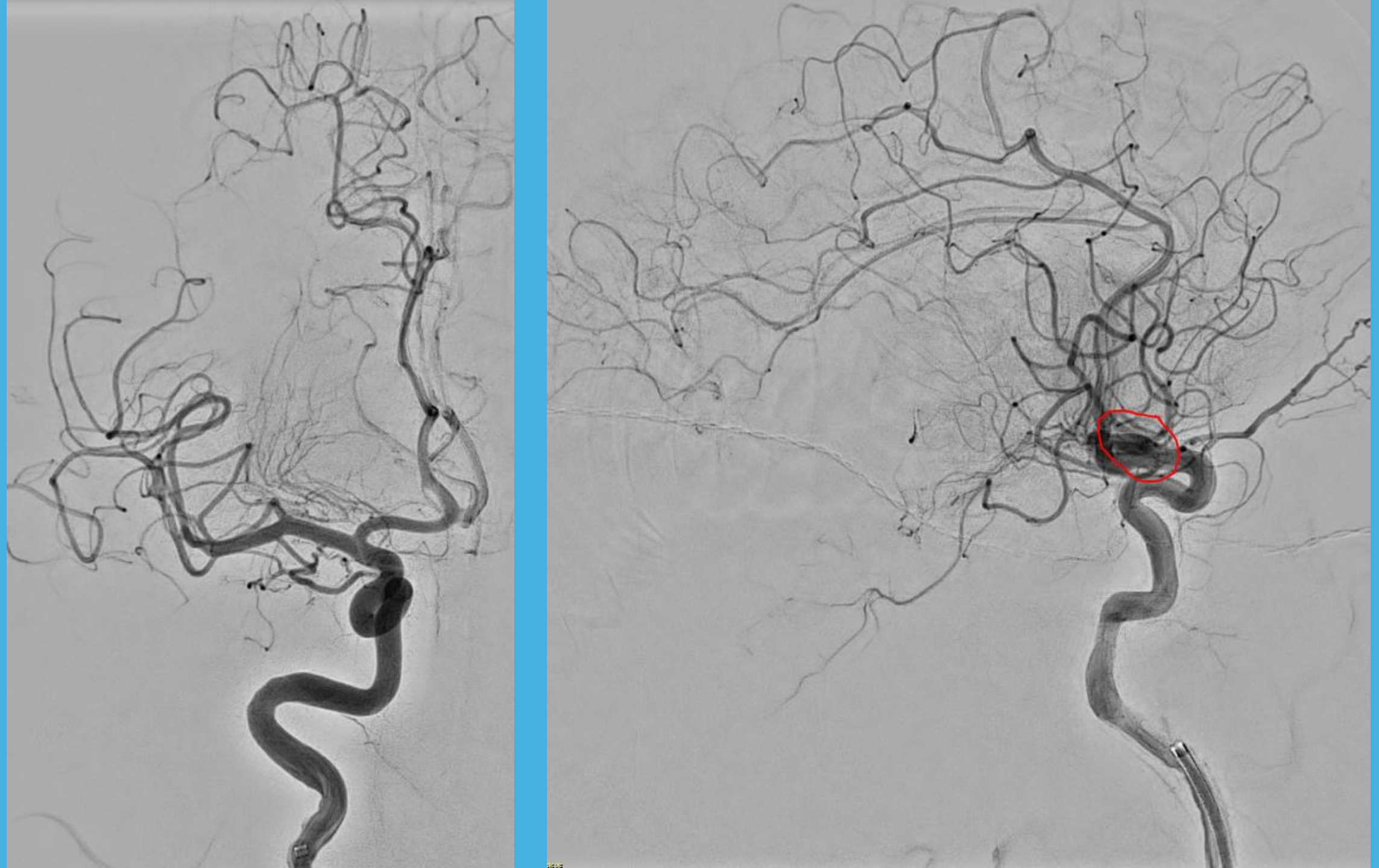

Dec 31, 2024
9:36 PM
RAH
P
R
F
A
L
H
SE: 23
20 mm
Head Del1 AxMip 20x3 Soft UNL1EDCT1
LPF
40 of 64

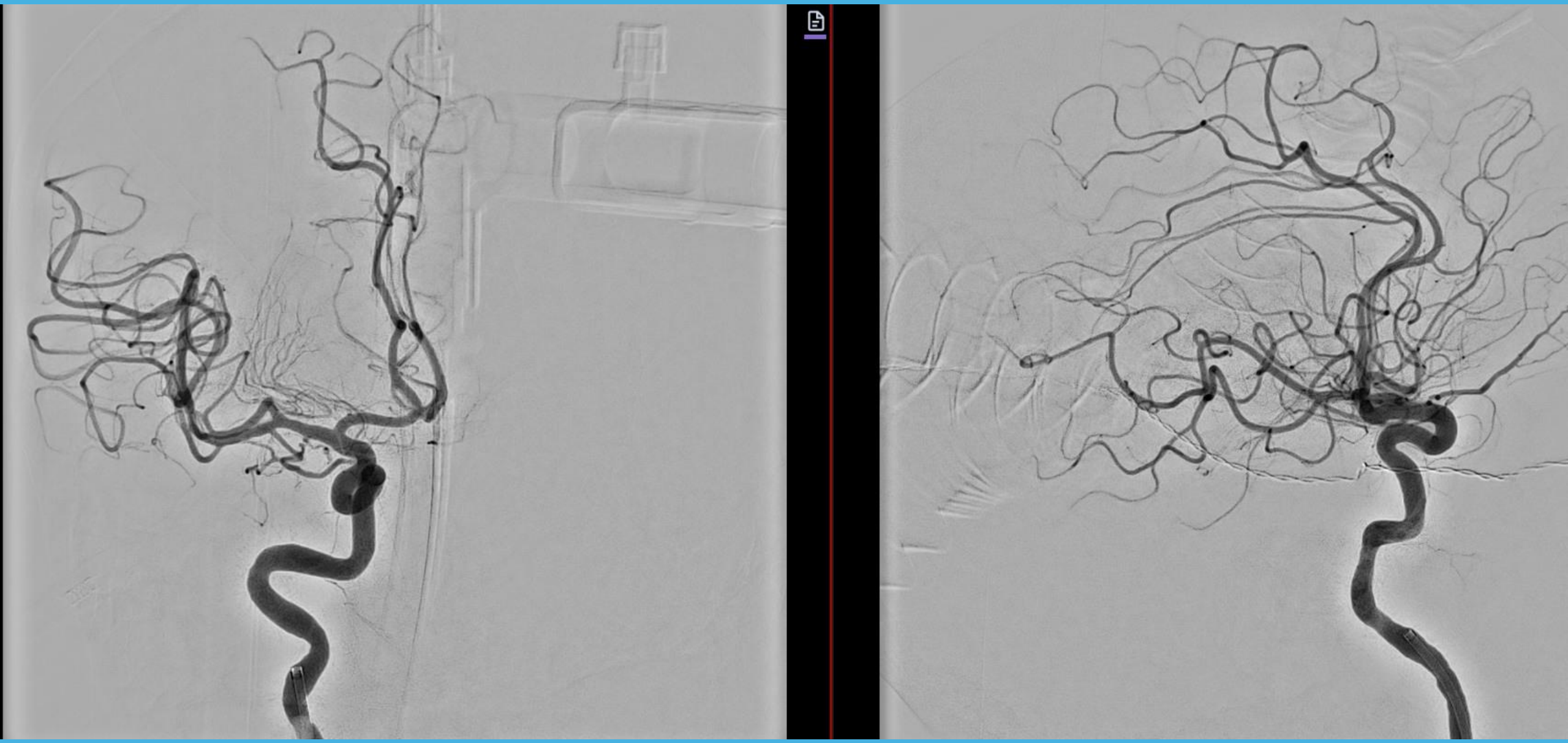

Dec 31, 2024
9:36 PM
RHP
P
R
F
SE: 21
10 mm
Head Del1 CorMip 10x3 Soft UNL1EDCT1
LFA
47 of 79


LF
A

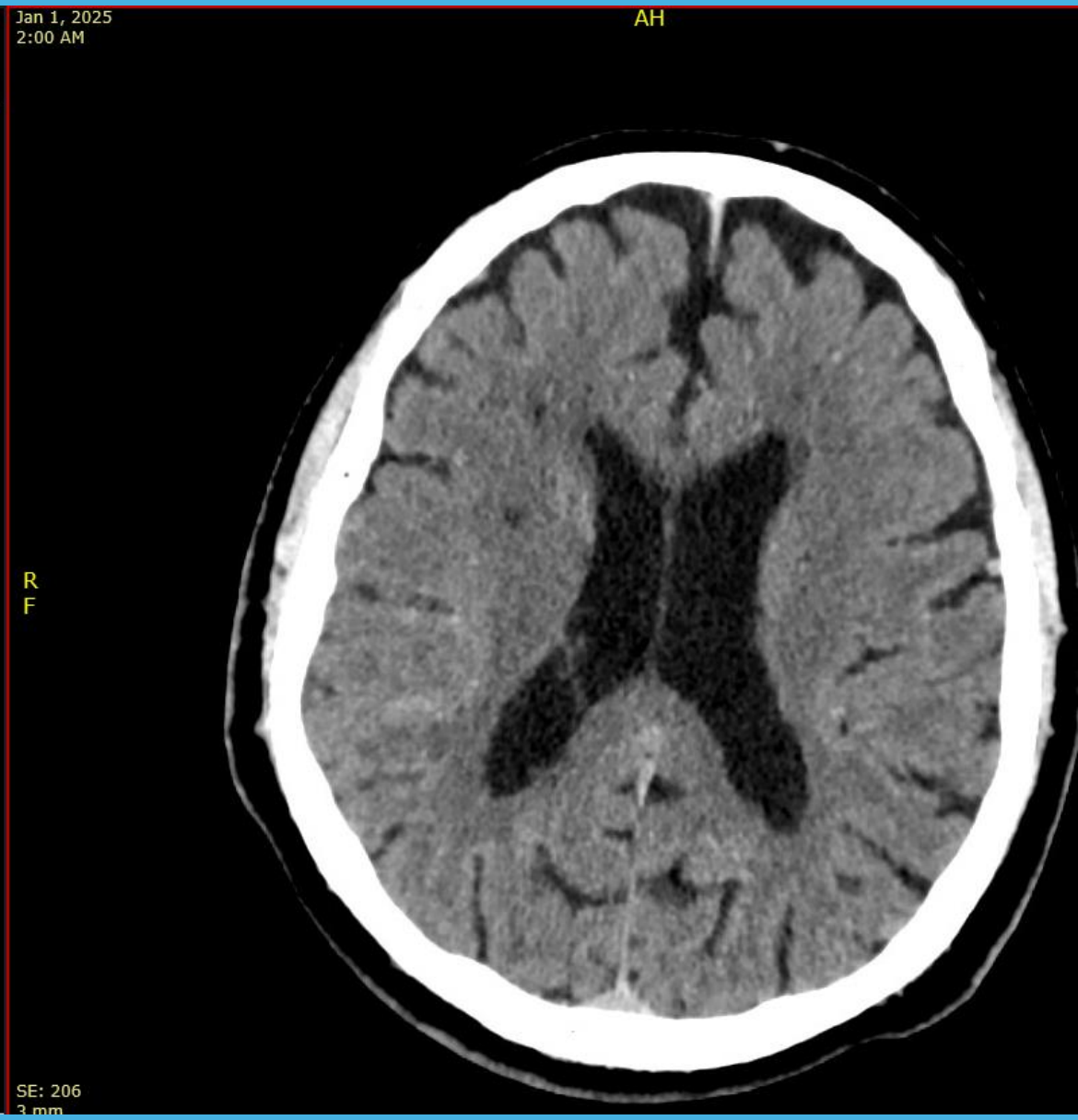

A
50 of 101

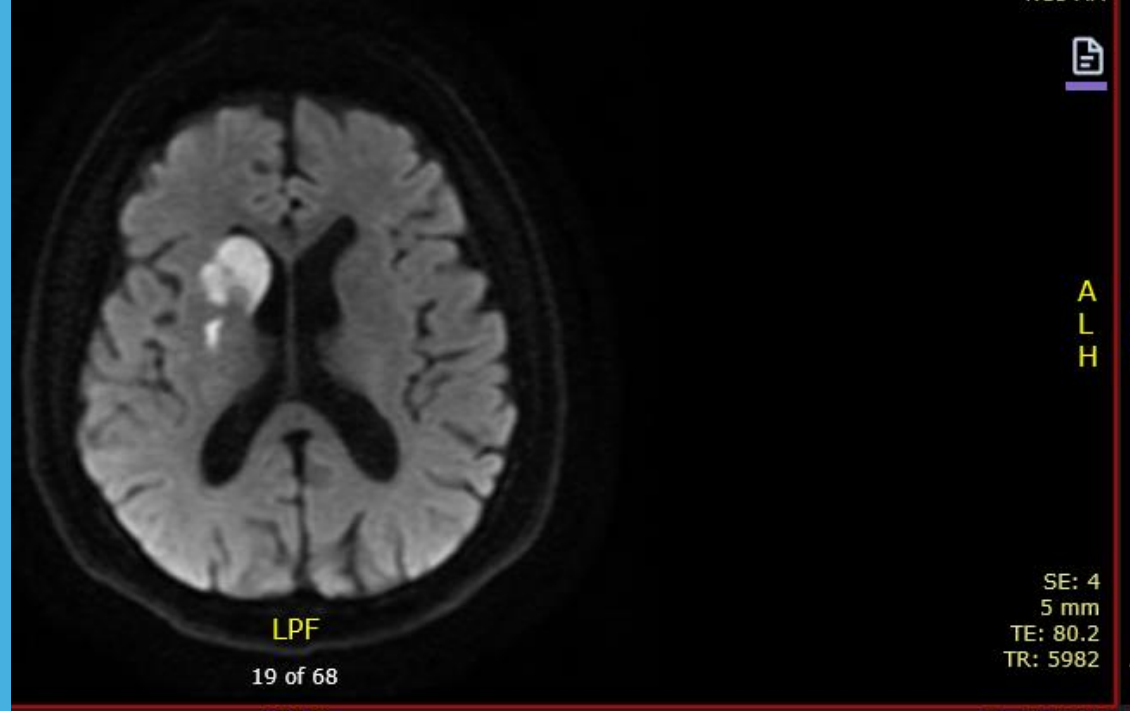

9:36 PM
A
L R
SE: 14
3 mm
-123
Head Neck Art 3x3 Soft UNL1EDCT1
P
116 of 123

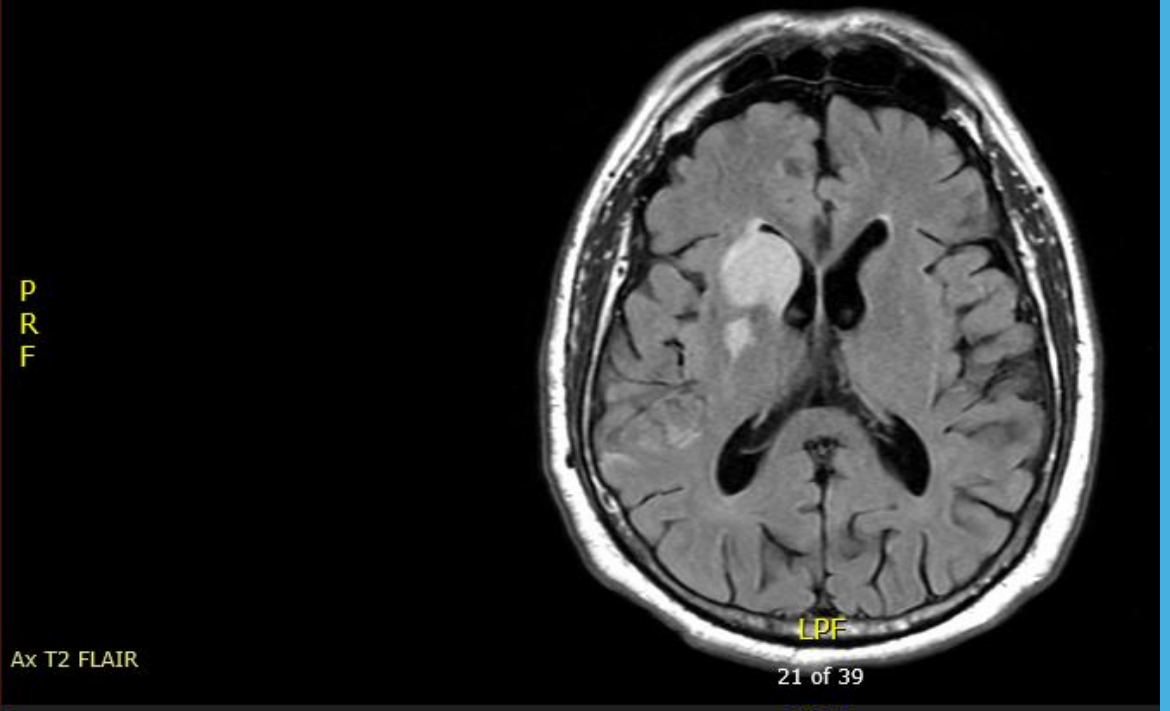


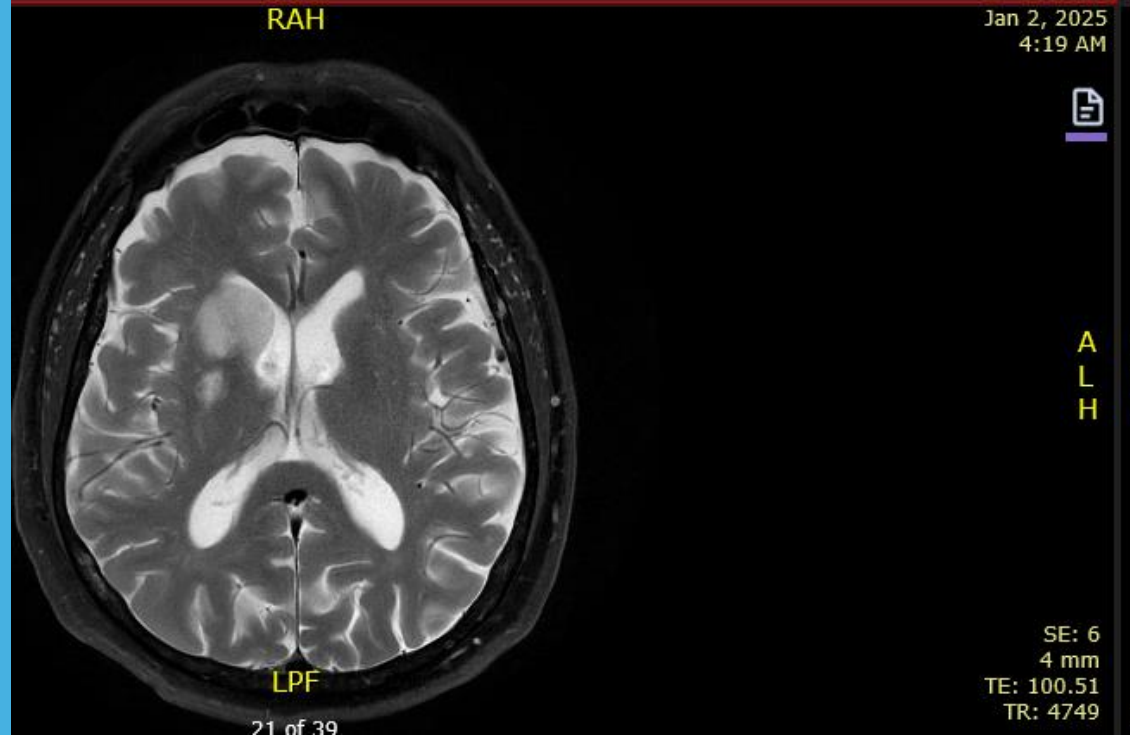


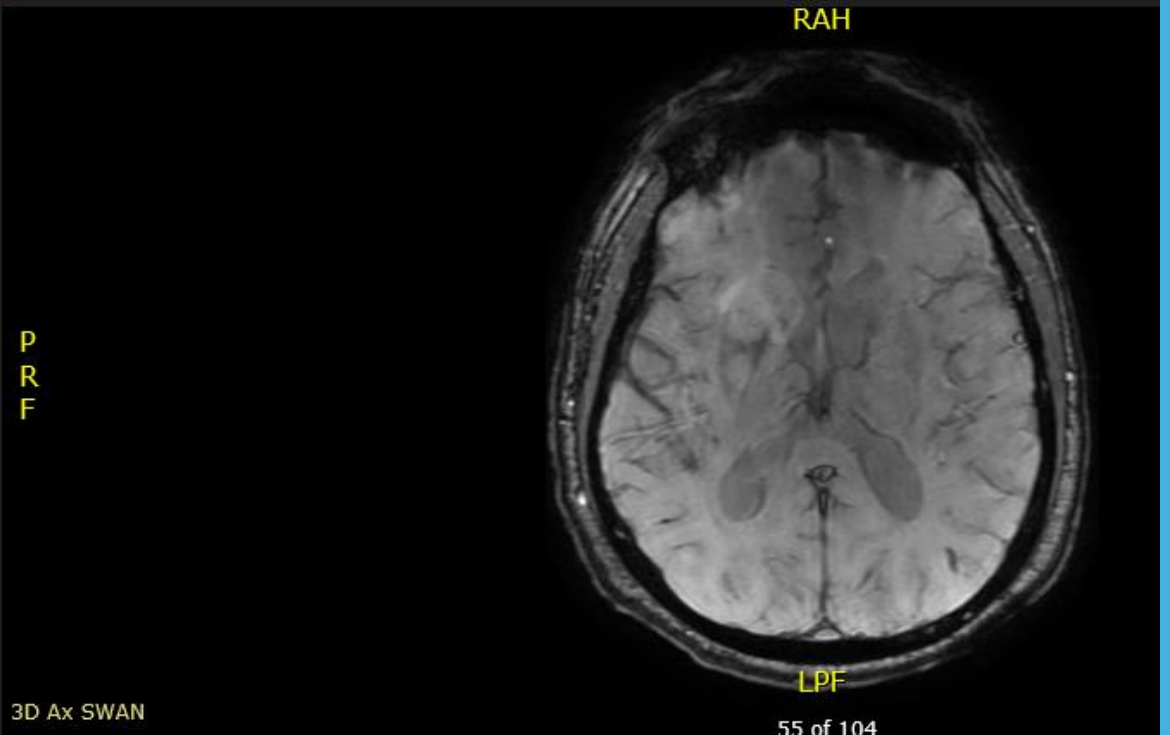

Jan 1, 2025
2:00 AM
AH
R
F
L
H
SE: 201
5 mm


Jan 1, 2025
2:00 AM
AH
R
F
SE: 206
3 mm

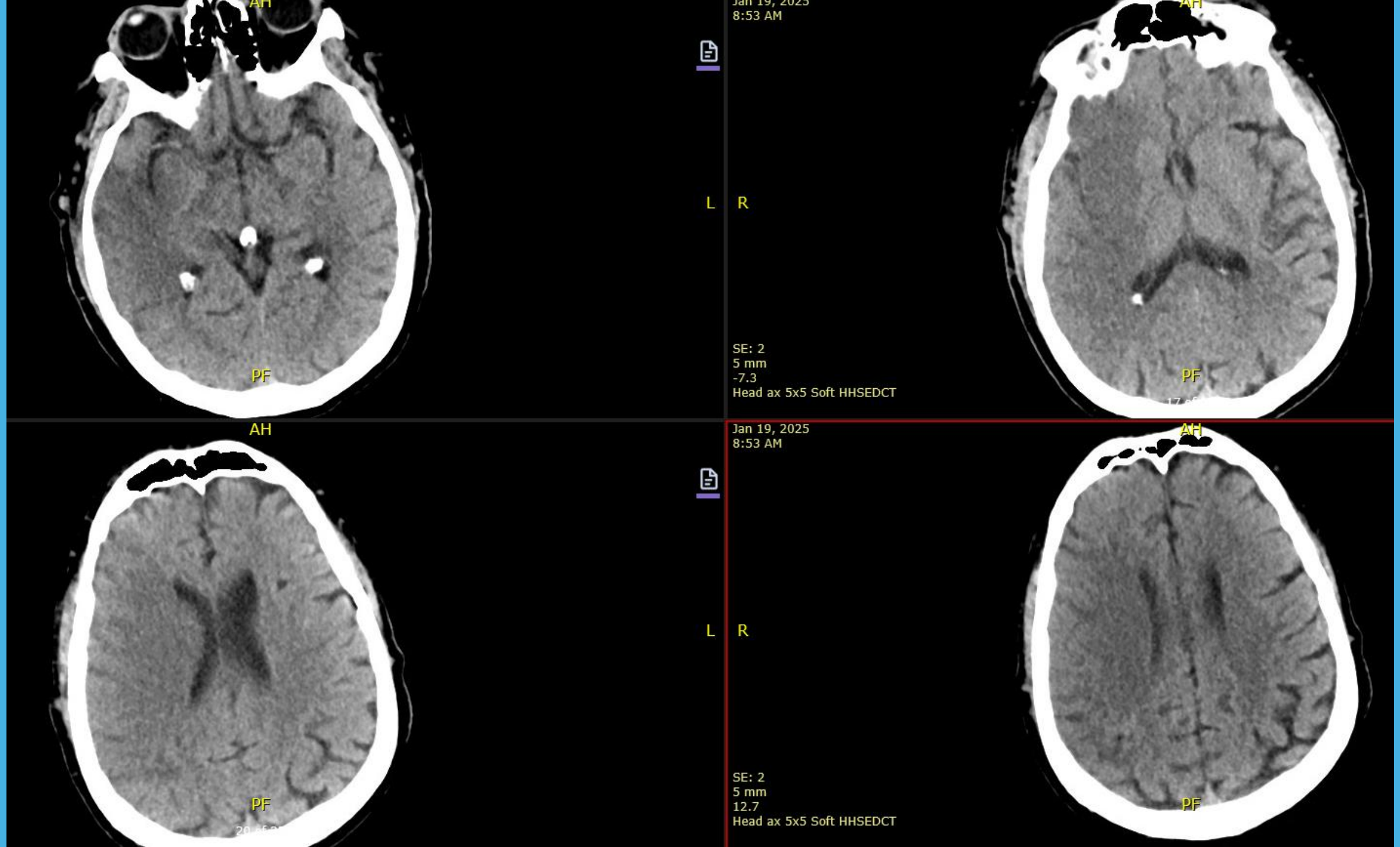

A
L
H
P
R
F
SE: 4
5 mm
TE: 80.2
TR: 5982
LPF
19 of 68
RAH
Jan 2, 2025
4:19 AM

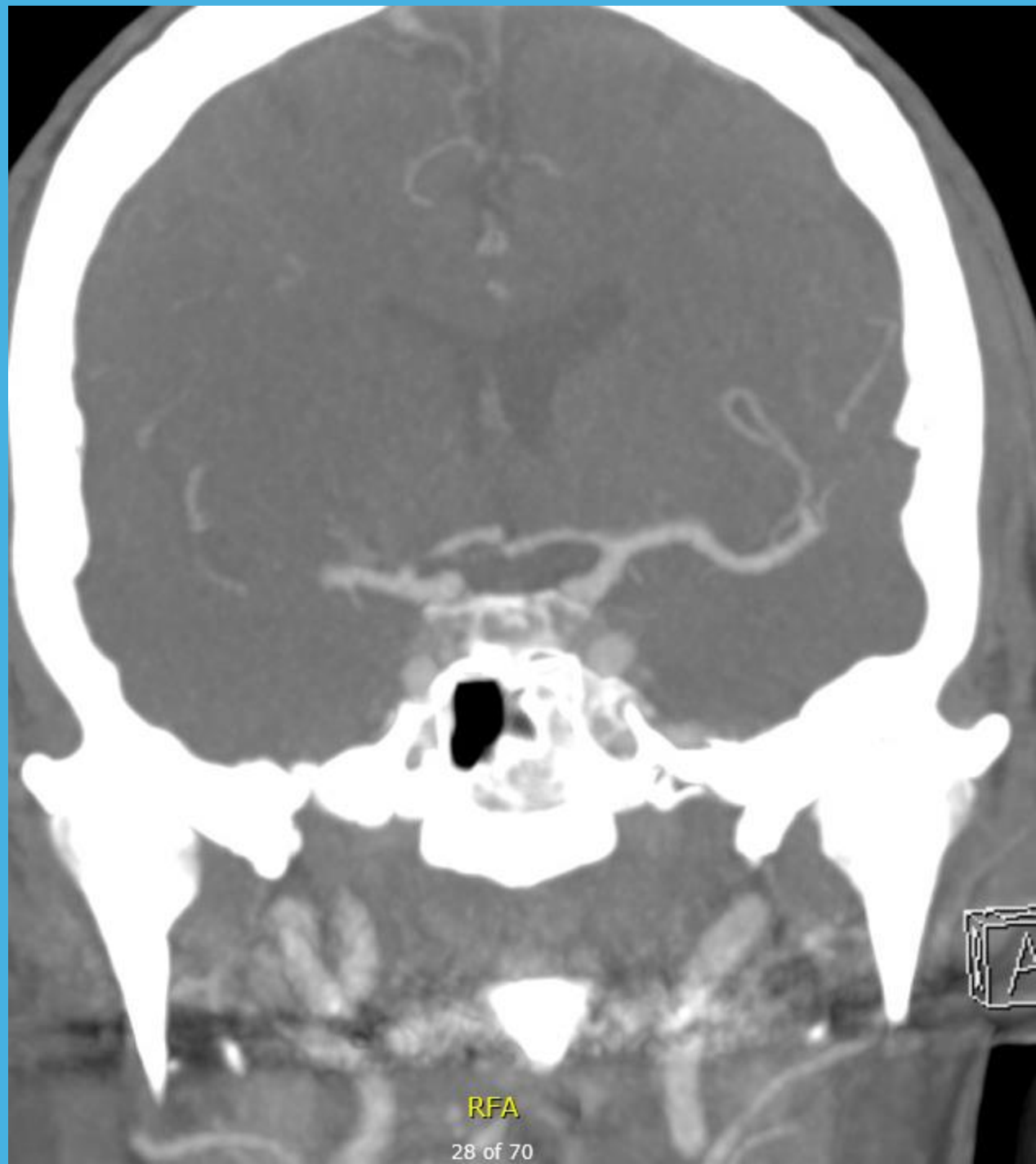

Ax T2 FLAIR
LPF
21 of 39
RAH


A
L
H
P
R
F
SE: 6
4 mm
TE: 100.51
TR: 4749
LPF
21 of 39


3D Ax SWAN
LPF
55 of 104

- 66-year-old man with history of hypertension, hyperlipidemia, prior MI, GERD, recent right inguinal incarcerated hernia repair 2 weeks ago, who last known well was 7 PM last night when he went to bed, woke up around 7:30 AM today try to get out of the bed and he fell due to a left-sided hemiplegia. Patient NIH stroke scale was 18.

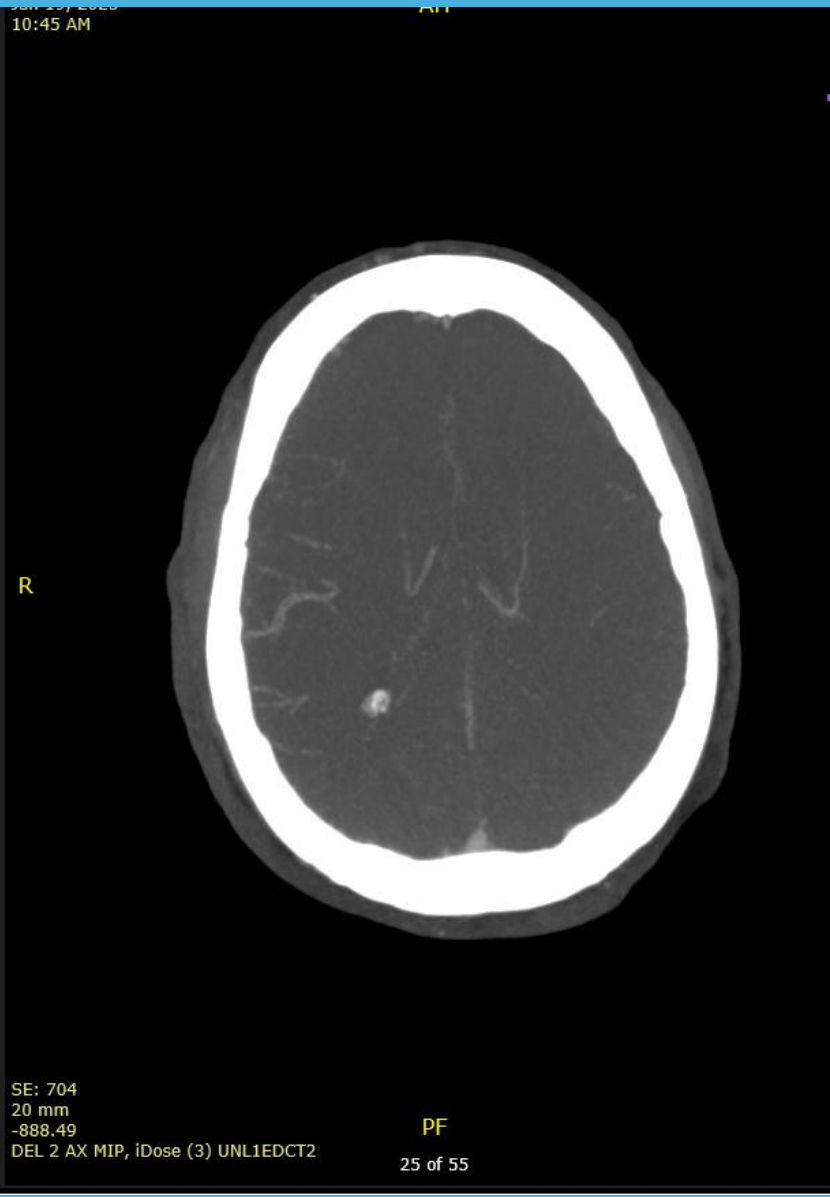

AH
PF
Jan 19, 2025
8:53 AM
L
R
SE: 2
5 mm
-7.3
Head ax 5x5 Soft HHSEDCT
AH
PF
AH
PF
Jan 19, 2025
8:53 AM
L
R
SE: 2
5 mm
12.7
Head ax 5x5 Soft HHSEDCT
AH
PF

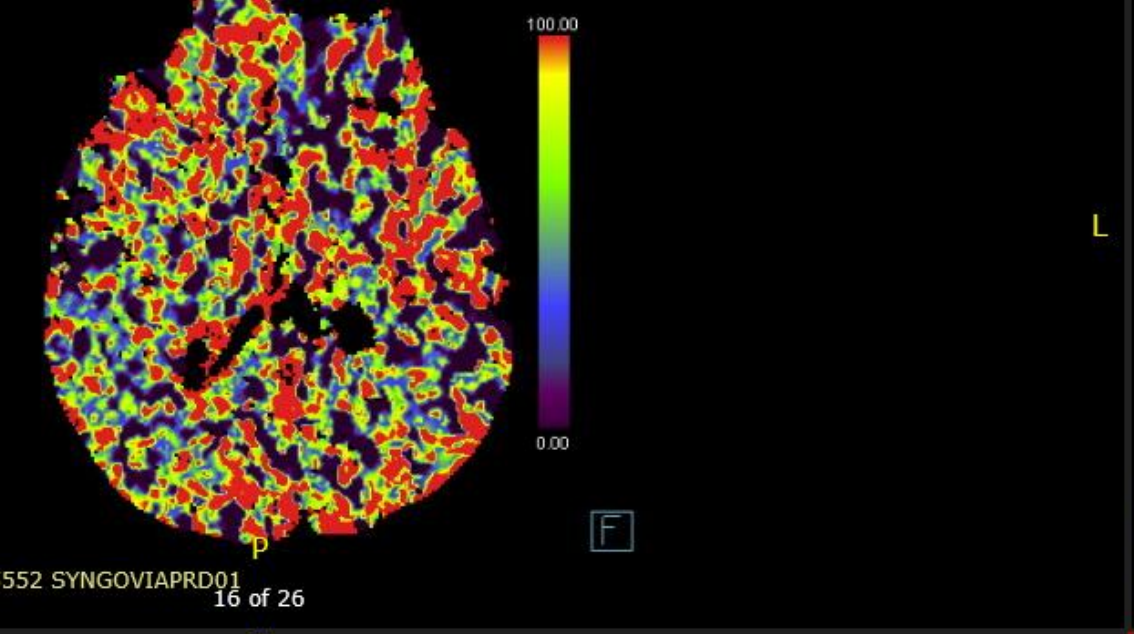

RFA
28 of 70

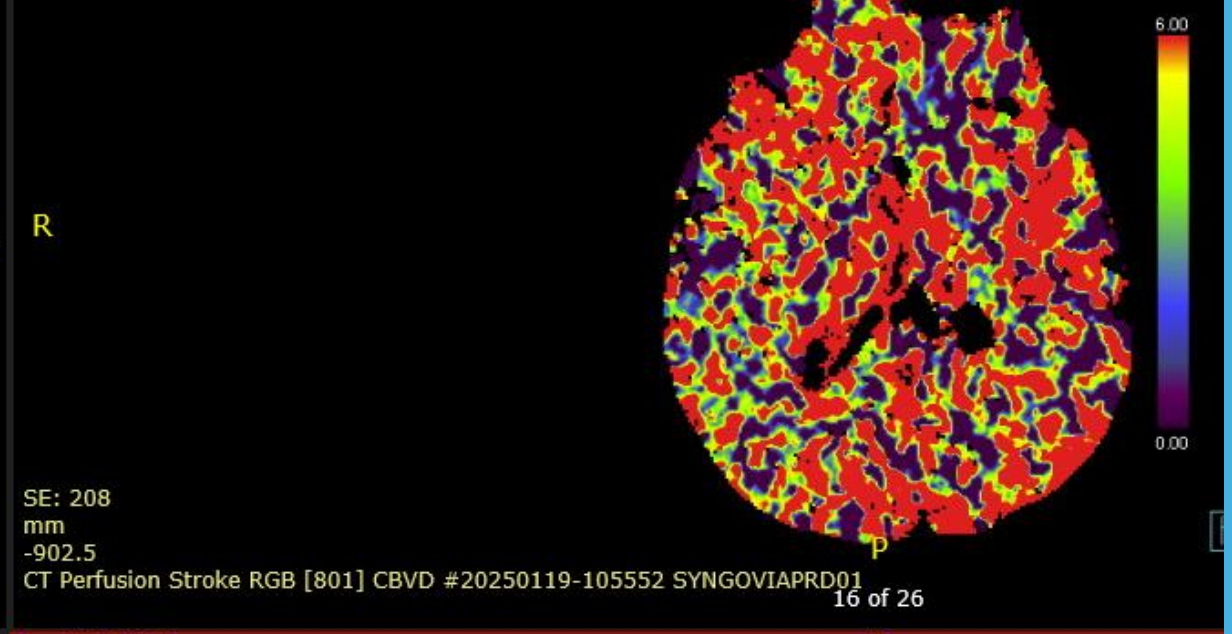

L
R
PF
SE: 604
20 mm
-917.22
DEL 1 AX MIP, iDose (3) UNL1EDCT2
L
R
PF
SE: 704
20 mm
-917.13
DEL 2 AX MIP, iDose (3) UNL1EDCT2

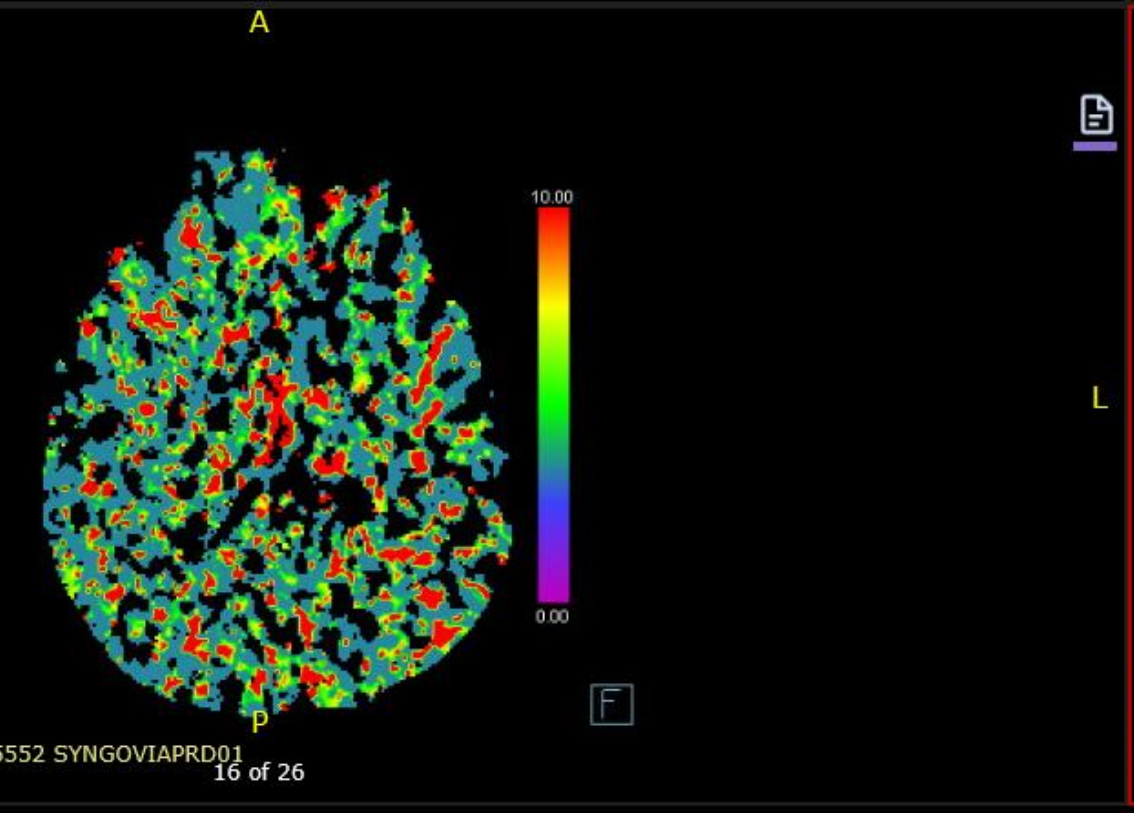

10:44 AM
R
L
SE: 504
20 mm
-888.49
AX HEAD MIP, iDose (3) UNL1EDCT2
PF
26 of 57

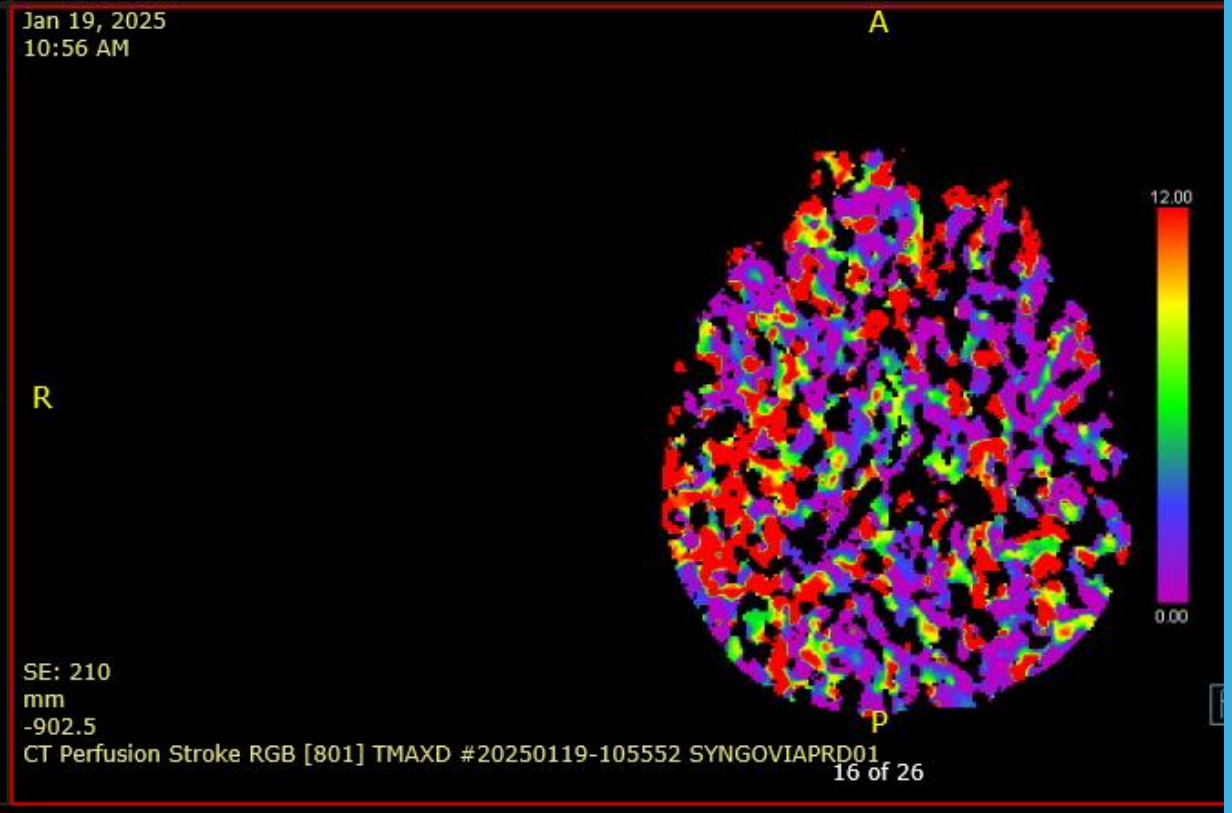

10:44 AM
R
L
SE: 604
20 mm
-888.58
DEL 1 AX MIP, iDose (3) UNL1EDCT2
PF
25 of 55


10:45 AM
R
SE: 704
20 mm
-888.49
DEL 2 AX MIP, iDose (3) UNL1EDCT2
PF
25 of 55


100.00
0.00
P
F
552 SYNGOVIAPRD01
16 of 26


L
R
6.00
0.00
P
SE: 208
mm
-902.5
CT Perfusion Stroke RGB [801] CBVD #20250119-105552 SYNGOVIAPRD01
16 of 26

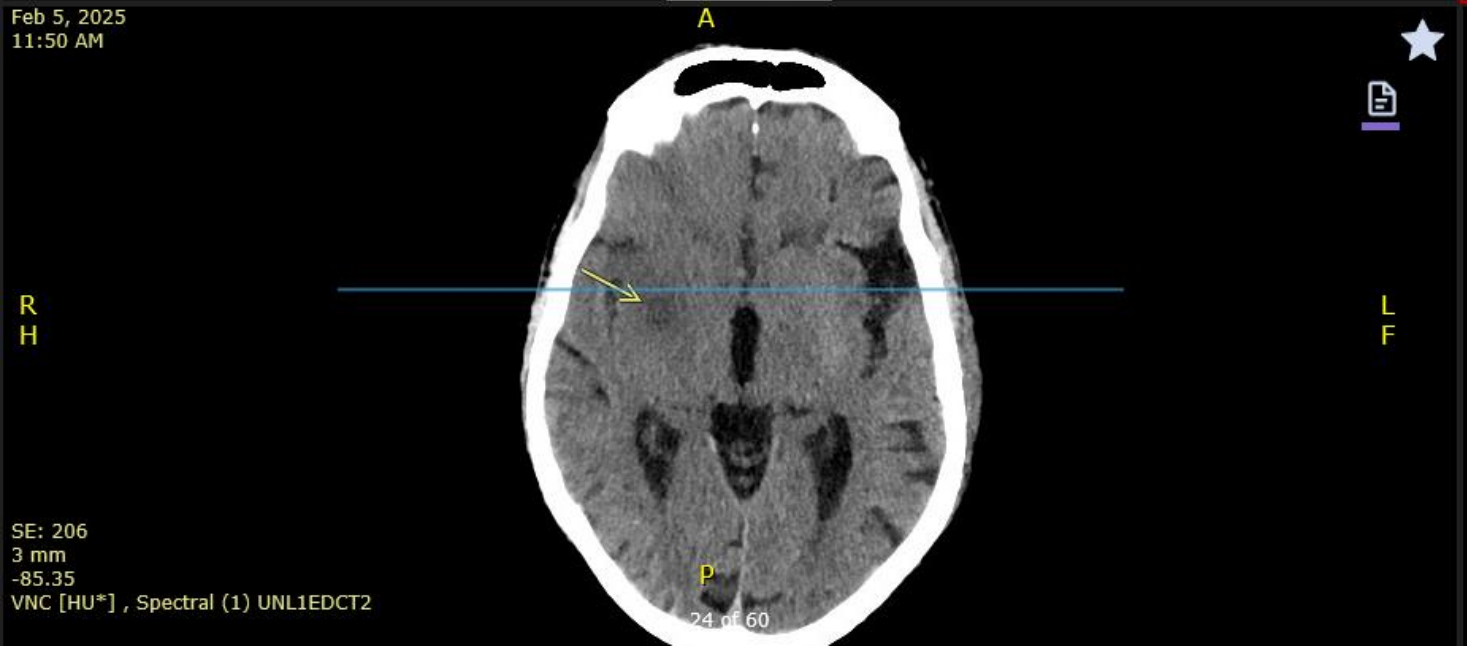

A
10.00
0.00
P
F
5552 SYNGOVIAPRD01
16 of 26

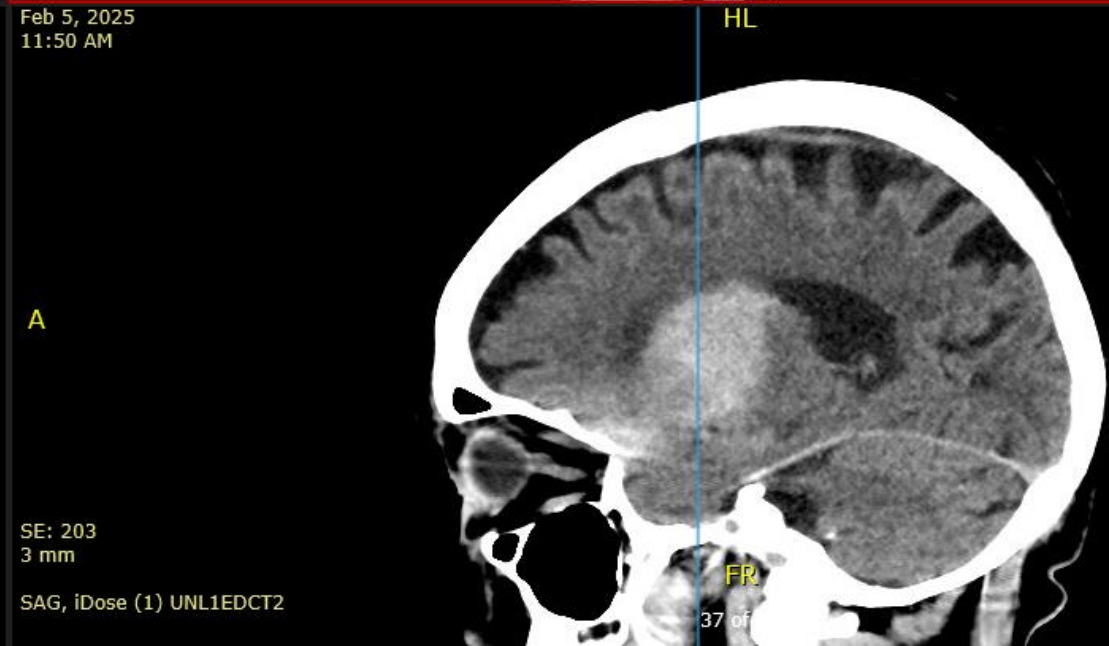

Jan 19, 2025
10:56 AM
A
L
R
12.00
0.00
P
SE: 210
mm
-902.5
CT Perfusion Stroke RGB [801] TMAXD #20250119-105552 SYNGOVIAPRD01
16 of 26

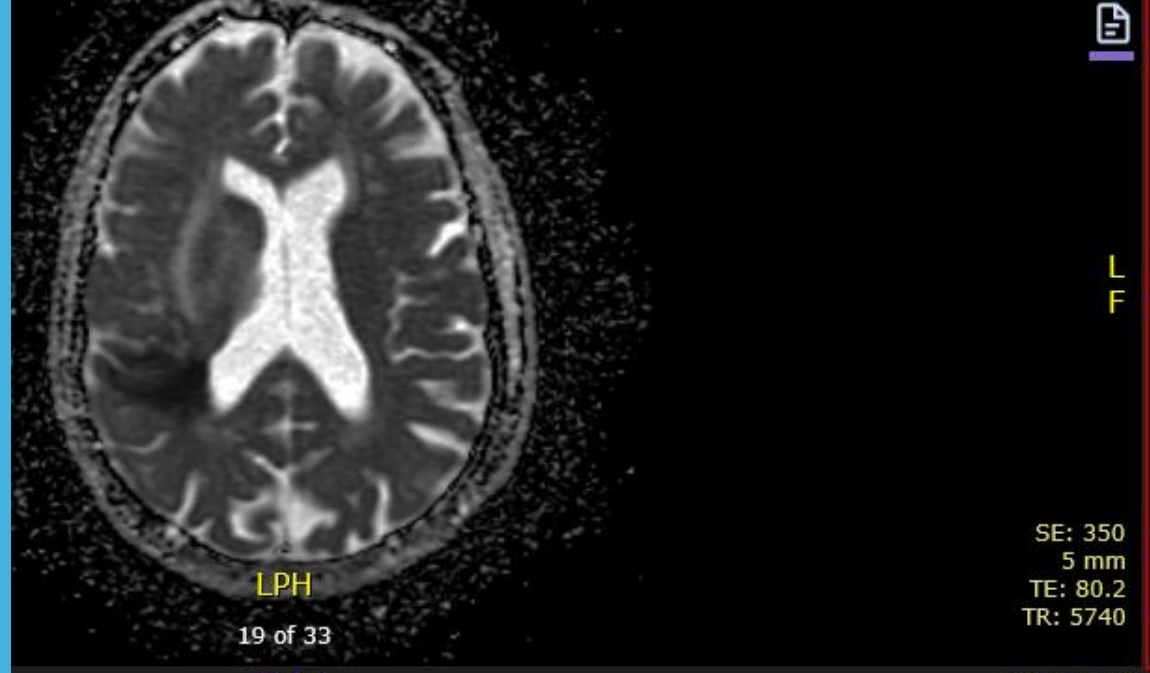
Post op Imaging
Spectral CT

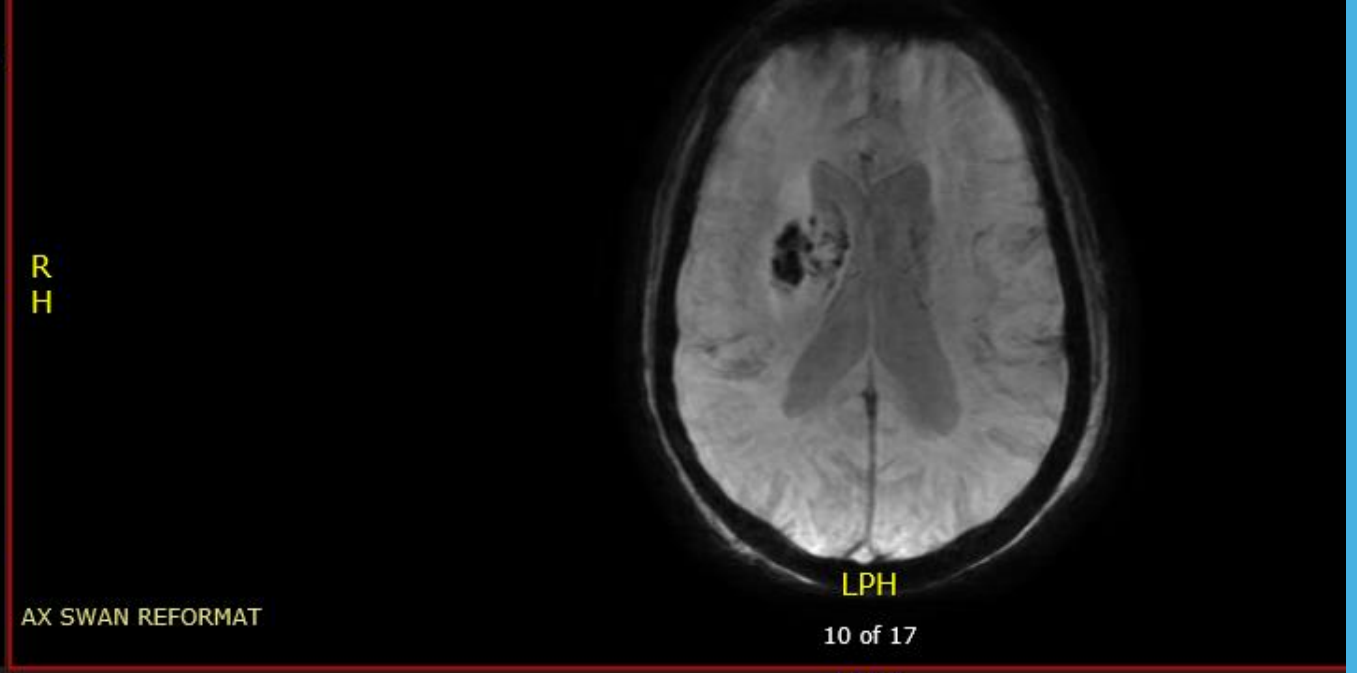

11:50 AM
A
R
H
L
F
P
SE: 201
5 mm
-83.35
AXIAL ST, iDose (1) UNL1EDCT2
15 of 36

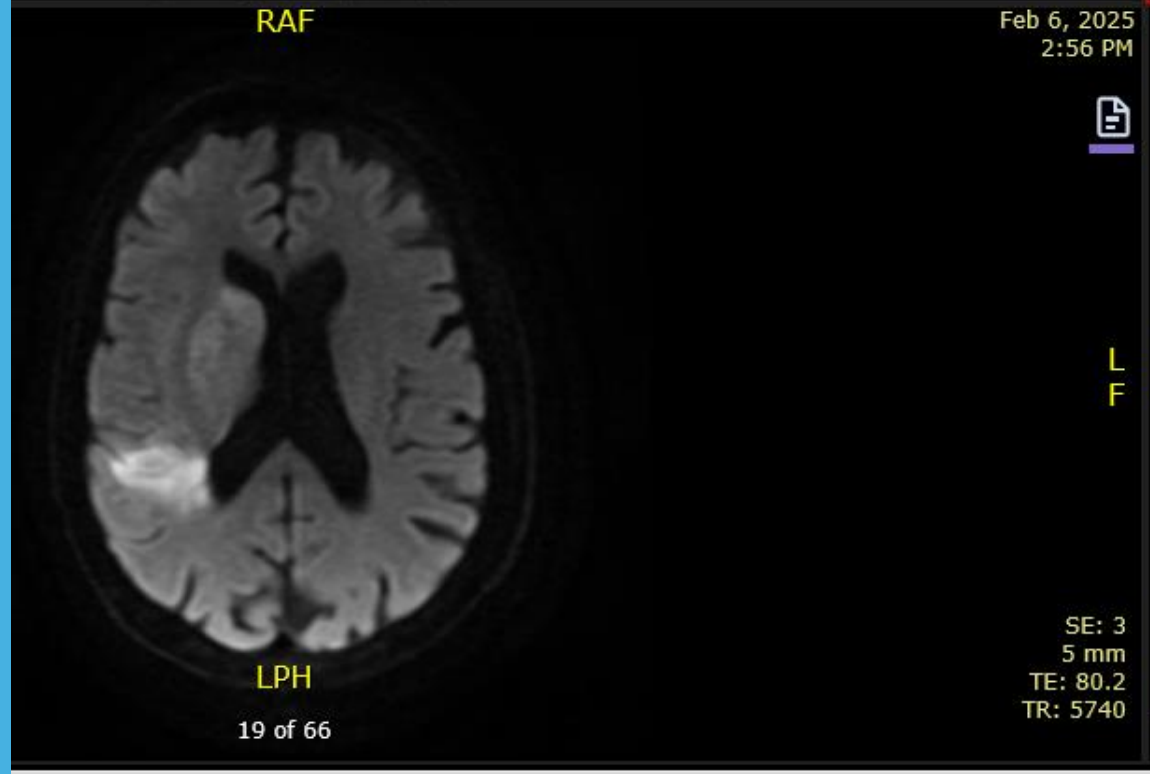

11:50 AM
HL
R
H
FR
SE: 202
3 mm
COR, iDose (1) UNL1EDCT2
33 of 78

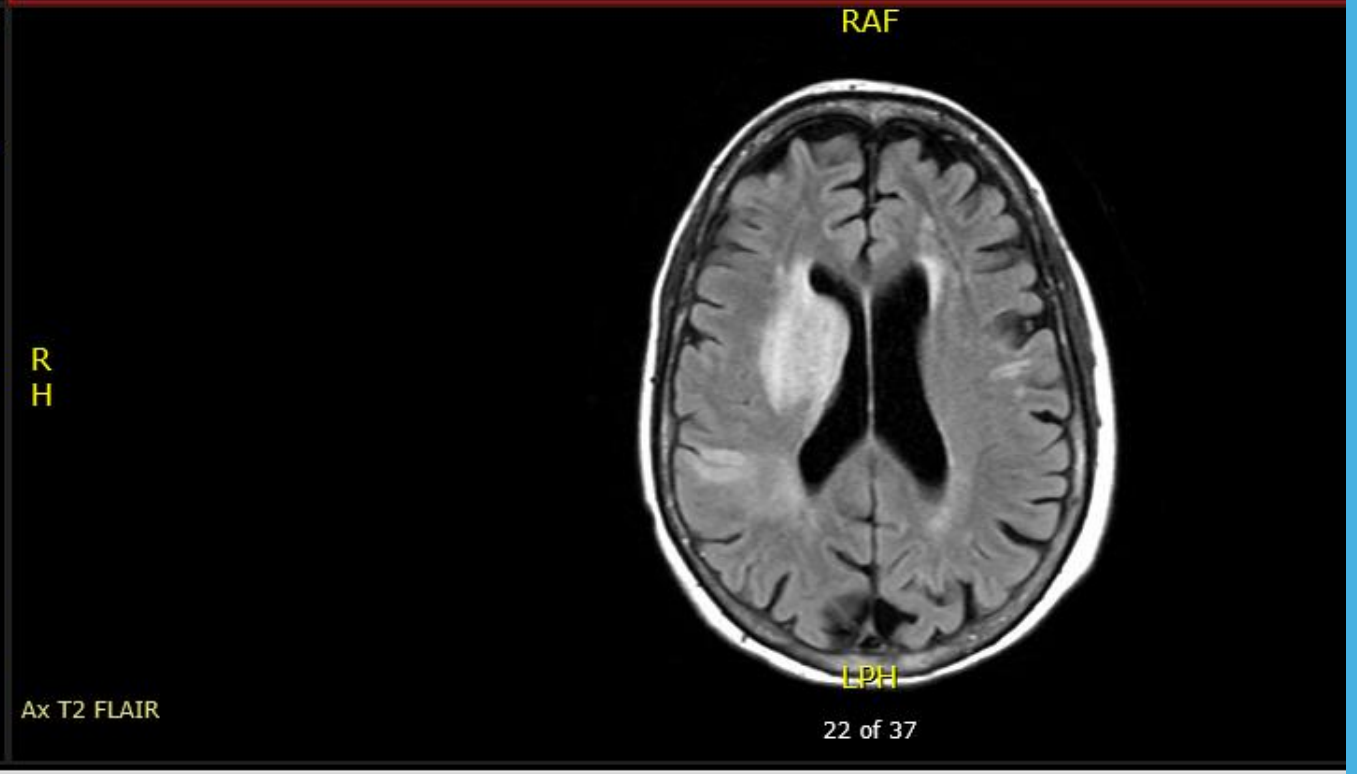

Feb 5, 2025
11:50 AM
A
R
H
L
F
P
SE: 206
3 mm
-85.35
VNC [HU*] , Spectral (1) UNL1EDCT2
24 of 60


Feb 5, 2025
11:50 AM
HL
A
FR
SE: 203
3 mm
SAG, iDose (1) UNL1EDCT2

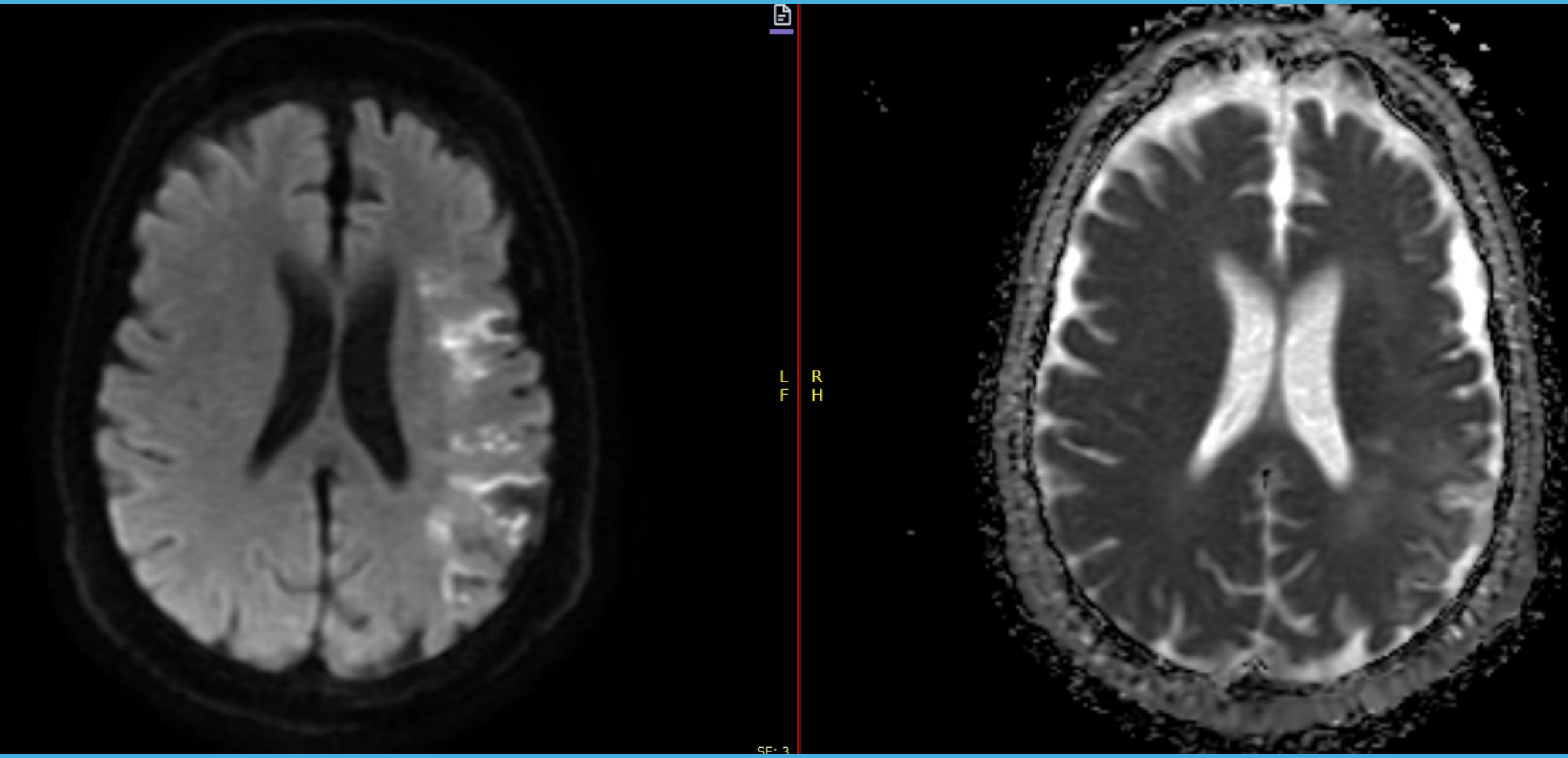

L
F
SE: 350
5 mm
TE: 80.2
TR: 5740
LPH
19 of 33
RAF

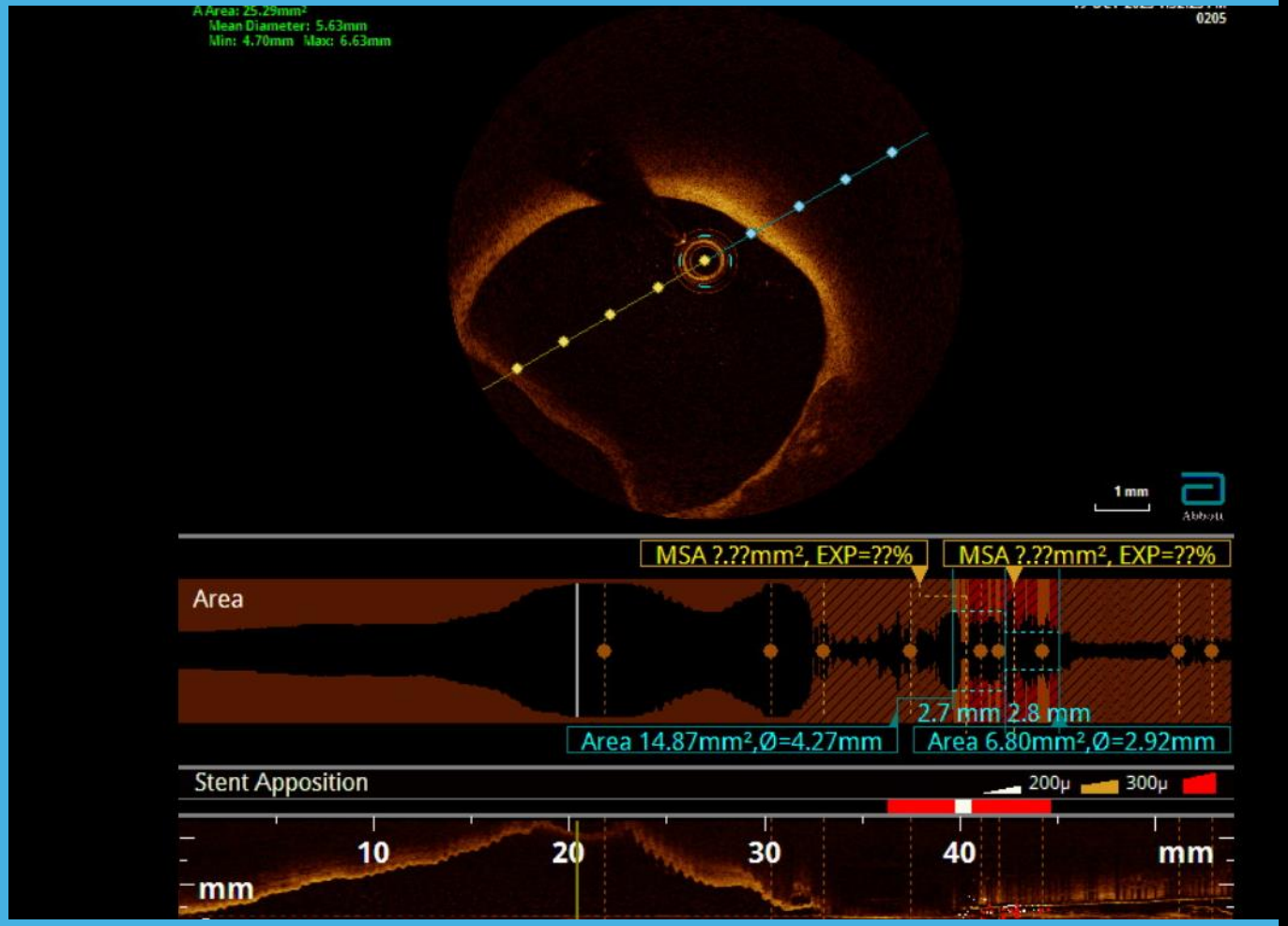

R
H
AX SWAN REFORMAT
LPH
10 of 17
RAF

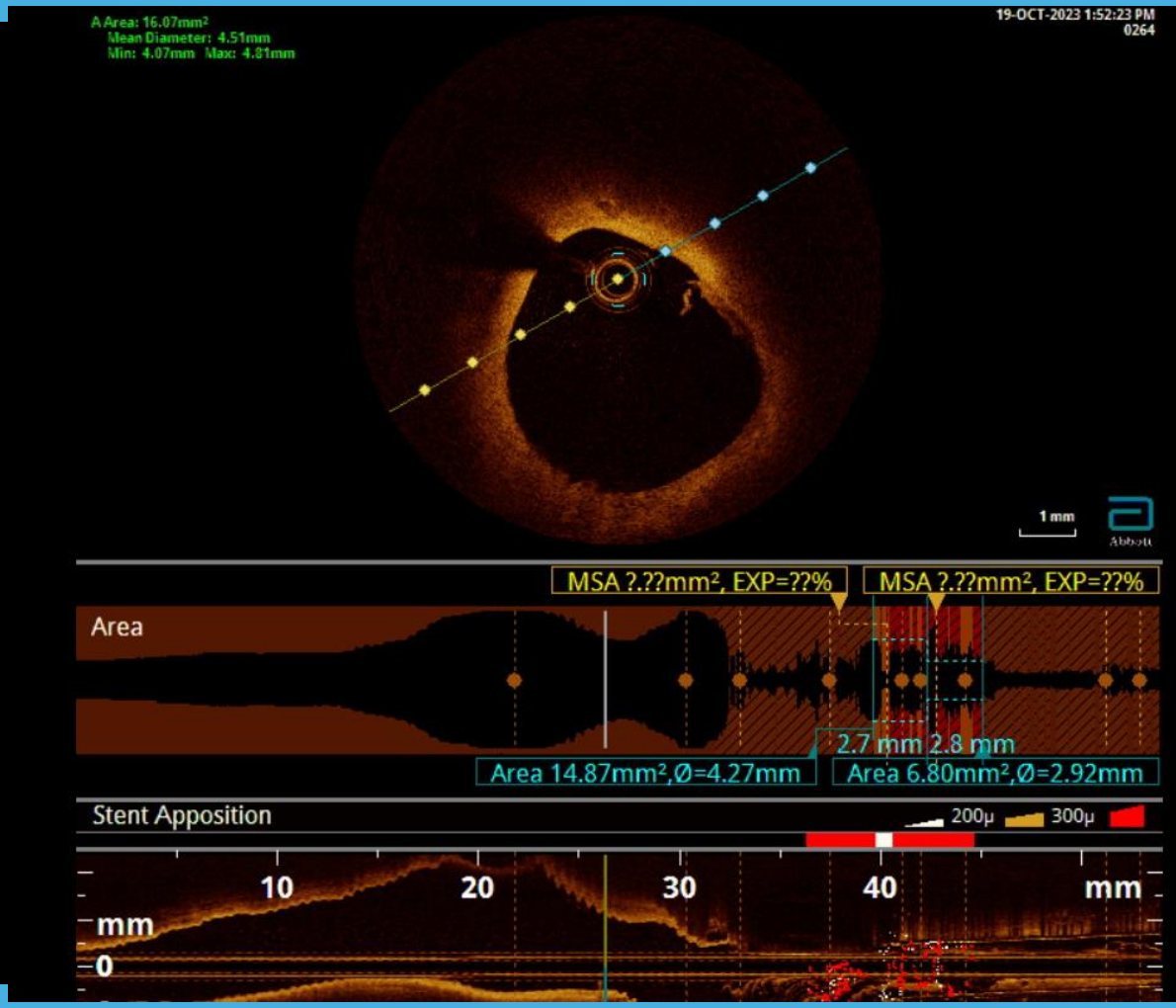

Feb 6, 2025
2:56 PM
L
F
SE: 3
5 mm
TE: 80.2
TR: 5740
LPH
19 of 66

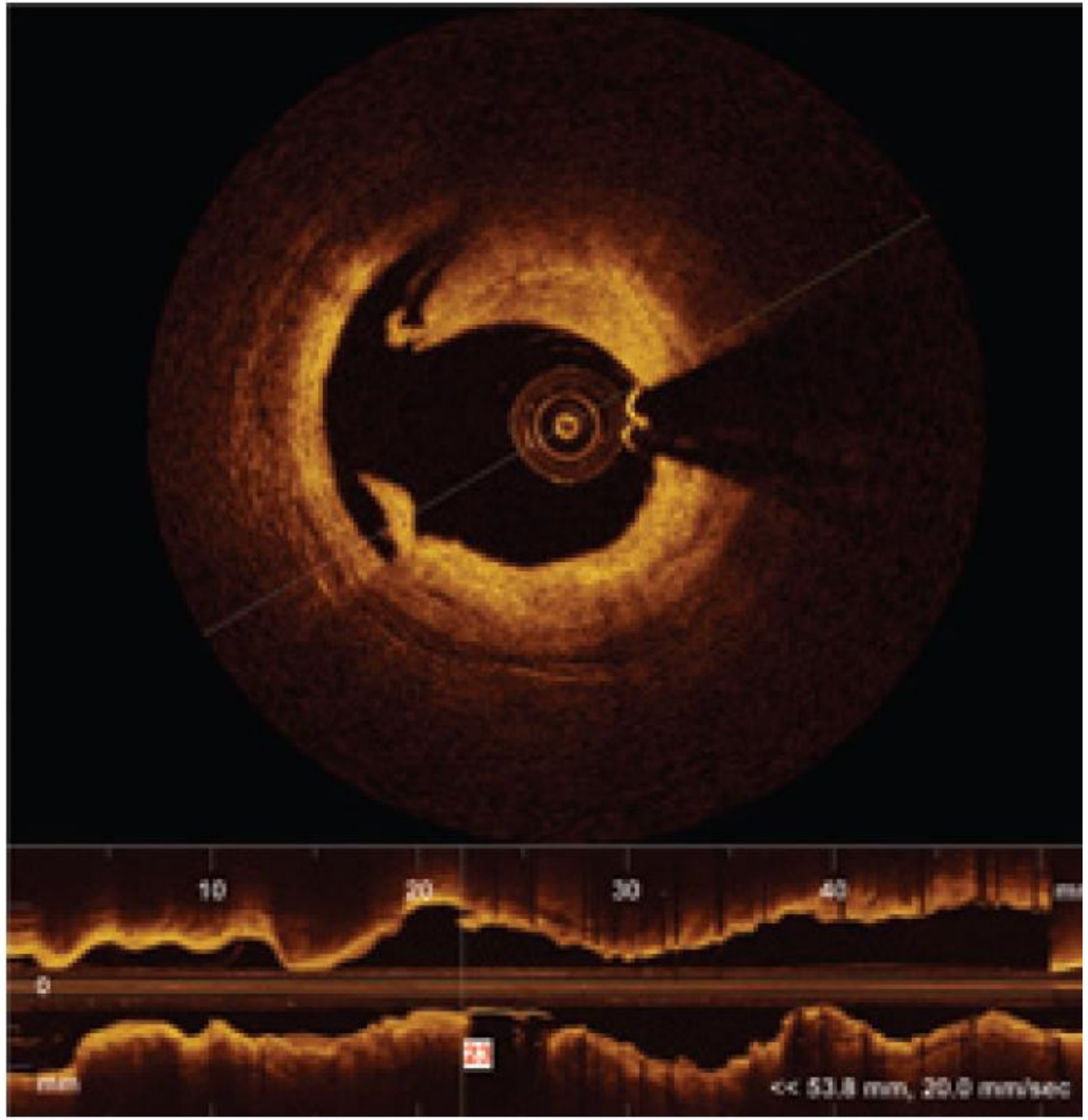

R
H
Ax T2 FLAIR
LPH
22 of 37


1:05 PM

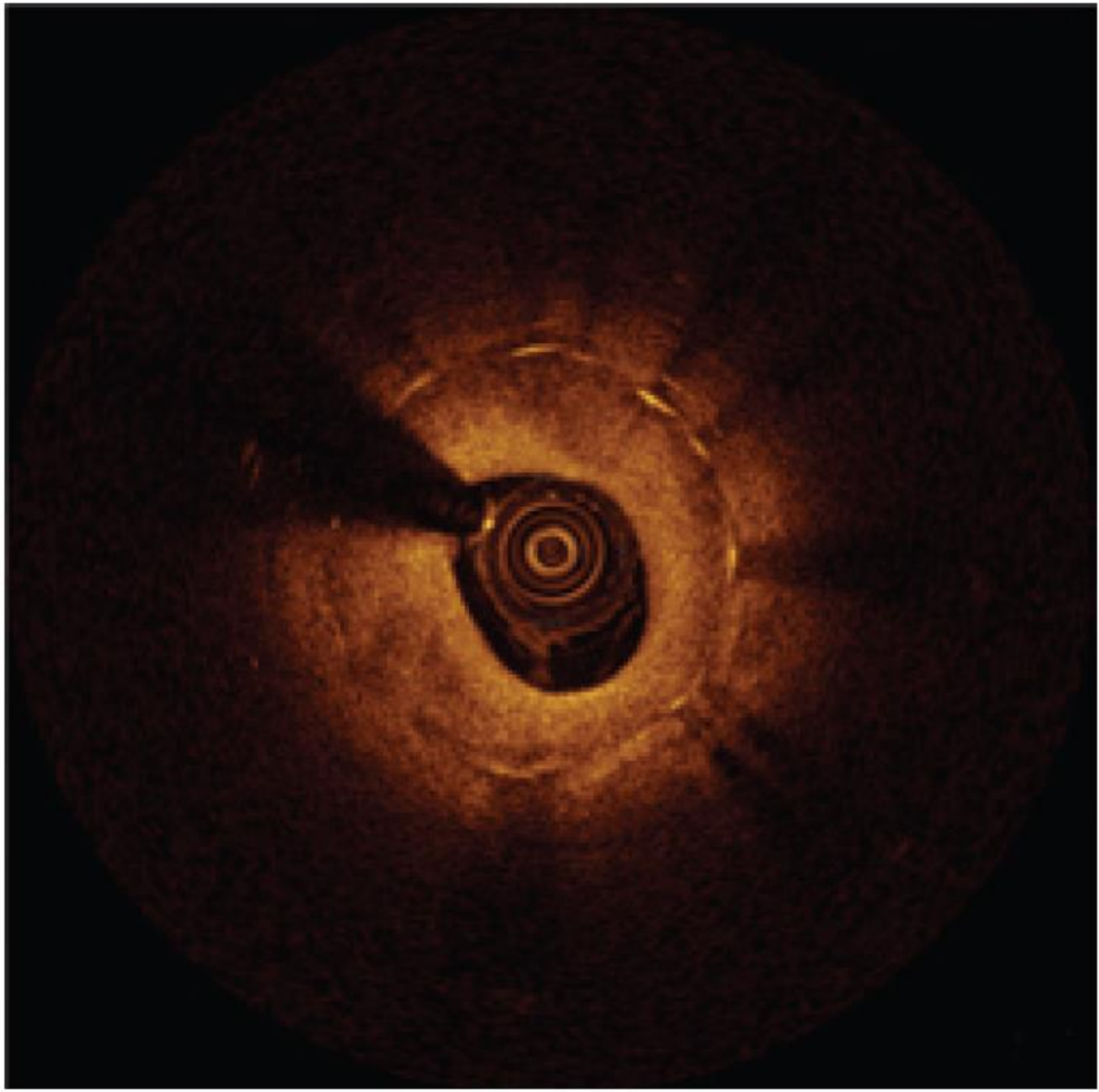

L
F
R
H


A Area: 25.29mm²
Mean Diameter: 5.63mm
Min: 4.70mm Max: 6.63mm
0205
1 mm
MSA ?.??mm², EXP=??%
MSA ?.??mm², EXP=??%
Area
2.7 mm 2.8 mm
Area 14.87mm²,Ø=4.27mm
Area 6.80mm²,Ø=2.92mm
Stent Apposition
200µ
300µ
10
20
30
40
mm
mm

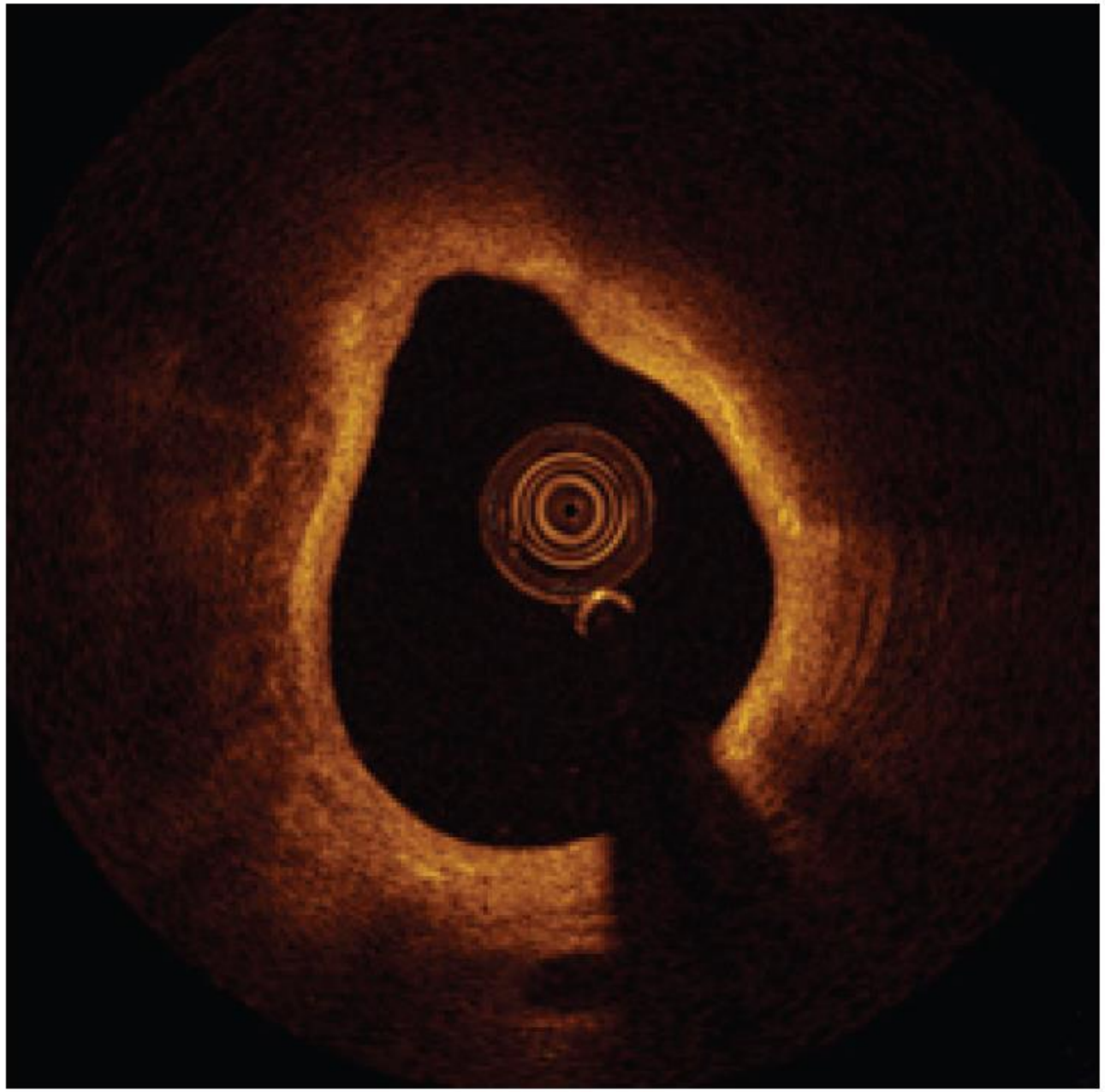

A Area: 16.07mm²
Mean Diameter: 4.51mm
Min: 4.07mm Max: 4.81mm
19-OCT-2023 1:52:23 PM
0264
1 mm
MSA ?.??mm², EXP=??%
MSA ?.??mm², EXP=??%
Area
2.7 mm 2.8 mm
Area 14.87mm²,Ø=4.27mm
Area 6.80mm²,Ø=2.92mm
Stent Apposition
200µ
300µ
10
20
30
40
mm
mm
0



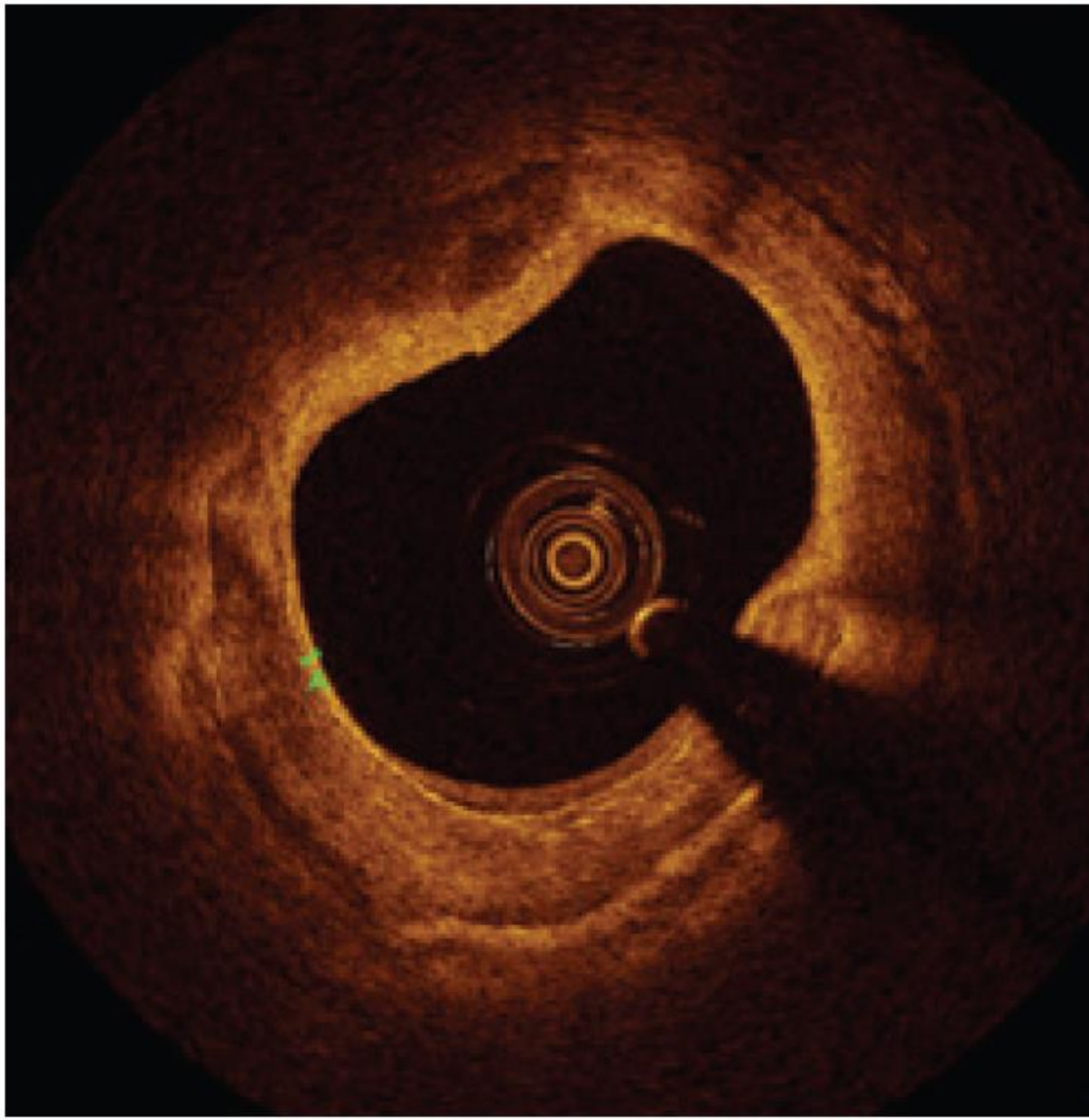
Two, edge dissections



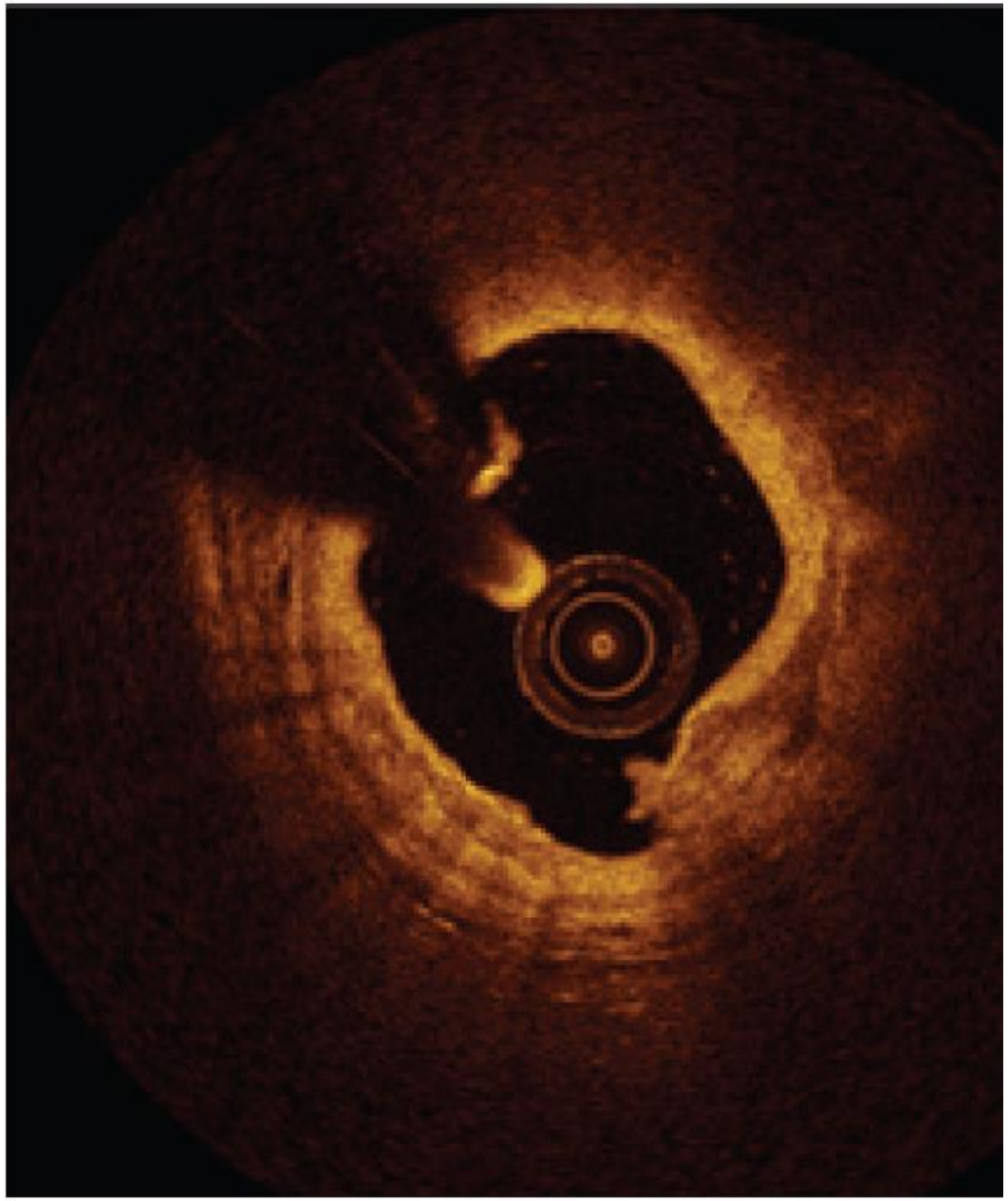
In-stent restenosis



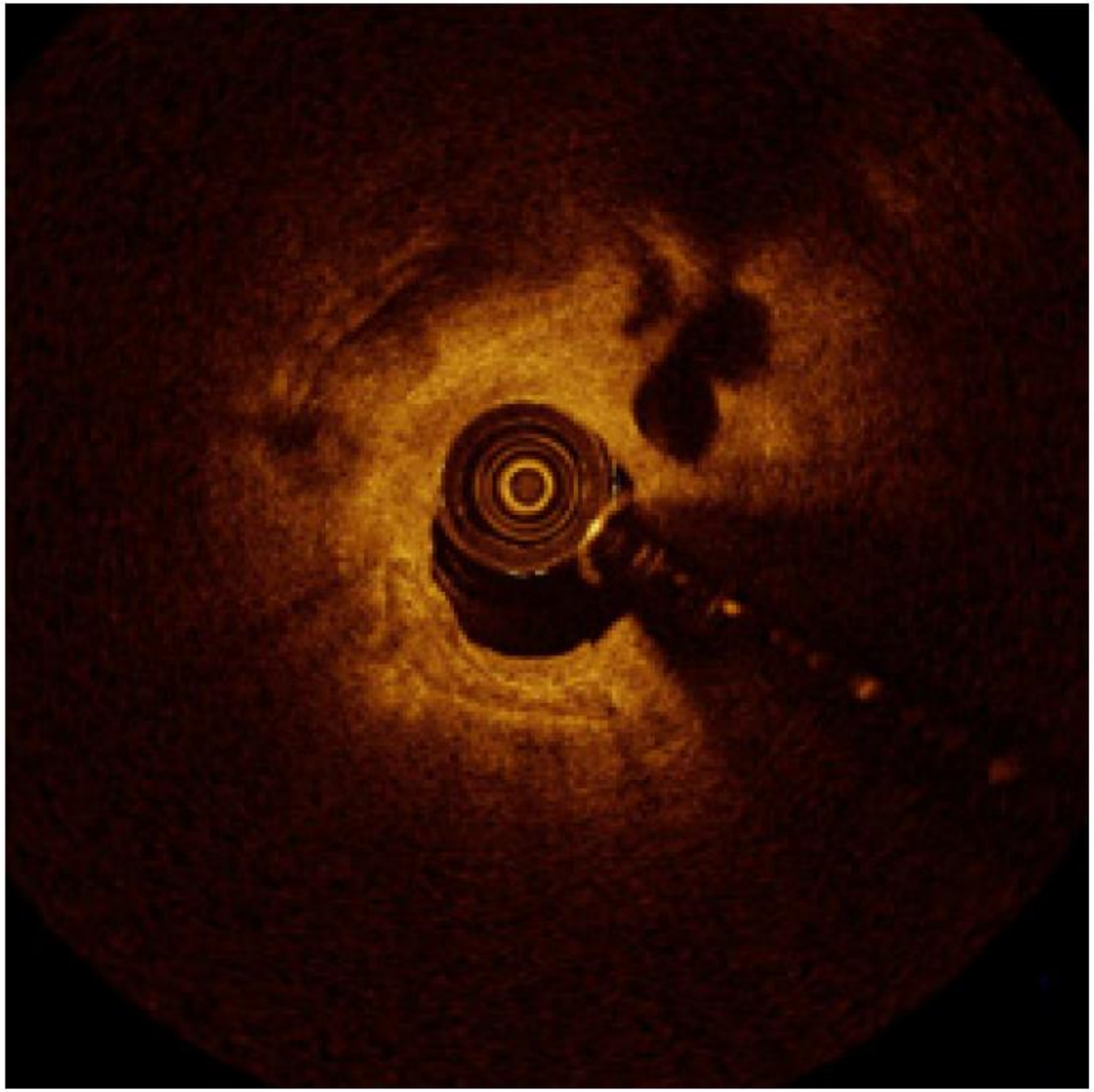
Calcium on left, lipid on right



Circumfrential calcium



Thin cap rupture



Tight stenosis with two calcium nodules and sidebranch

Role of AI

Commercially available software platforms and their applications

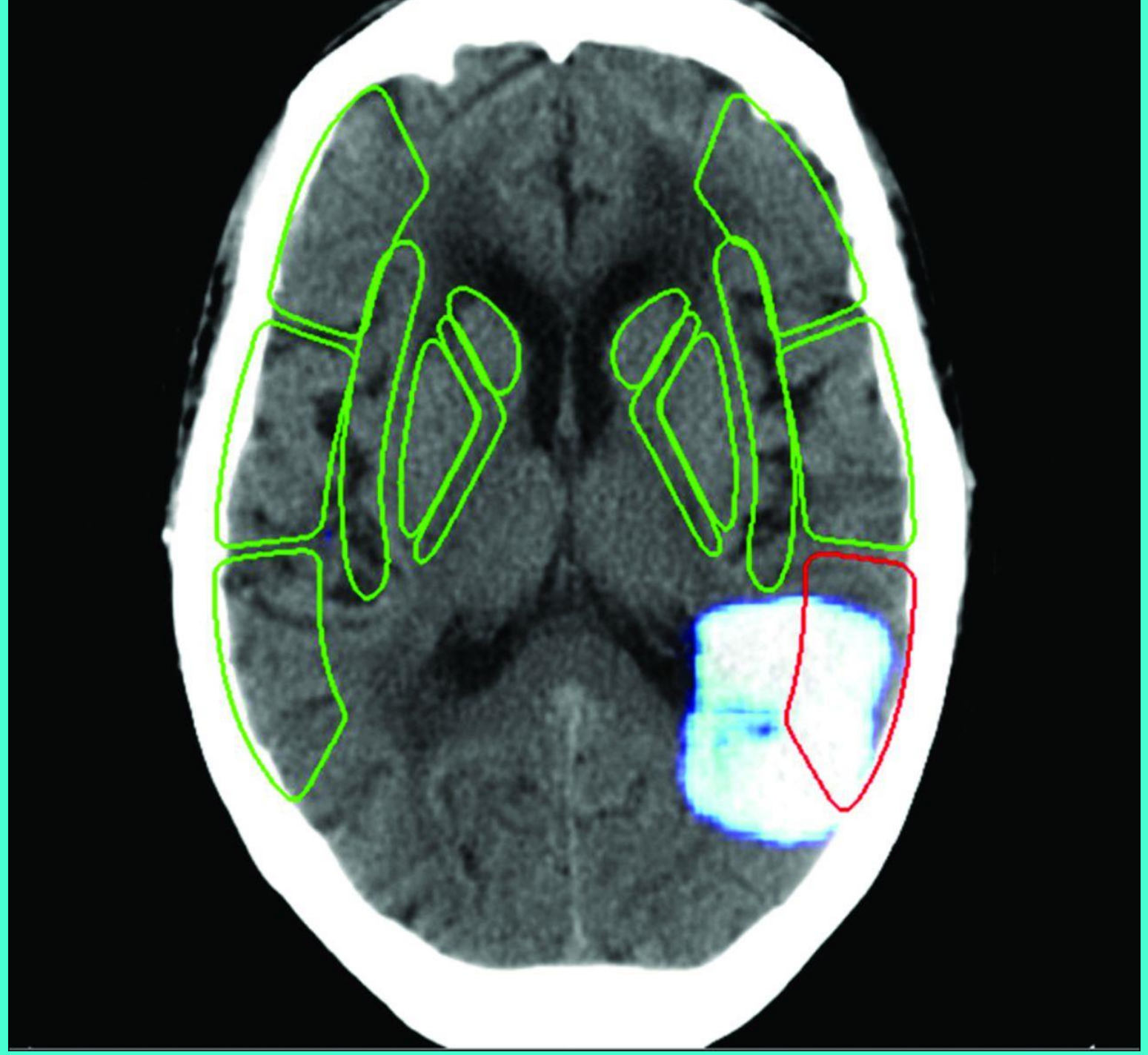
Software	Applications	Machine Learning Algorithm	Imaging Technique
Aidoc	ICH: identifies ICH, triage, and notification	DL	CT
	LVO: identifies LVO, triage, and notification	DL	CTA
	CTP: orchestration of third-party perfusion results	Other	CTP
Avicenna.AI	CINA ICH: identifies ICH, triage, and notification	DL	CT
	CINA LVO: identifies LVO, triage, and notification	DL	CTA
	CINA ASPECTS: ASPECTS scoring; provides heat map	DL	CT
Brainomix	e-Blood: identifies and quantifies ICH volume with mask overlay	DL	CT
	e-ASPECTS: identifies ASPECTS, voxelwise map of early ischemic change, and core infarct volume	Predominantly ML	CT
	e-CTA: identifies and notifies LVO, collateral score, and collateral vessel attenuation; voxelwise map of collateral deficit	Combination of DL and traditional ML	CTA
	e-ASPECTS HDVS: identifies and measures hyperattenuated vessel	DL	CT
	e-Mismatch: identifies mismatch on CTP and MR imaging	Deconvolution	CTP, MR imaging, MRP
RapidAI	Rapid ICH: identifies and classifies ICH	DL	CT
	Rapid ASPECTS: identifies ASPECTS, measurement, and scoring	RF	CT
	Rapid CTA: identifies and notifies LVO and collateral vessel attenuation	Other	CTA
	Rapid CTP: identifies mismatch on CTP, collateral maps, and scoring	Other	CTP
	Rapid MR: identifies mismatch on MR, collateral maps, and scoring	Other	MR imaging, MRP
Viz.ai	Viz ICH: identifies and triages ICH	DL	CT
	Viz LVO: identifies and triages LVO	DL	CTA
	Viz CTP: automated perfusion color maps and calculations	DL	CTP

Note:—HDVS indicates hyperattenuated vessel sign.

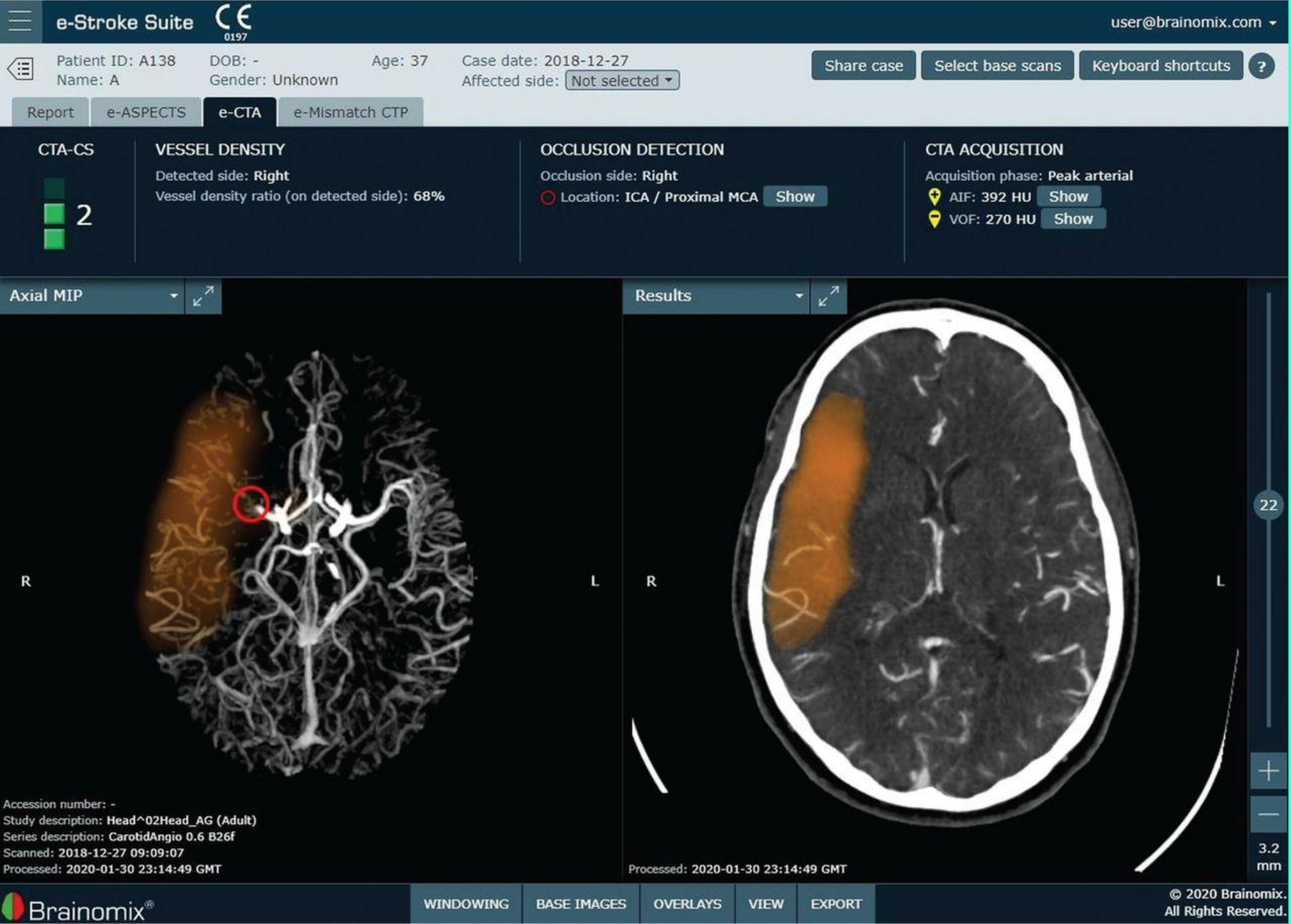
[a] Some, but not all, of these products have FDA, European, and/or worldwide regulatory clearance at the time of publication.

Aidoc stroke triage mobile interface.

J.E. Soun et al. AJNR Am J Neuroradiol 2021;42:2-11



Avicenna.AI DL-based ASPECTS tool demonstrating identification of ASPECTS and a heat map overlay (white). *Image courtesy of Avicenna.AI*.



Brainomix e-CTA tool demonstrating identification and localization of an LVO of the right MCA, collateral score and collateral vessel attenuation, and a heat map of the collateral deficit (orange). Images courtesy of Brainomix.

Thanks