UMC Utrecht

Perfusie CT bij een herseninfarct: de dagelijkse praktijk

Jan Willem Dankbaar

- No disclosures

Background ischemic stroke

- Acute ischemic stroke is serious business causing death and disability

Imaging based treatment selection

- 80% of stroke centers use CT:
  - NCCT
  - CTP
  - CTA

Int J Stroke. 2015 Jul;10(5):759-62. doi: 10.1111/ijs.12491. Epub 2015 Apr 2

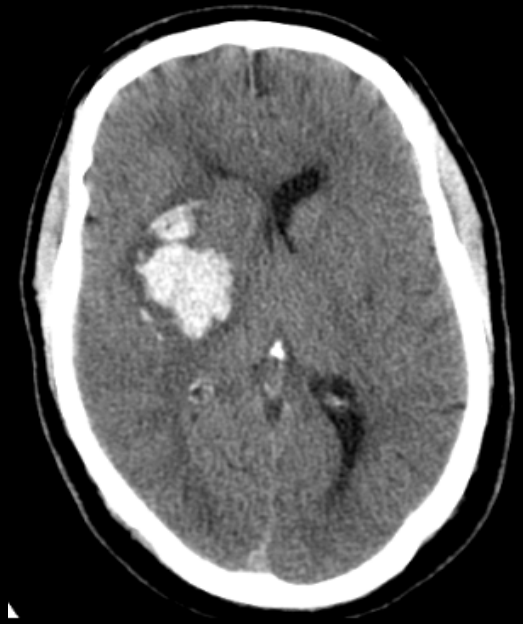
Imaging based treatment selection

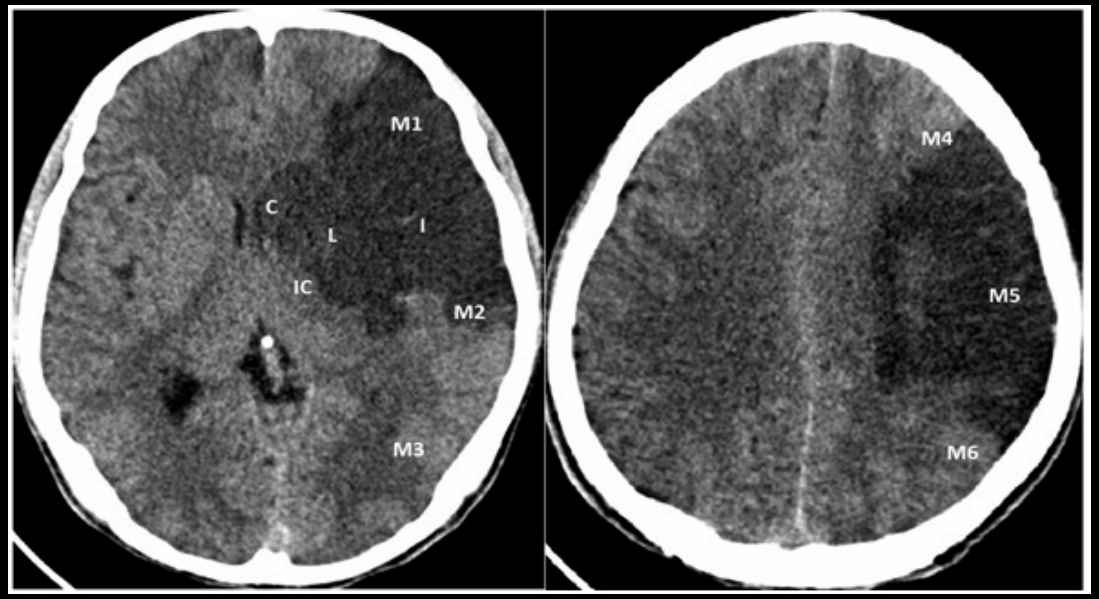
- IV rtPA <4.5 hours→ only NCCT

NCCT

- Rule out hemorrhage and other causes of symptoms
- Identify early ischemic changes (ASPECTS)

NCCT

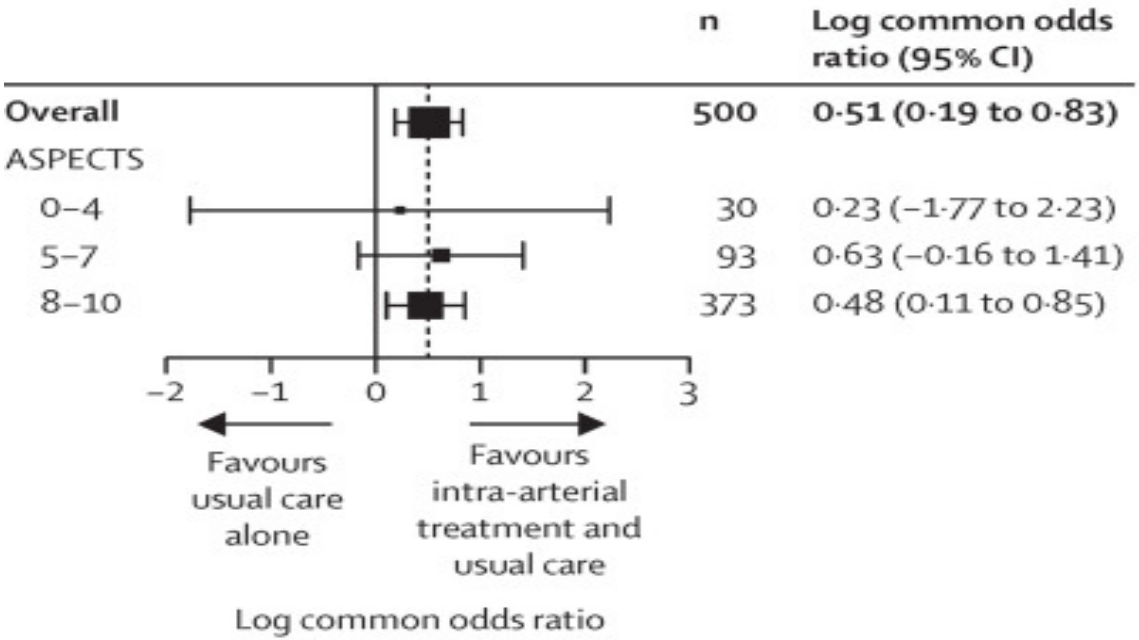




ASPECTS

Effect of baseline Alberta Stroke Program Early CT Score on safety and efficacy of intra-arterial treatment: a subgroup analysis of a randomised phase 3 trial (MR CLEAN)

A



Albert J. Yoo et al. Lancet Neurology 2016: http://dx.doi.org/10.1016/S1474-4422(16)00124-1

NCCT

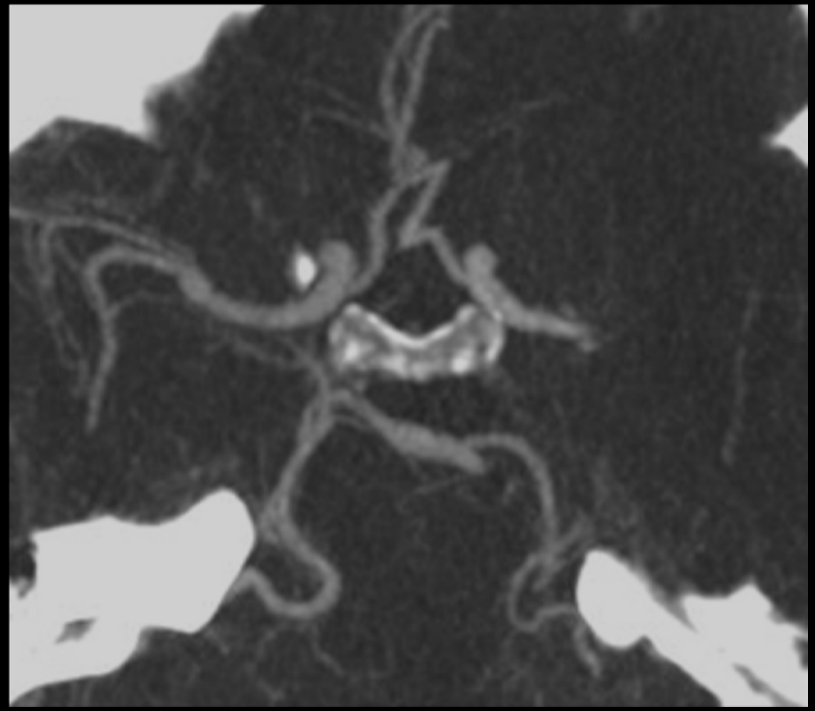
- Low ASPECTS → Large infarct core

CTA

- Occlusion site
- Collaterals
- Treatment plan
- Cause of stroke

Trial	NIHSS	Age	Timing	Occlusion	Additional exclusion criteria	Control arm	Intervention arm
MR CLEAN	≥2	>18	6h	Distal ICA-M2 and A2		Standard ± IV rtPA	IA thrombo-lysis or thromb-ectomy ± IV rtPA
ESCAPE	>5	>18	12h	At least M1;	ASPECTS<6; Poor collaterals	"	Stent retreiver
SWIFT PRIME	8-30	>18	6h	Distal ICA/M1	Hypodensity >1/3 MCA; ASPECTS<6	IV rtPA	Stent retreiver
REVASCAT	>5	>18	8h	Distal ICA/M1	ASPECTS<7	Standard ± IV rtPA	Stent retreiver
EXTEND IA	Eligible for IVrtPA	>18	6h	Distal ICA-M2	Hypodensity >1/3 MCA Mismatch ratio >1.2; mismatch volume >10 ml; core <70mL (**p75 = 32 ml**)	IV rtPA	Stent retreiver

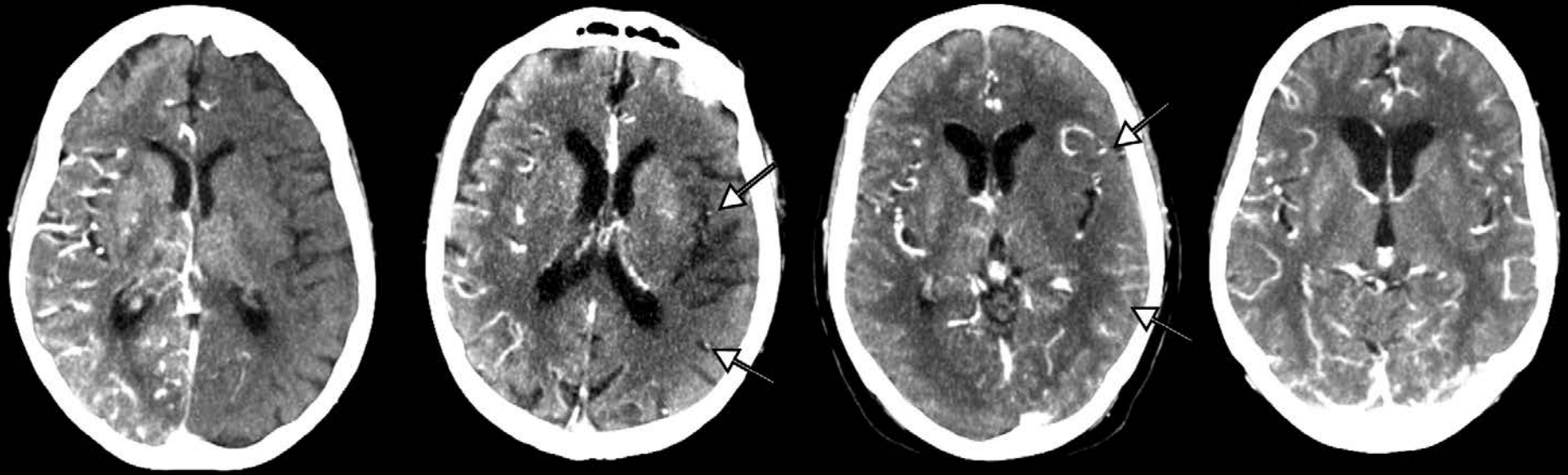
Occlusion site



Collaterals

- CTA
- Multiphase CTA
- 4D CTA

Collaterals



0=absent filling

1=filling<50%

2=filling 50-100%

3=filling 100%

Collaterals

- Poor collaterals → Large infarct core

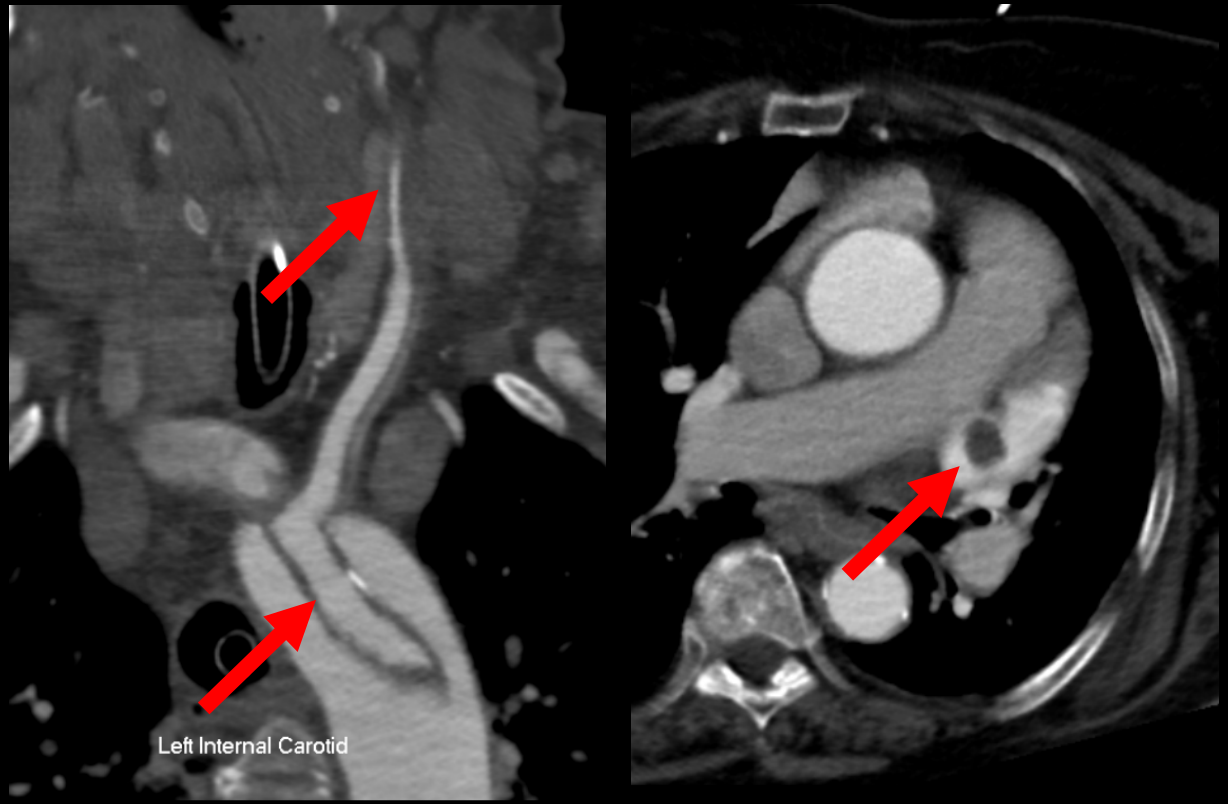
Modified Rankin Scale (mRS) scores at 90 days per collateral grade.

mRS at 90 days	Grade 0	Grade 1	Grade 2	Grade 3
OR (95% CI)	1.0 (0.1 to 8.7)	1.2 (0.7 to 2.3)	1.6 (1 to 2.7)	3.2 (1.7 to 6.2)

American Heart Association.

Olvert A. Berkhemer et al. Stroke. 2016;47:768-776

Treatment plan and cause



Treurniet KM,et al. MR Clean. Stroke. 2016;47:2972-2978.

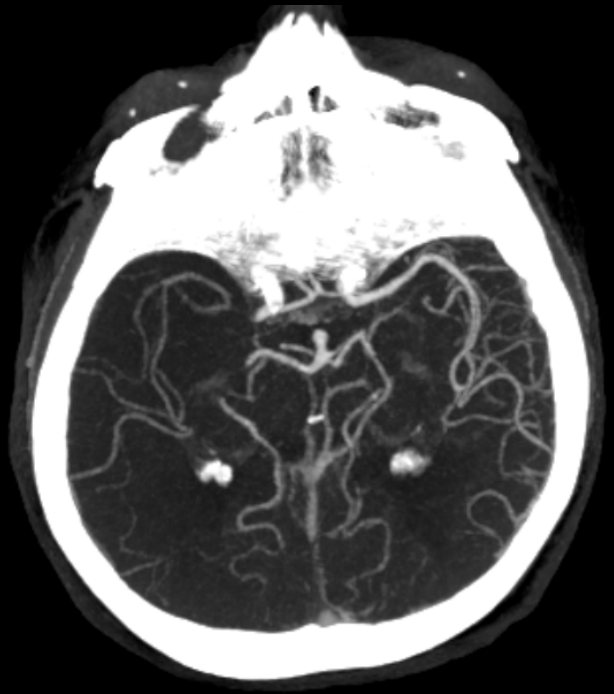
CTP

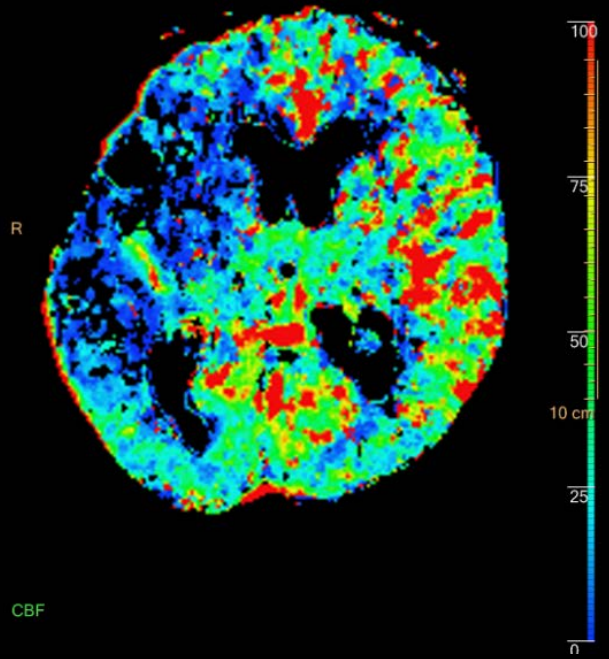
- Why?

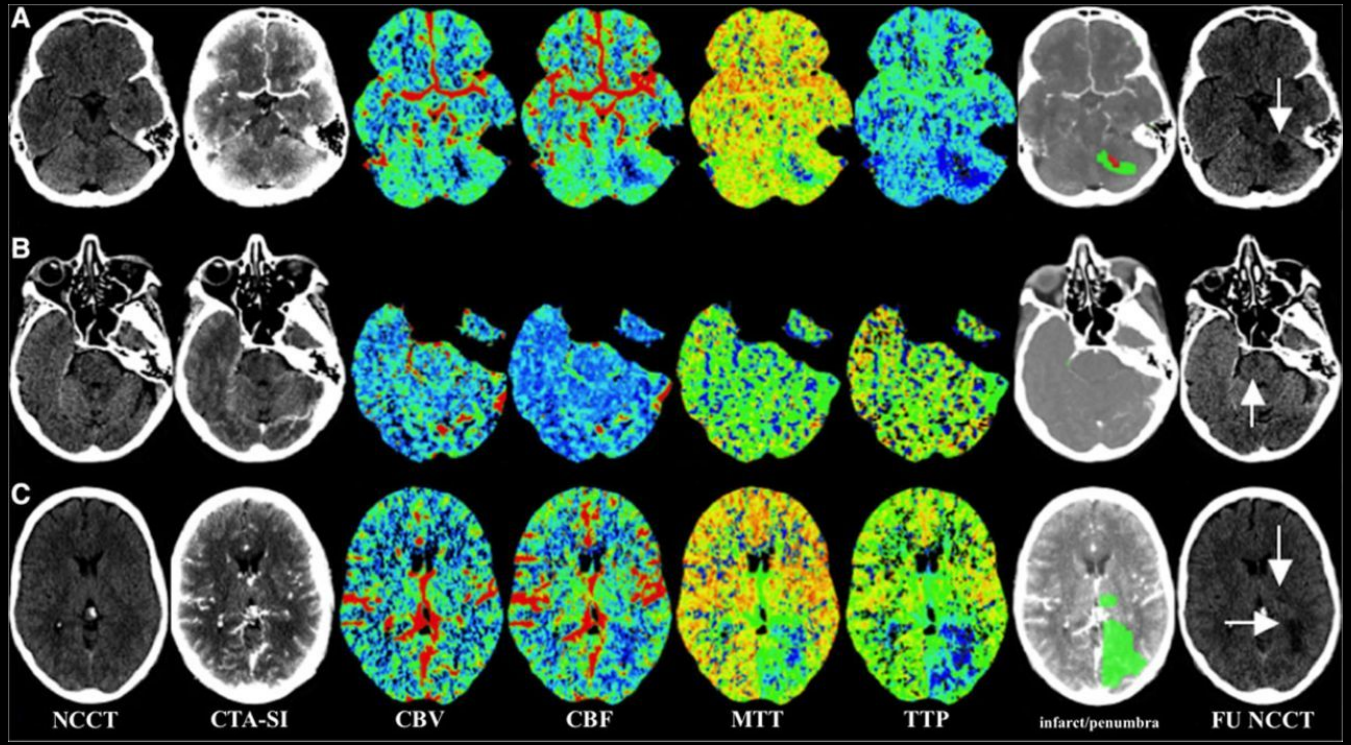
CTP

- Detection
- Treatment selection

CTP

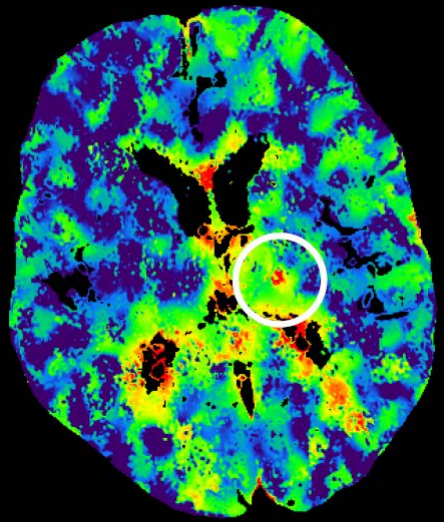


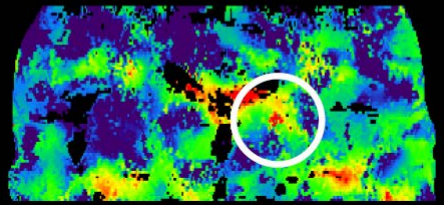




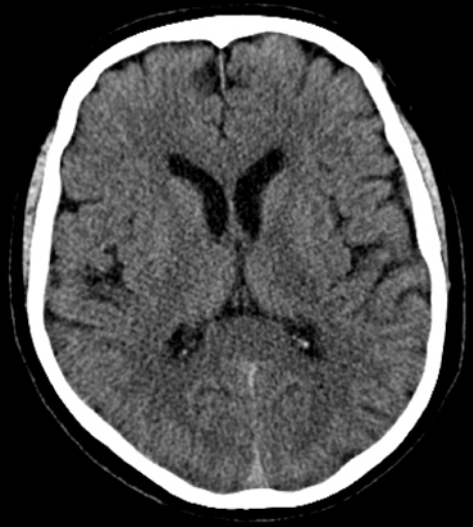
Erik J.R.J. van der Hoeven. Stroke. Additional Diagnostic Value of Computed Tomography Perfusion for Detection of Acute Ischemic Stroke in the Posterior Circulation, Volume: 46, Issue: 4, Pages: 1113-1115, DOI: (10.1161/STROKEAHA.115.008718)

Admission MTT

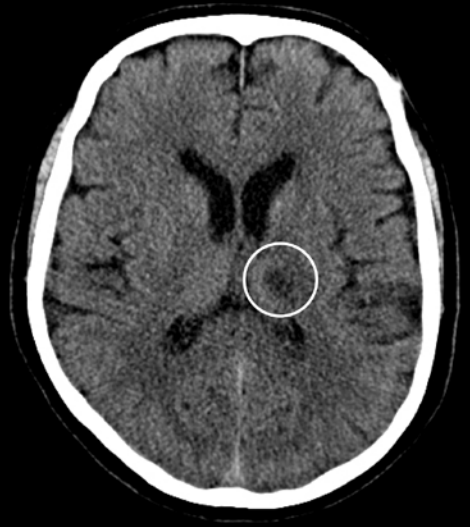




Admission NCCT



Follow-up NCCT



CTP

- Detection
- Treatment selection

Trial	NIHSS	Age	Timing	Occlusion	Additional exclusion criteria	Control arm	Intervention arm
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Imaging based treatment selection

- IV rtPA with unknown onset time
- EVT <24 hours

Thrombolysis Guided by Perfusion Imaging up to 9 Hours after Onset of Stroke (EXTEND)

- Inclusion criteria:
  - ≥18 years
  - NIHSS 4-26
  - CTP (RAPID):
    - Penumbra/infarct core ratio >1.2 (**<45% core**)
    - absolute difference >10ml
    - ischemic-core <70 ml (**p75 = 23 ml**)
  - Not eligible for EVT

H Ma et al. N Engl J Med 2019;380:1795-1803.

Thrombolysis Guided by Perfusion Imaging up to 9 Hours after Onset of Stroke (EXTEND)

- mRs 0-1 higher percentage in alteplase group

- **secondary analysis of mRs distribution → no significant difference in functional improvement**

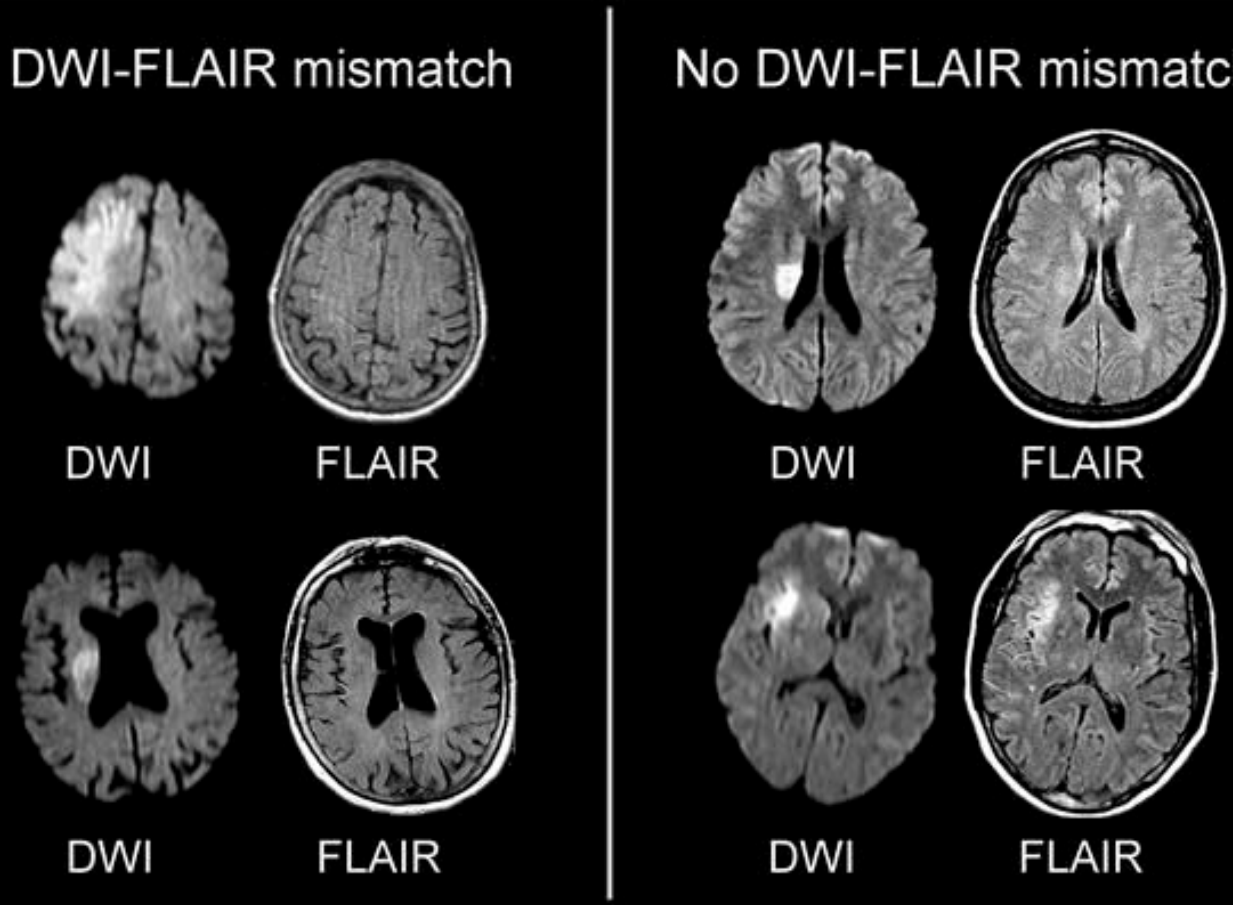
H Ma et al. N Engl J Med 2019;380:1795-1803.

MRI-Guided Thrombolysis for Stroke with Unknown Time of Onset (WAKE-UP)

- Inclusion:
  - time since last known well >4.5 hours (no upper limit)
  - Mismatch abnormal DWI and no signal change on FLAIR
- Exclusion:
  - DWI changes >1/3 MCA.
  - Not eligible for EVT
  - NIHSS >25

G Thomalla et al. N Engl J Med 2018;379:611-622.

- V



Thomalla, G. & Fiehler, J. Curr Radiol Rep (2014) 2: 30. https://doi.org/10.1007/s40134-013-0030-z

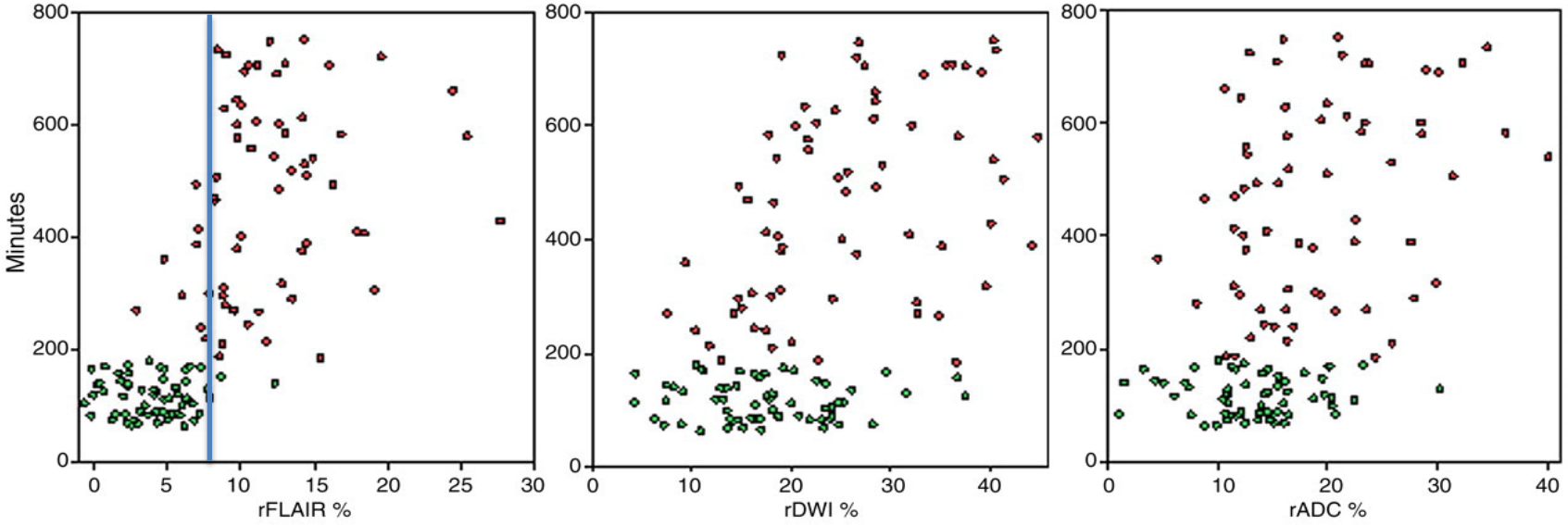
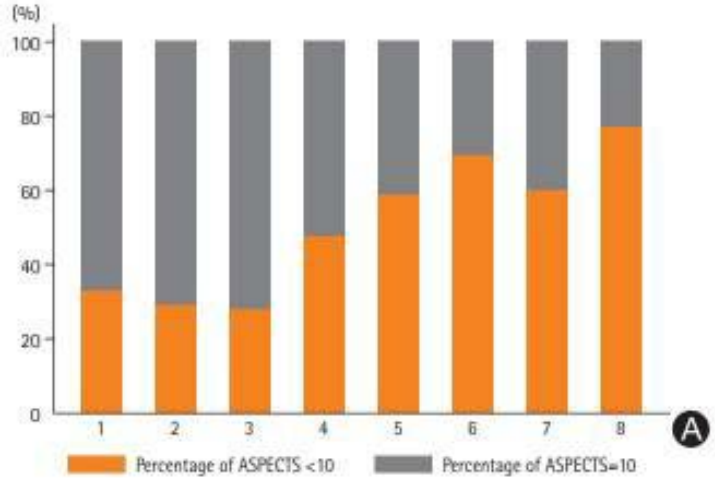
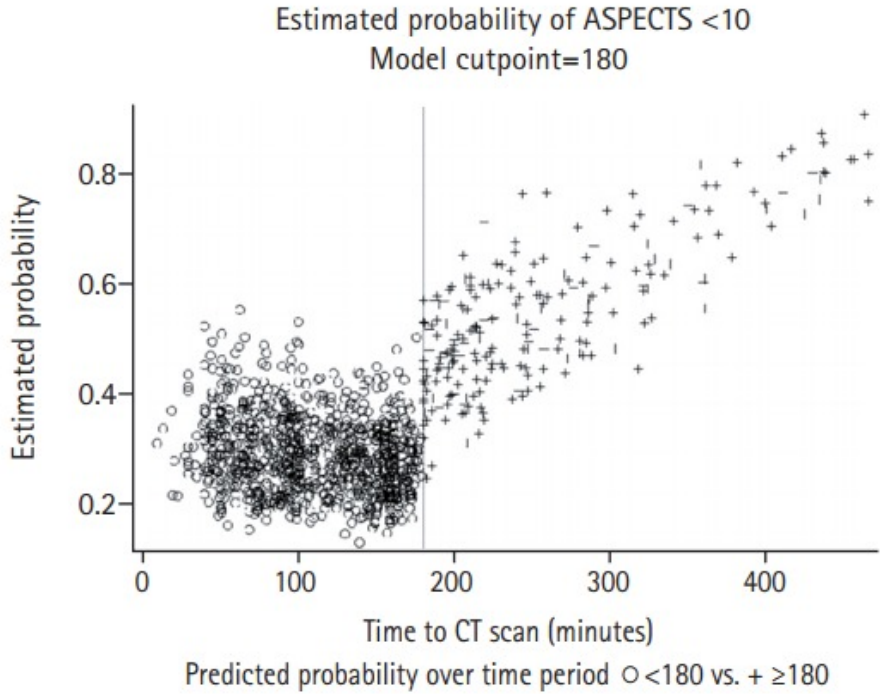


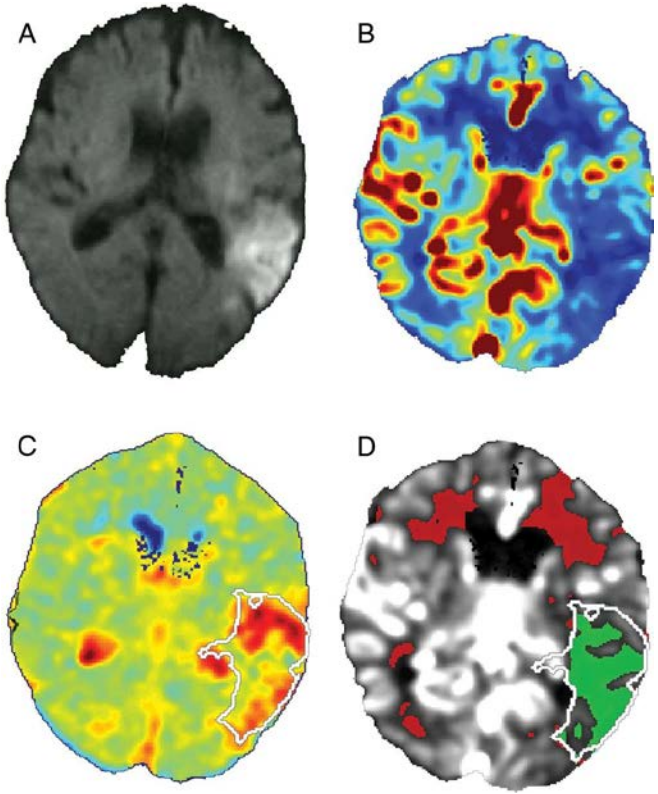
Figure 8: Scatterplots of imaging ratios and time from stroke onset (in minutes). Green symbols represent values for patients imaged 0–3 hours after stroke onset, and red symbols represent values for patients imaged more than 3 hours after stroke onset. *rADC* = ADC ratio, *rDWI* = DW imaging ratio, *rFLAIR* = FLAIR ratio.

https://doi.org/10.1148/radiol.10100461





doi: 10.5853/jos.2016.01424



Bruce C.V. Campbell. Stroke. Comparison of Computed Tomography Perfusion and Magnetic Resonance Imaging Perfusion-Diffusion Mismatch in Ischemic Stroke, Volume: 43, Issue: 10, Pages: 2648-2653, DOI: (10.1161/STROKEAHA.112.660548)

Thrombectomy for Stroke at 6 to 16 Hours with Selection by Perfusion Imaging (DEFUSE 3)

- Inclusion Criteria:
  - Baseline NIHSSS is ≥6
  - Mismatch on CTP or MRI (RAPID):
    - core <70 ml (**p75 = 25 ml**)
    - hypoperfusion/core ratio >1.8 (**<55% core**)
- Exclusion Criteria:
  - **ASPECTS <6**
  - Mass effect with midline shift

GW Albers et al. N Engl J Med 2018;378:708-718.

Thrombectomy 6 to 24 Hours after Stroke with a Mismatch between Deficit and Infarct (DAWN)

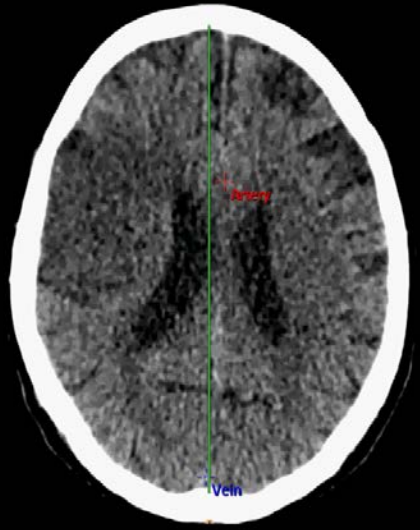
- Inclusion:
  - No evidence of intracranial hemorrhage on CT or MRI
  - **Infarct <1/3 MCA**
  - Mismatch between severity of clinical deficit and infarct volume:
    - Group A: ≥80 years, NIHSS ≥10, infarct volume <21ml
    - Group B: <80 years, NIHSS ≥10, infarct volume <31ml
    - Group C: <80 years, NIHSS ≥20, infarct volume 31- 51 ml.
    - **P75 of baseline infarct core was 16 ml**
  - Infarct volume was assessed with DWI or CTP with RAPID, iSchemaView.

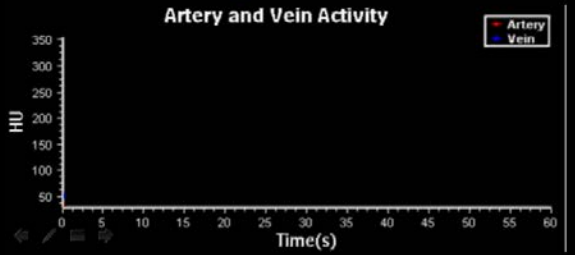
RG Nogueira et al. N Engl J Med 2018;378:11-21.

CTP core volume

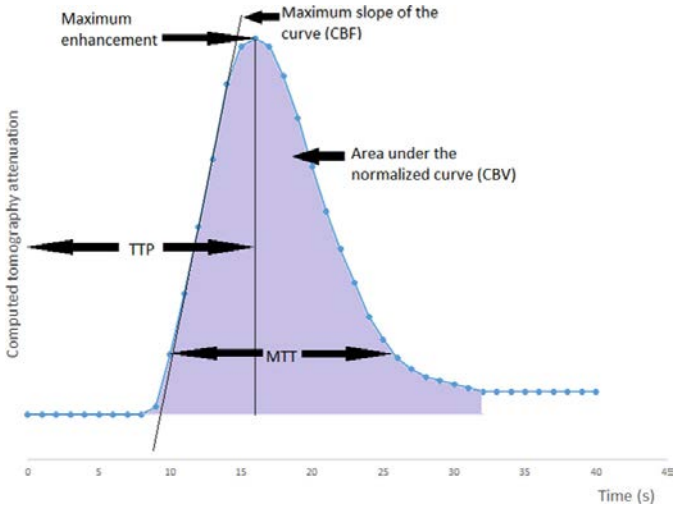
- Scanning parameters
- Filtering
- Algorithm
- Mask
- Thresholds
- Volume assessment (region growth, next neighbor etc.)

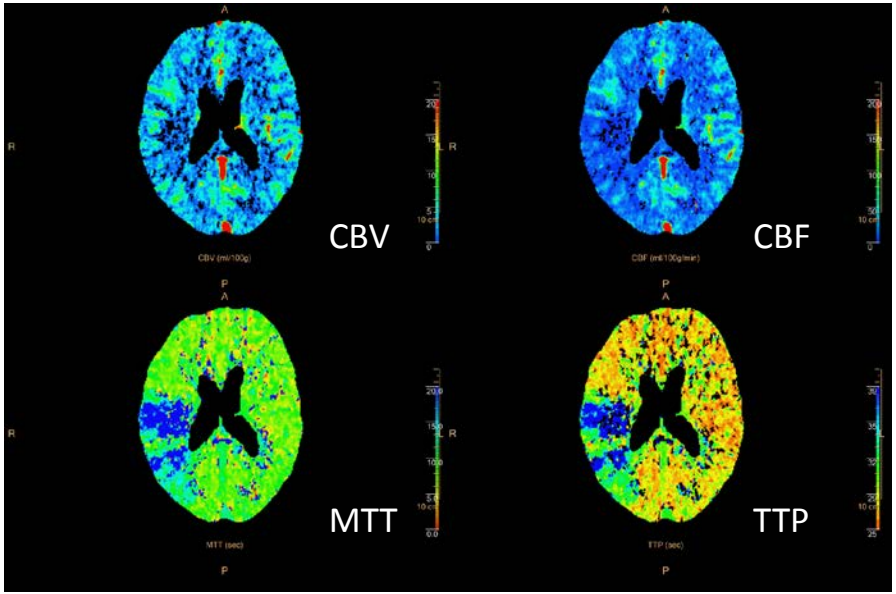
CTP

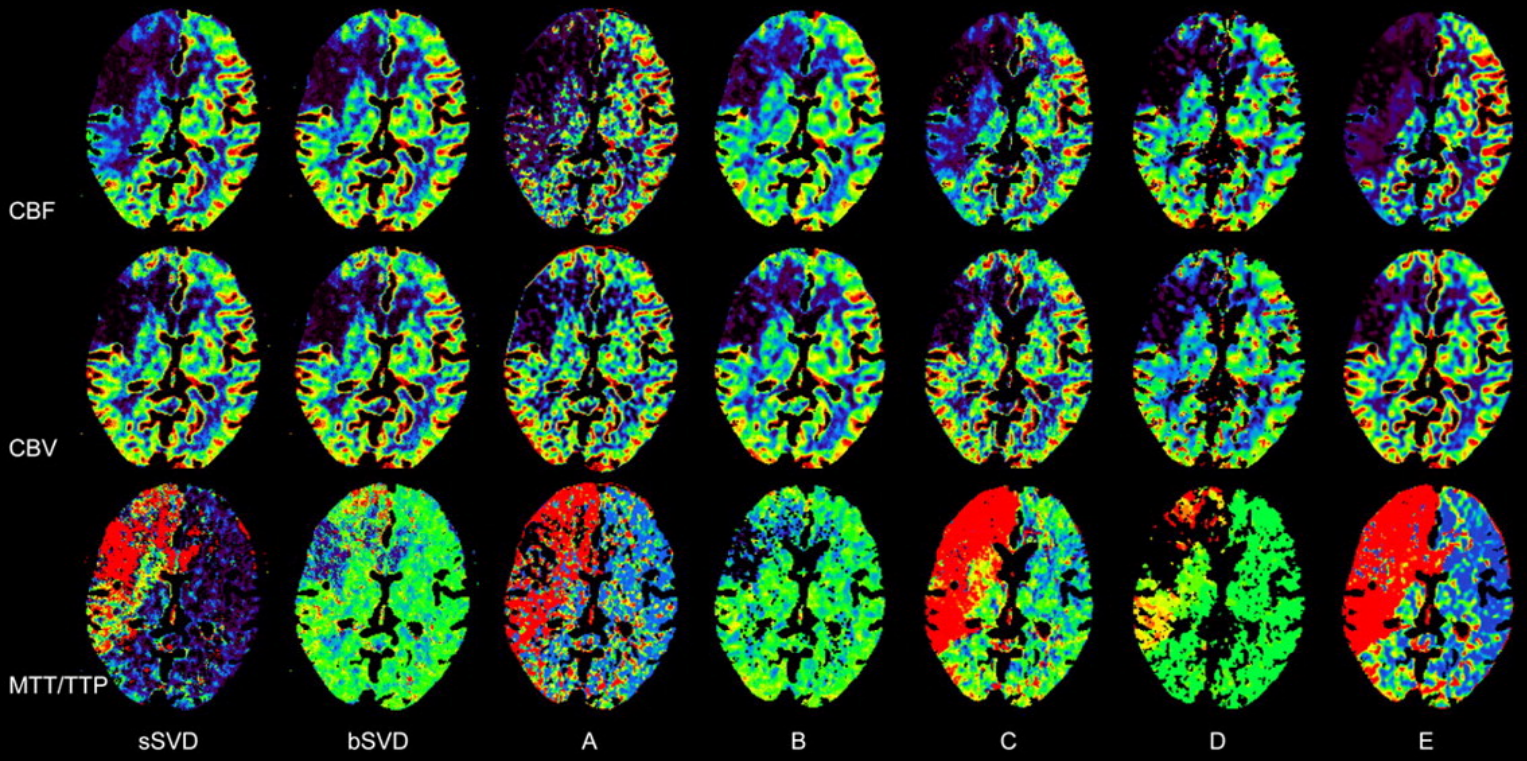

Artery
Vein


Artery and Vein Activity
Artery
Vein
HU
350
300
250
200
150
100
50
0
5
10
15
20
25
30
35
40
45
50
55
60
Time(s)

CTP

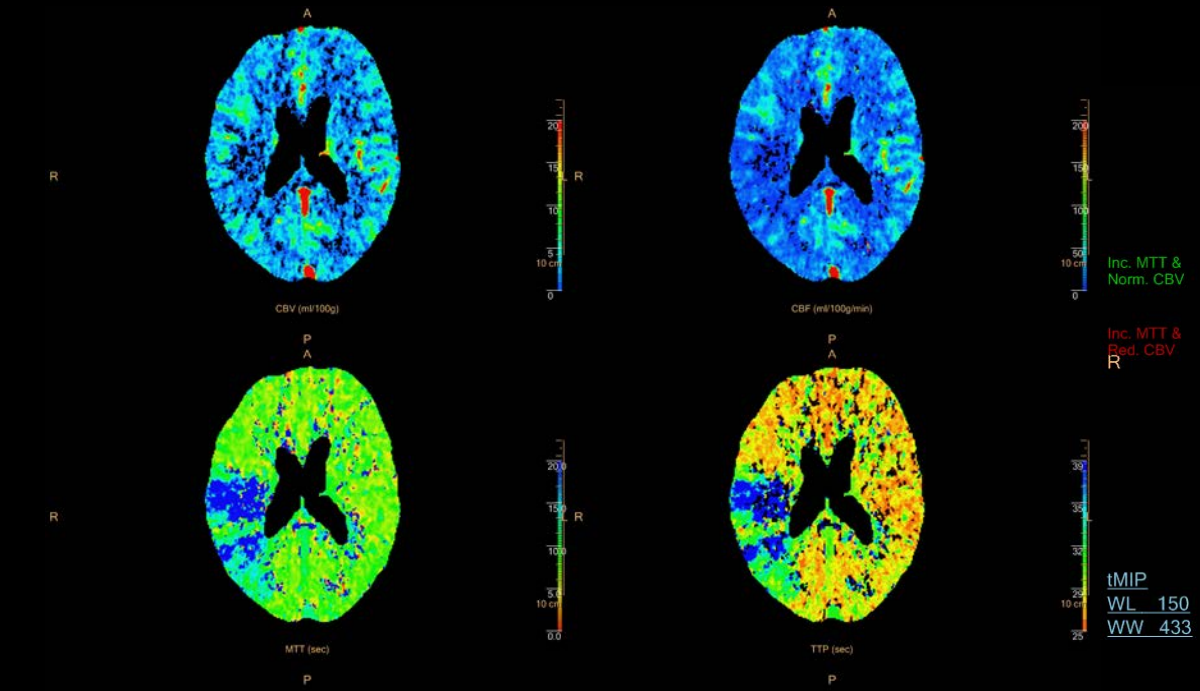

Maximum enhancement
Maximum slope of the curve (CBF)
Area under the normalized curve (CBV)
TTP
MTT
Computed tomography attenuation
Time (s)

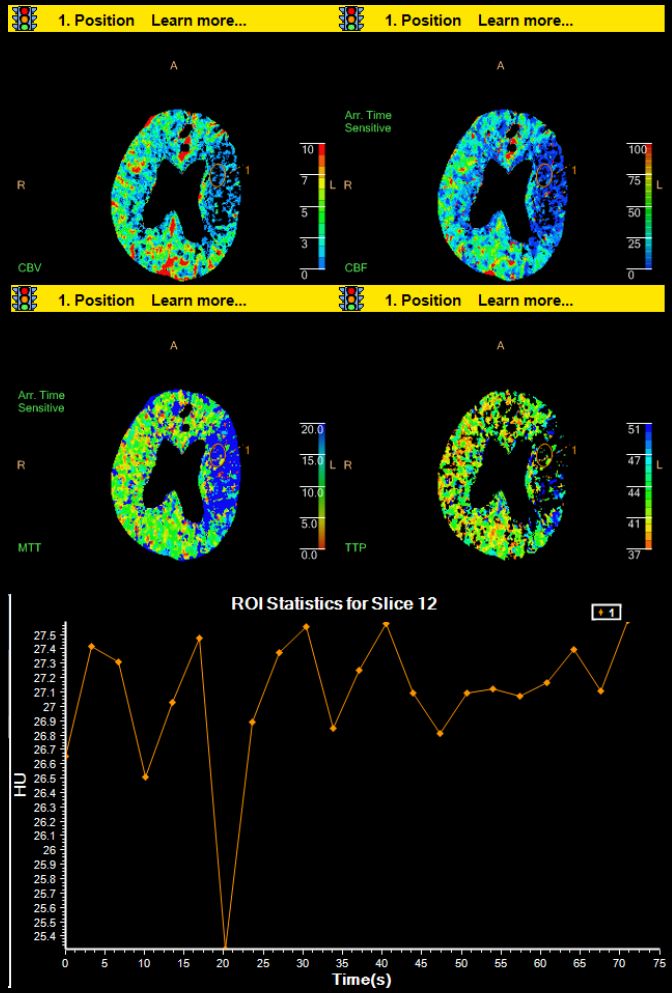

CBV
CBF
MTT
TTP

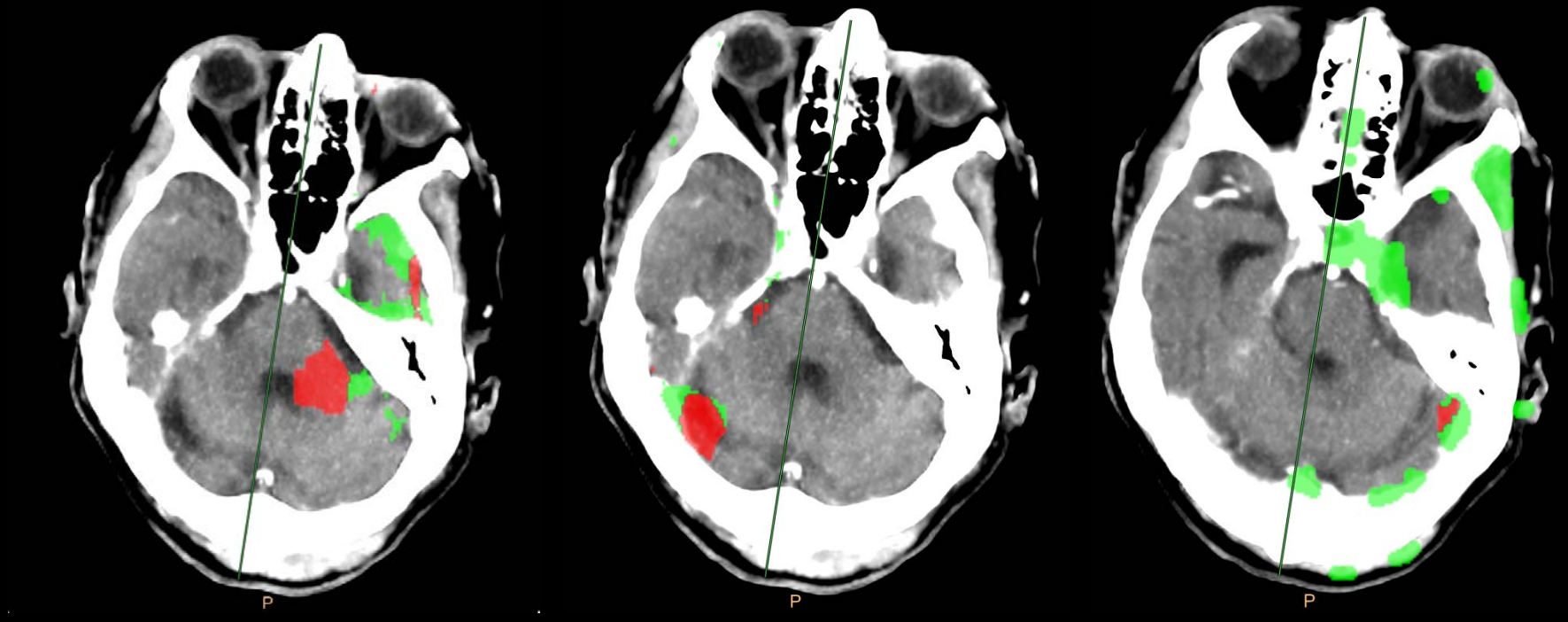


https://doi.org/10.1148/radiol.254082000

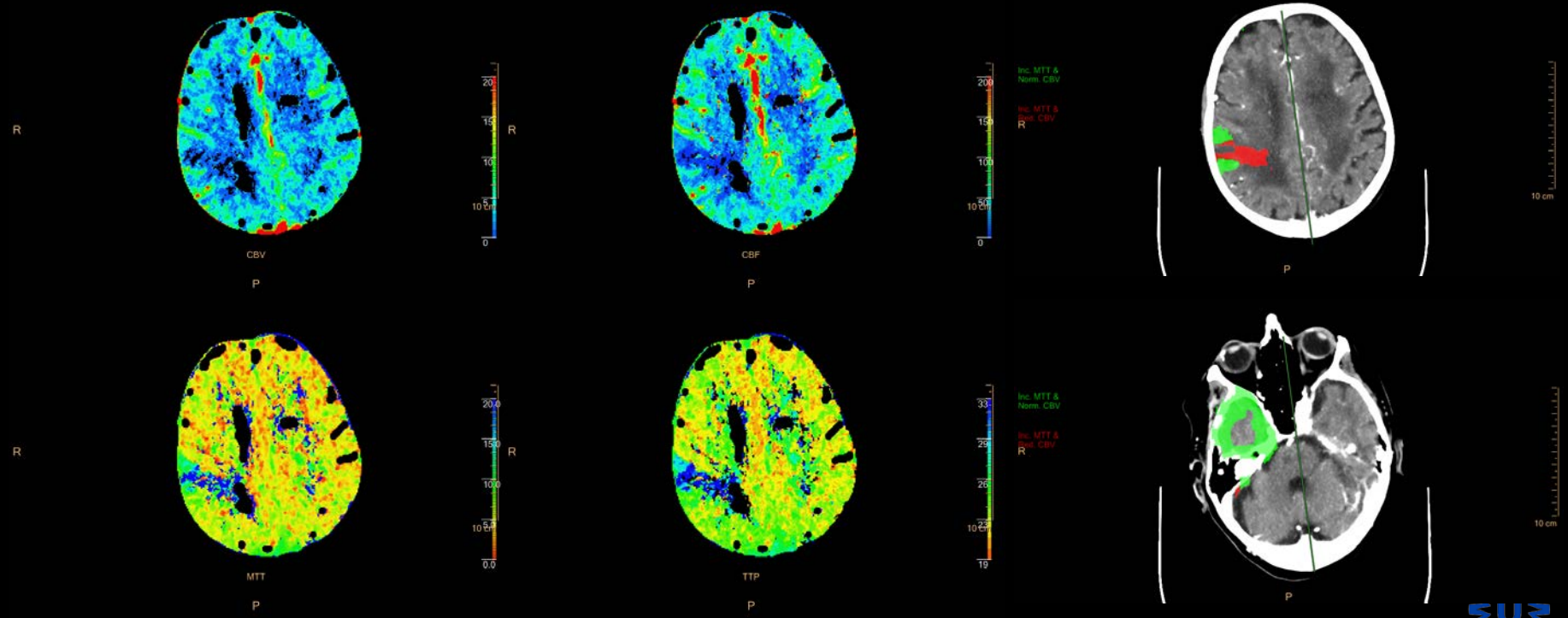
12 ml core, ratio 4.5

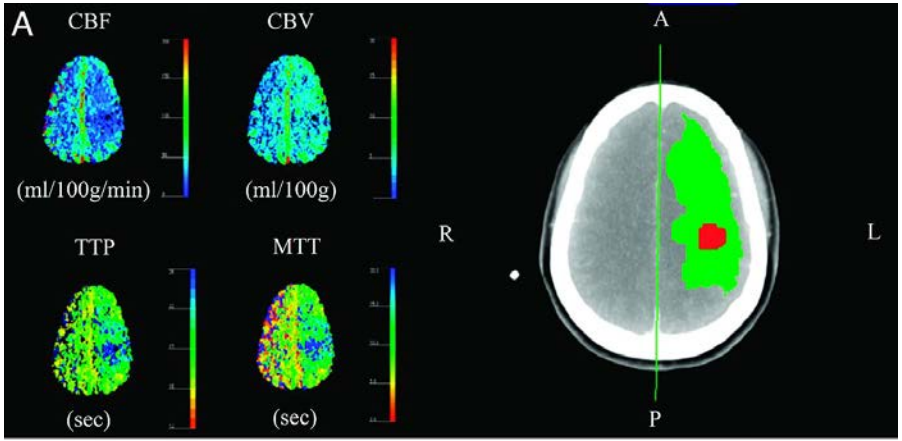


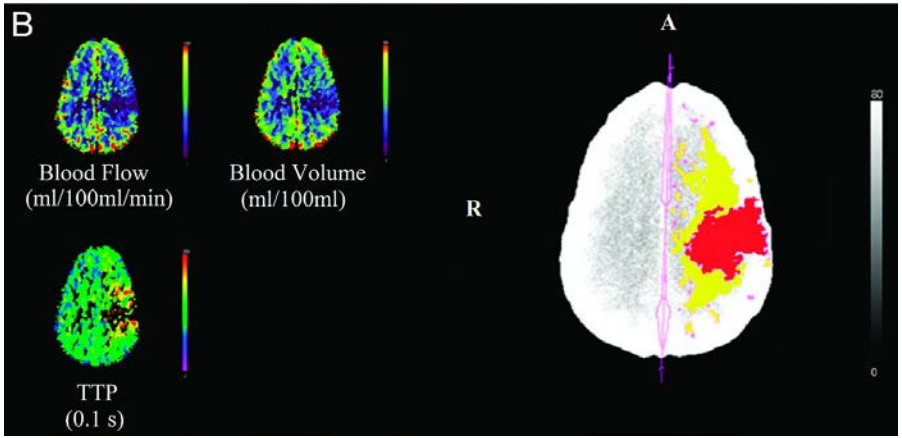

1. Position Learn more...
1. Position Learn more...
A
A
R
Arr. Time Sensitive
10
7
5
3
0
L R
CBV
CBF
100
75
50
25
0
1. Position Learn more...
1. Position Learn more...
A
A
Arr. Time Sensitive
R
20.0
15.0
10.0
5.0
0.0
MTT
TTP
51
47
44
41
37
ROI Statistics for Slice 12
HU
Time(s)

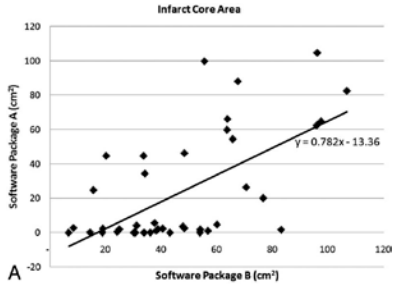

P
P
P

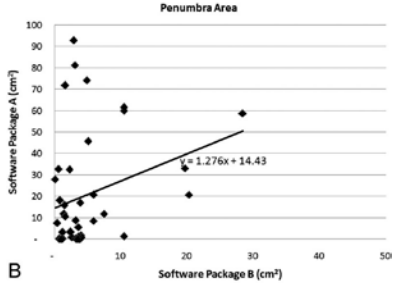
7 ml core, ratio 6.7?

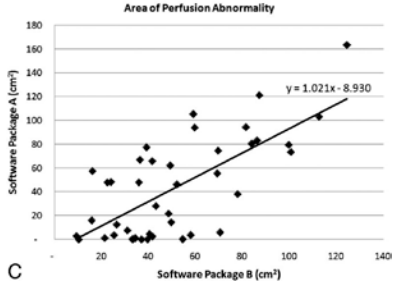






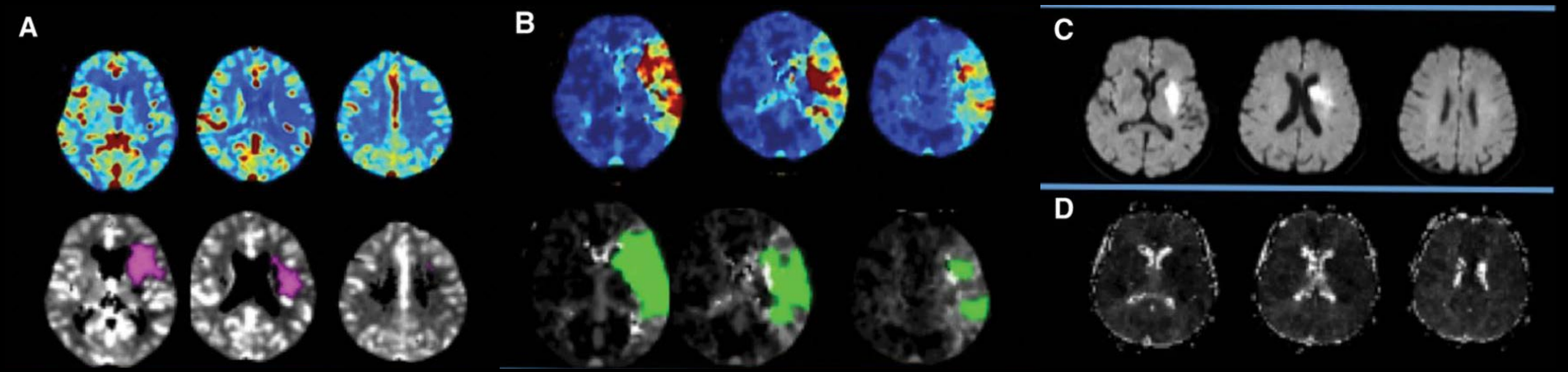






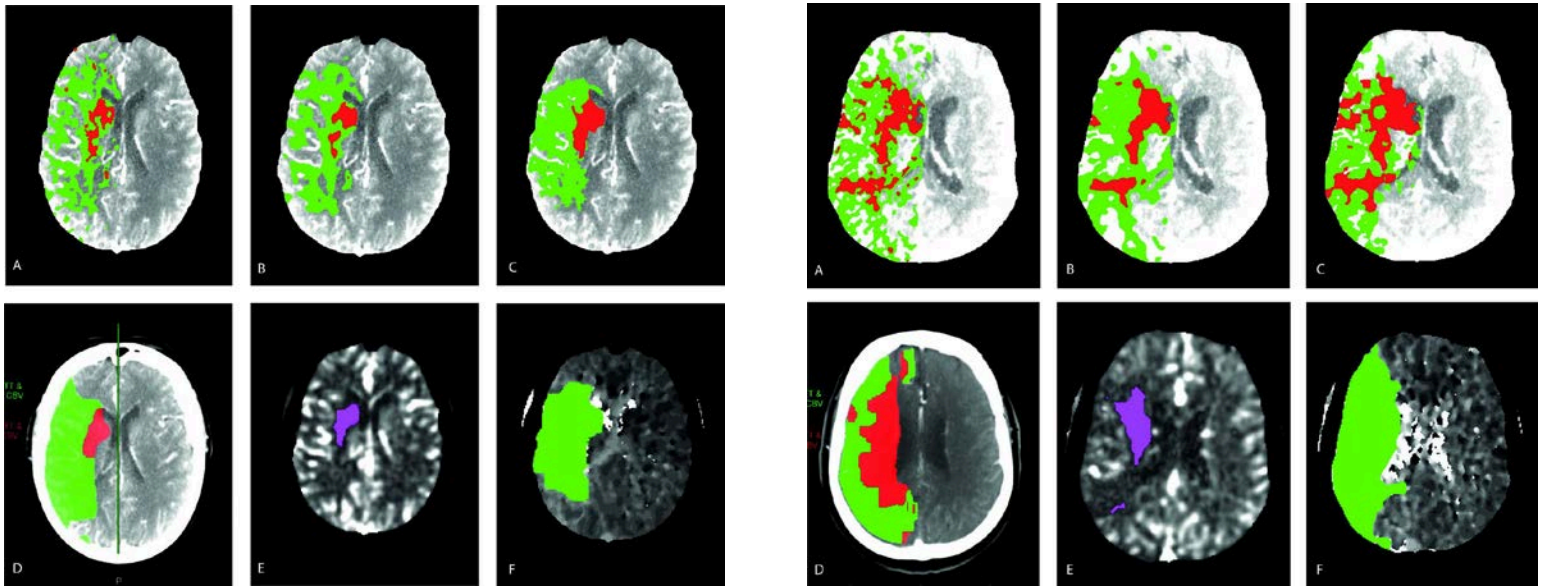
DOI: https://doi.org/10.3174/ajnr.A3110

Computed tomographic perfusion (CTP) imaging paradigm in a patient with proximal left middle cerebral artery occlusion (maps and segmentation using RAPID software).

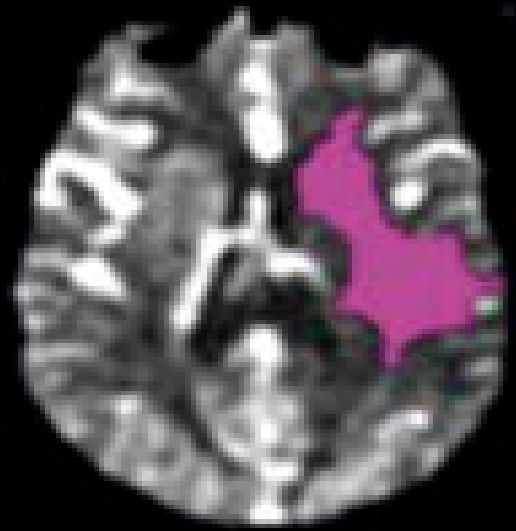


Bijoy K. Menon et al. Stroke. 2015;46:1453-1461

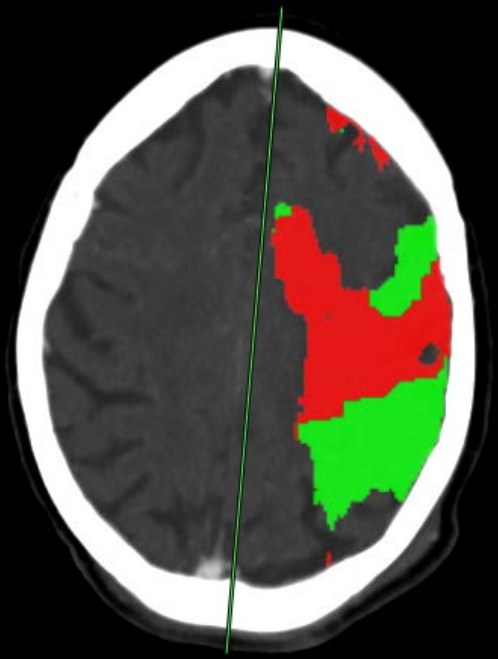
Comparison of three commonly used CT perfusion software packages in patients with acute ischemic stroke



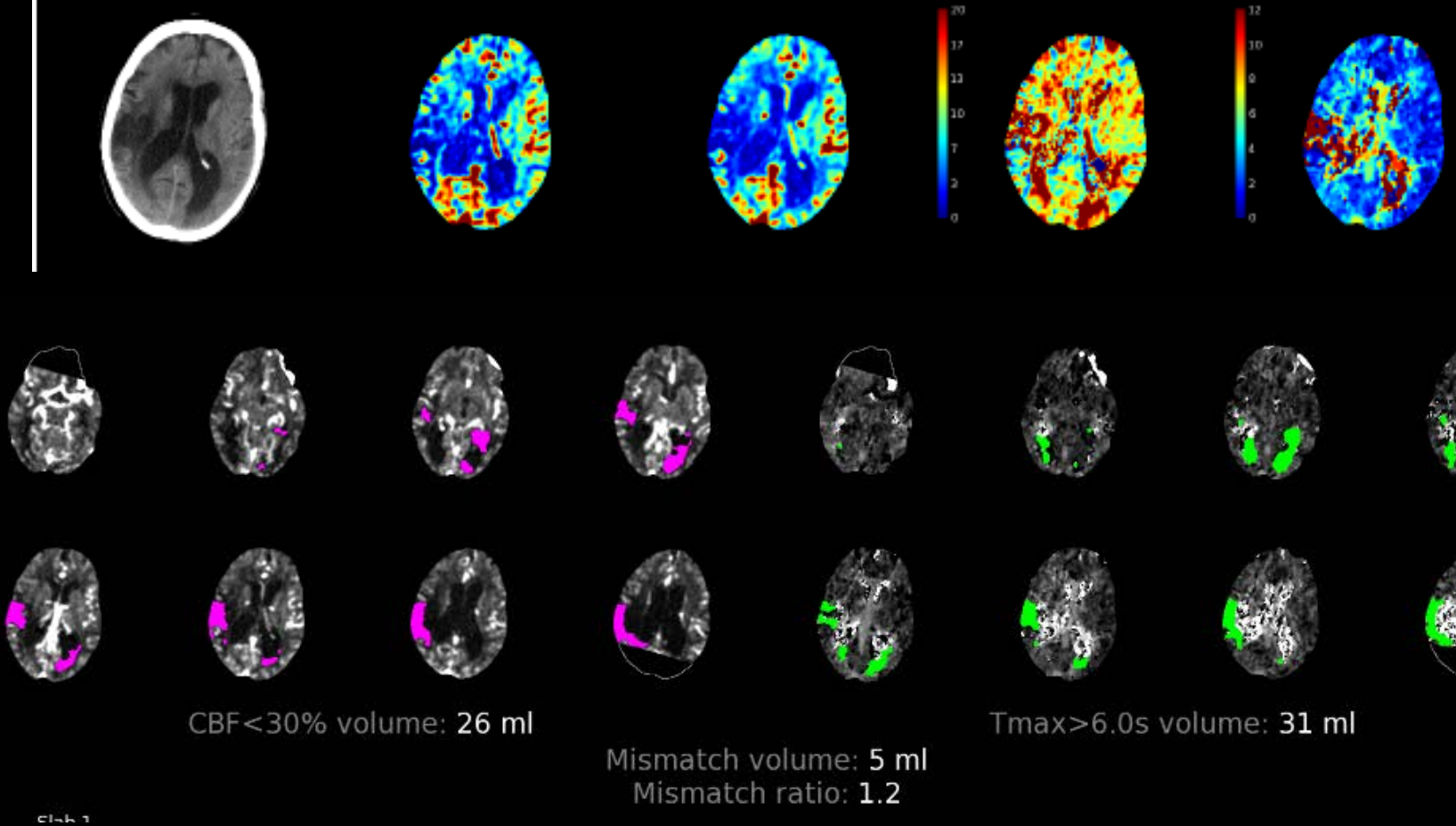
doi: 10.1136/neurintsurg-2019-014822



23 ml



50 ml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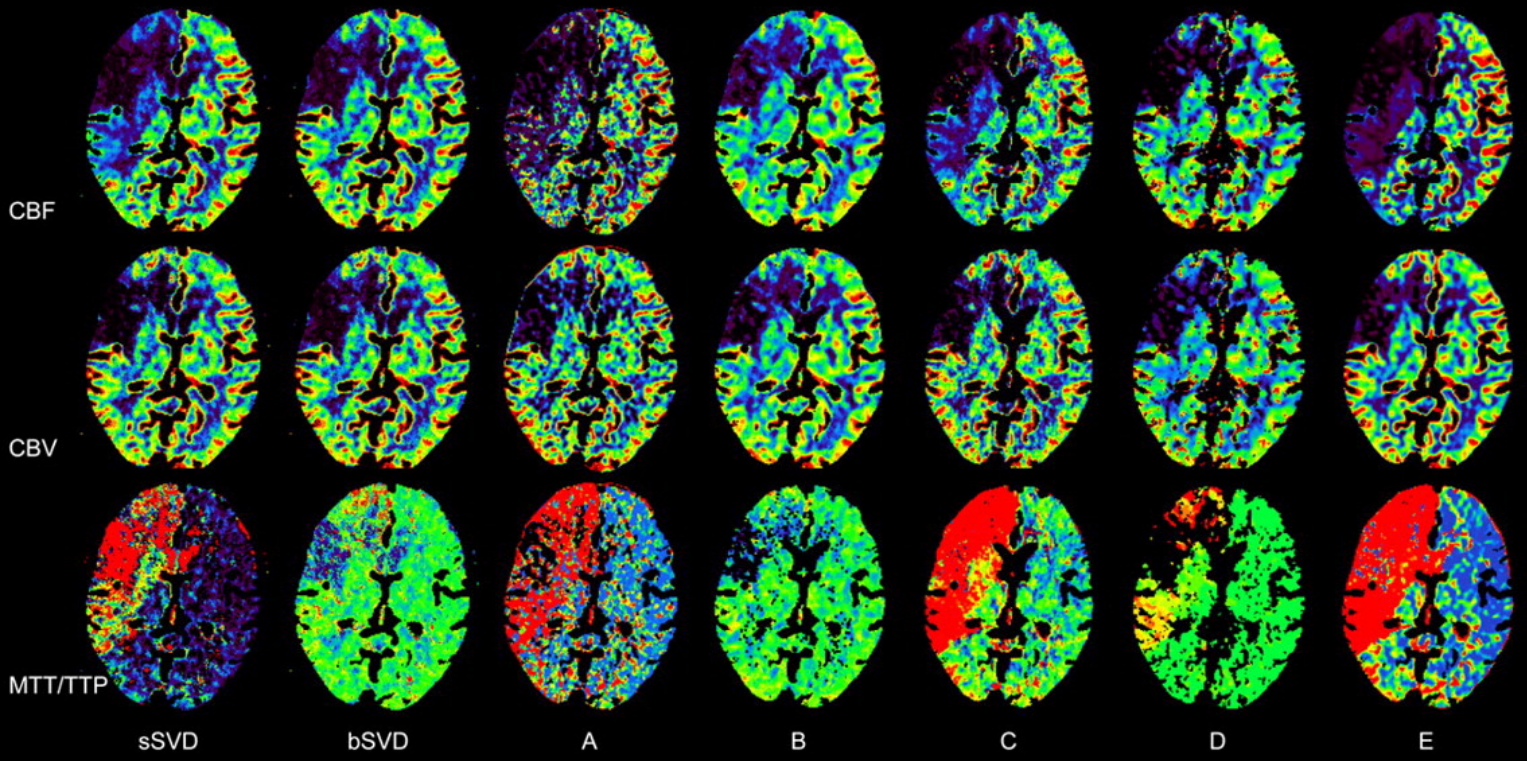
Tmax>6.0s volume: 31 ml
Mismatch volume: 5 ml
Mismatch ratio: 1.2



https://doi.org/10.1148/radiol.254082000

Conclusion

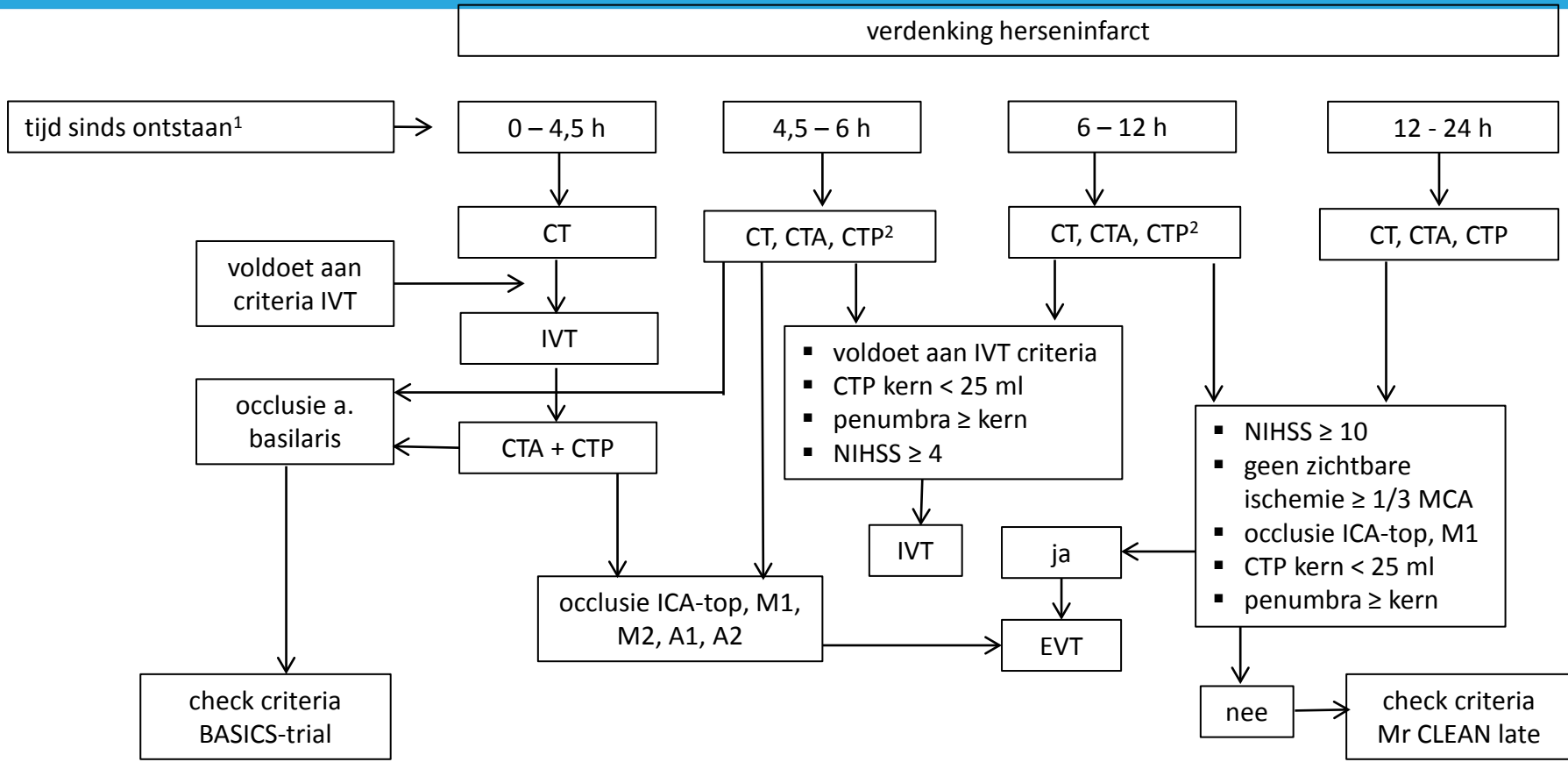
- A lot of hypodensity on NCCT = Large infarct core (ASPECTS <6 or >1/3 MCA)
- Poor collaterals = Large infarct core
- NO contrast enhancement on CTP = core

Conclusion

- All software packages are validate in the same way
- RAPID was applied for patient selection in large trials

2019 Update to the 2018 Guidelines for the Early Management of Patients With Acute Ischemic Stroke: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association

- In patients eligible for IV alteplase treatment should not delayed for additional multimodal neuroimaging, such as CT and MRI perfusion imaging.
- In patients with wake-up stroke or unknown onset > 4.5 hours, MRI within 4.5 hours to identify DWI-positive/FLAIR-negative lesions can be useful to select patients for IV alteplase.
- In patients with AIS 6 -24 hours with LVO, obtaining CTP, DW-MRI is recommended to aid in patient selection for EVT
- It may be reasonable to incorporate collateral flow status into clinical decision making in some candidates to determine eligibility for mechanical thrombectomy



1: indien niet geobserveerd, zoals bij ontwaken: sinds laatste moment zonder uitval; 2: overweeg MRI met DWI, FLAIR en SWI bij verdenking lacune bij 'wake up'; IVT = intraveneuze trombolyse; EVT = endovasculaire trombectomie.

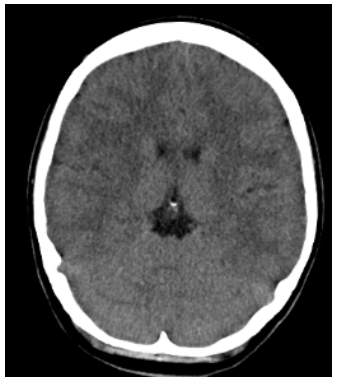
Conclusion

- IV rtPA <4.5 hours→ only NCCT
- IV rtPA with unknown onset time (<12 hours):
  - **Core <50% and <25 ml**
  - Low ASPECTS? >1/3 MCA?

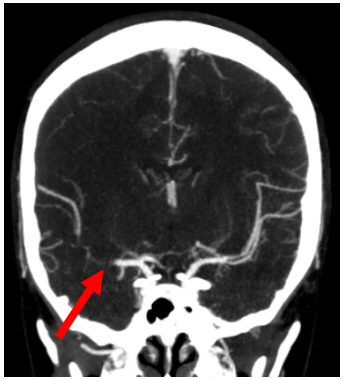
Conclusion

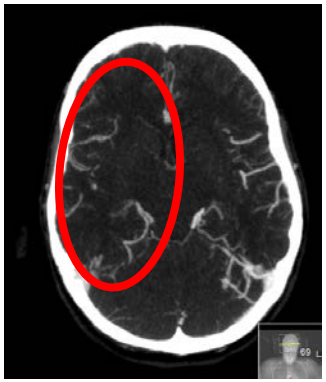
- EVT <6 hours:
  - < M2 occlusion
  - ASPECTS?
  - Collaterals?
- EVT 6-24 hours:
  - < M2 occlusion
  - **NCCT hypodensity <1/3 MCA**
  - **Core <50% and <25 ml**

28 yo F – Left-side paralysis with 2 hr onset time

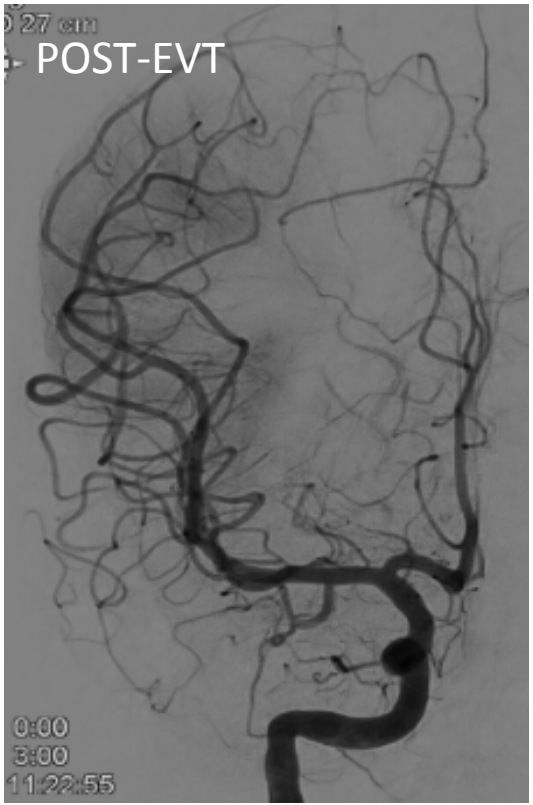


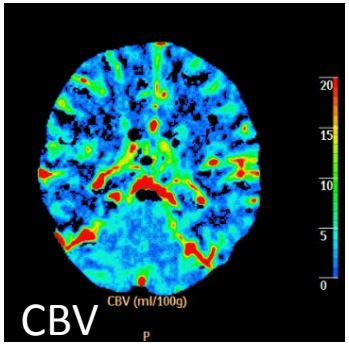
Non-contrast CT

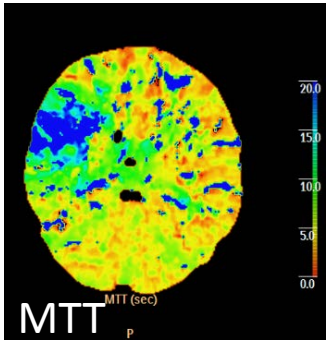


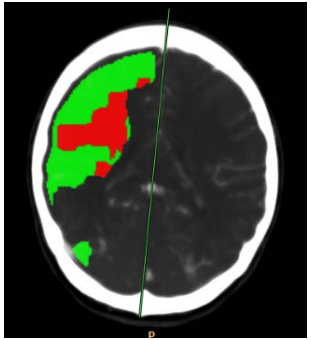


CTA





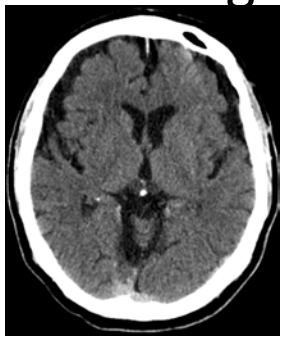


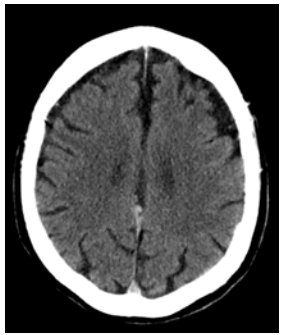


CTP

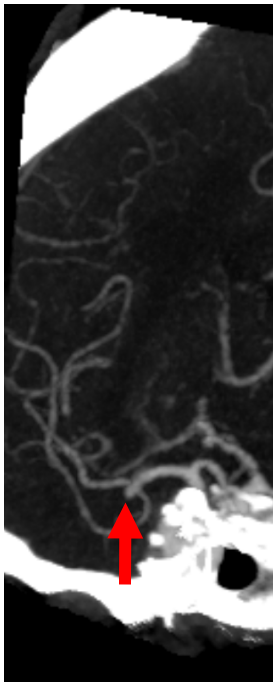
91 yo M – 18.00 stroke onset on Christmas Day – “drip and ship”

EVT 5 hrs after onset, excellent recovery with no neurological deficits

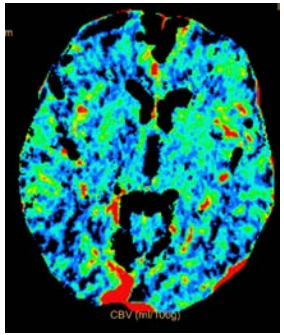


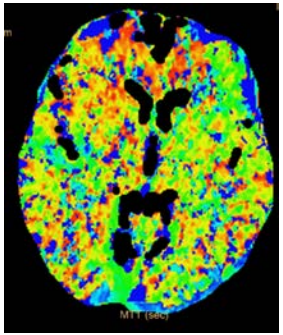


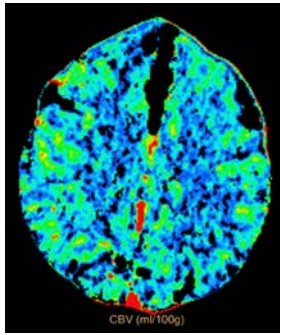
Non-contrast CT



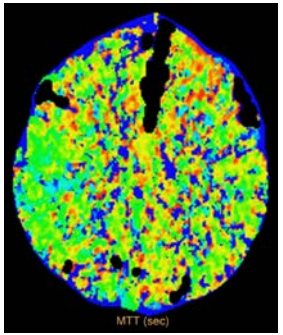
CTA



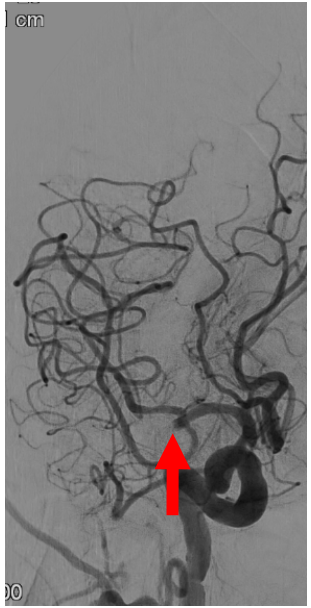




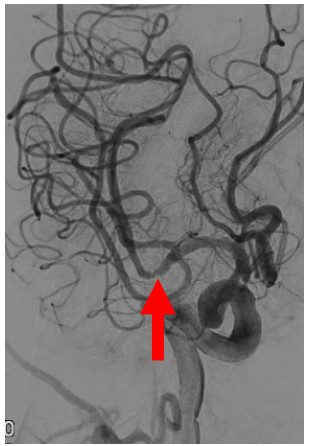
CTP - CBV



CTP - MTT



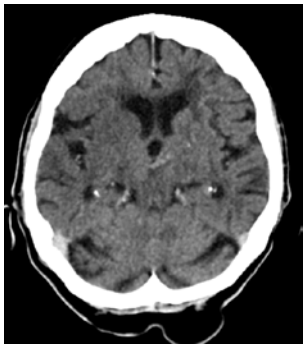
DSA pre-EVT

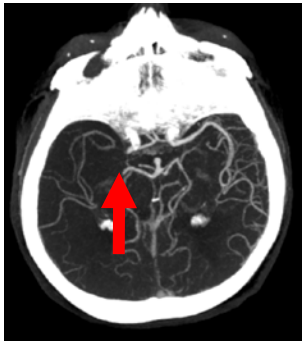


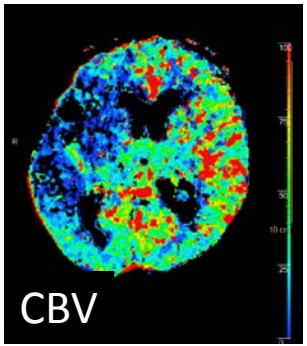
DSA post-EVT

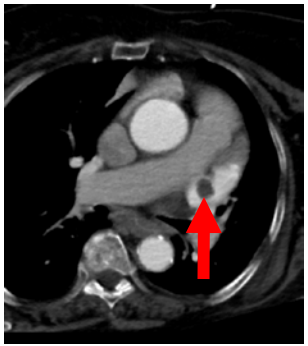
93 yo F – 4.5 hr stroke onset – beyond IVT time window – EVT?

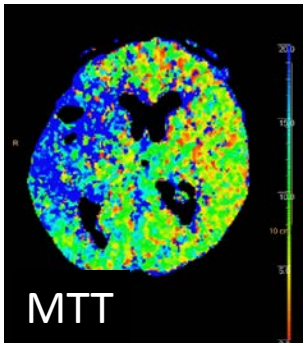
- Nursing home with senile alzheimer, HT +, DM2 + and AF on admission







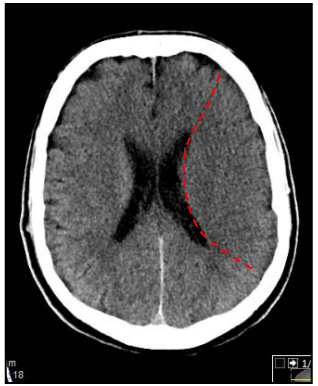




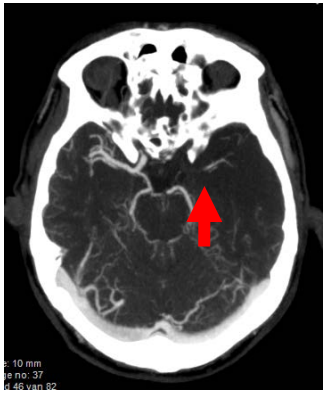
Non-contrast CT CTA CTP

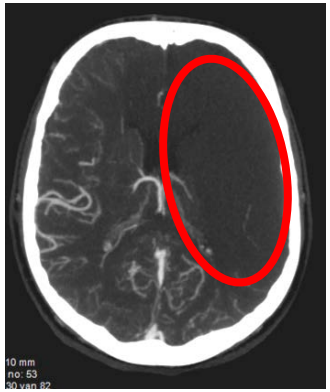
What would you do?

42 yo M – Right-side paralysis with 4.5 hr onset time

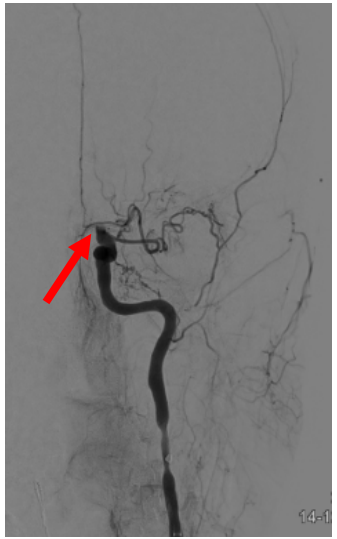


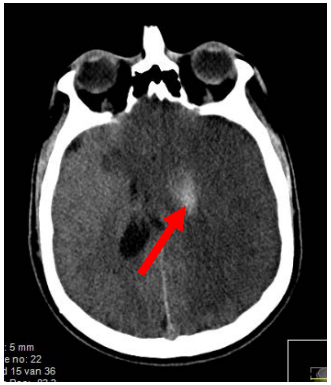
Non-contrast CT

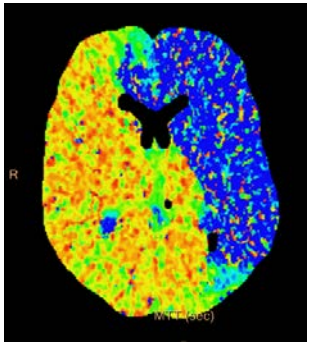


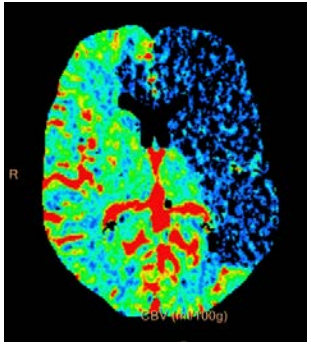


CTA

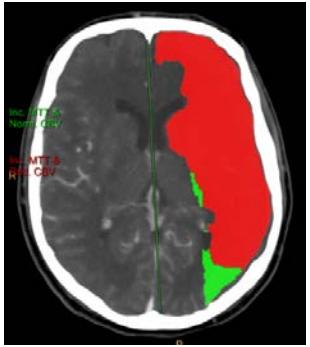


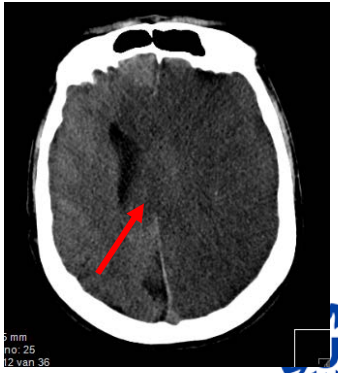






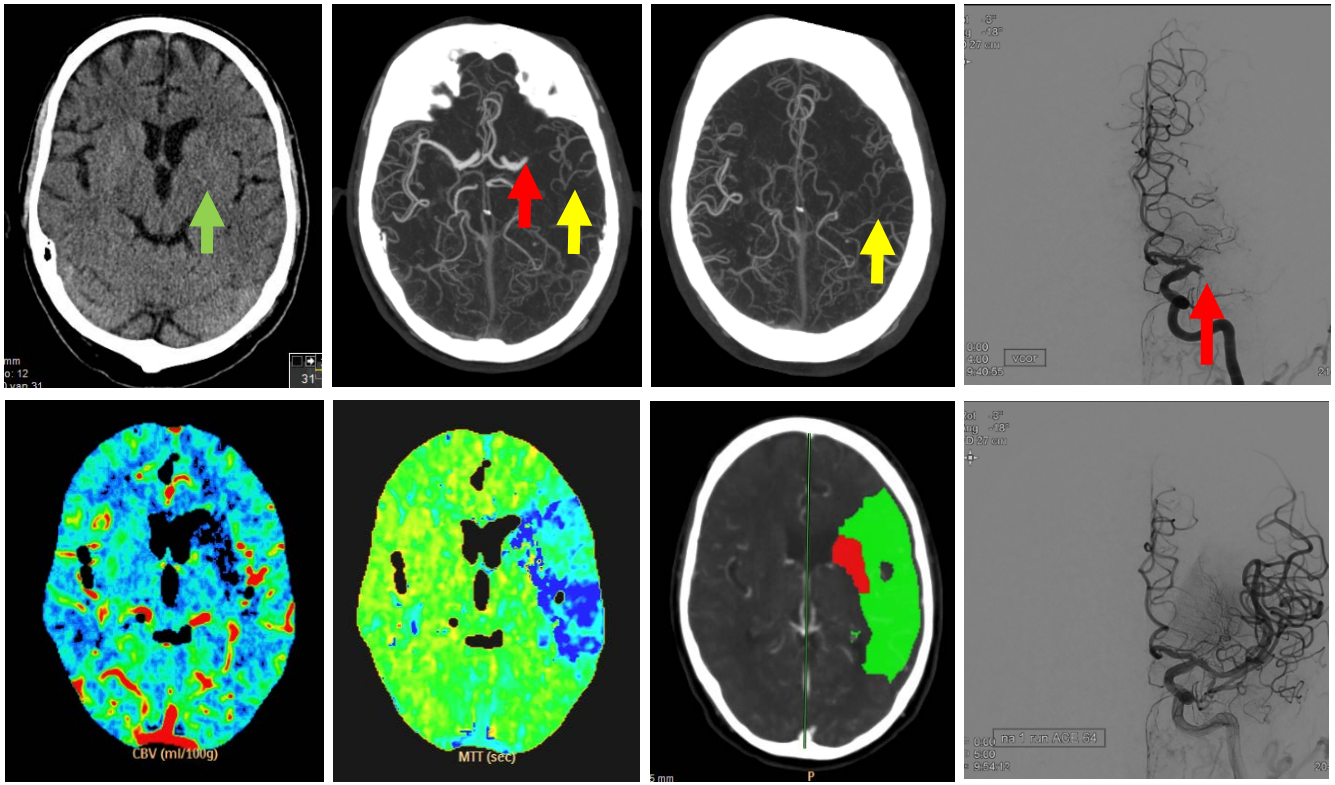
CTP





58 yo M – wake-up stroke 06.30 with aphasia and R hemiparesis

Last seen well 7.5 hours, NIHSS 15



CBV MTT Volume < 25 ml, mismatch >1.8

Discussion

- Use your brain