Tmax-MTT Mismatch in CT Perfusion Likely Indicates Collateralized Occlusions

PINYU CHEN, BA; KEVIN HIATT, MD

Wake Forest University
School of Medicine

The academic core of Atrium Health

Background

- CT perfusion can be instrumental in distinguishing core infarct from ischemic penumbra in the setting of large vessel occlusion. [1-2]

- However, standard thresholding of CBF and Tmax maps can be misleading in the setting of collateralized proximal (e.g. internal carotid artery) occlusions, leading to an overestimation of the volume of ischemic penumbra.[1]

- Collateralization is a hallmark of chronic arterial occlusions but can also be seen with acute occlusions when collateral pathways such as the circle of Willis are sufficiently intact. [3-4]

Purpose

- The purpose of this project is to investigate cases of discordance between MTT and Tmax maps on CT perfusion studies.

- We hypothesized that when Tmax is elevated > 6 seconds in the territory fed by an occluded common or internal carotid artery, the finding of preserved symmetric MTT is indicative of collateralization.

Methods

- After obtaining IRB approval, we retrospectively reviewed 5 years of CT perfusion data from a single large academic tertiary care center.
- Inclusion criteria:
  - common or internal carotid artery occlusion on CTA
  - visual mismatch between Tmax and MTT maps
  - brain MRI obtained within 72 hours of initial stroke imaging
- Cases meeting inclusion criteria had clinical data, treatment, and imaging studies reviewed.

Results

- 4 cases met the inclusion criteria
  - 3 cases had proximal cervical internal carotid artery occlusions
  - 1 case had a common carotid artery occlusion
- LKN ranged from 2 to 16 hours
- NIHSS was < 5 in 3 cases and was 14 in 1 case

Table I. Clinical Presentation

Patient	Age	Sex	Symptoms	Last Known Normal (Hrs)	NIHSS
1	66	M	Right facial droop	11	1
2	67	F	Left hemi-body weakness	2	4
3	70	F	Dysarthria, lower extremity weakness	4	3
4	92	F	Dysarthria	16	14

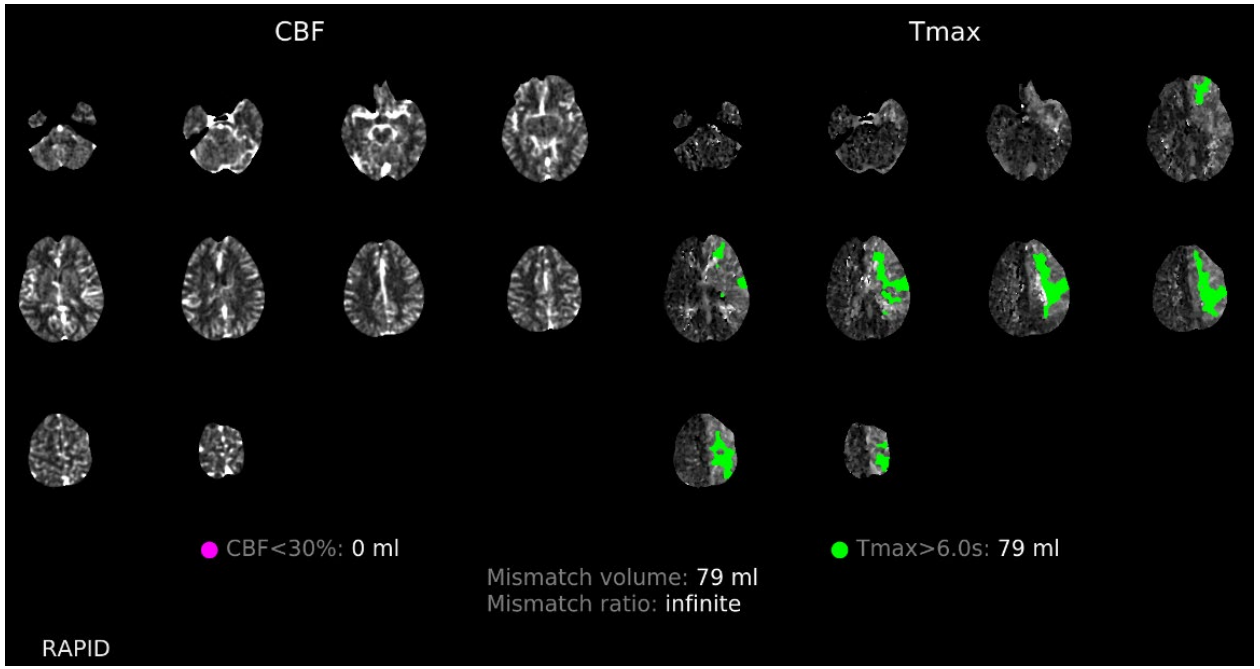
Results

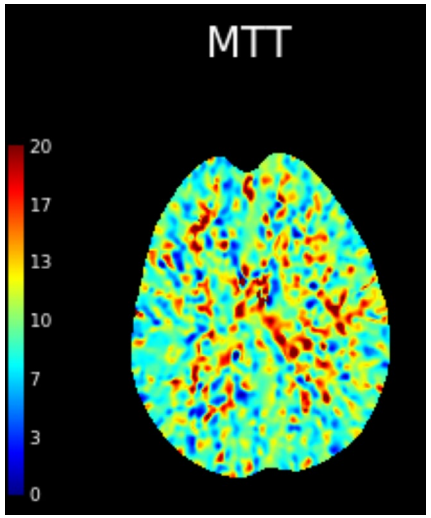
- For all 4 patients, CT Perfusion demonstrated areas of elevated Tmax > 6 seconds in the territory of the occluded vessel contrasted with more visually symmetric MTT maps.
- MR imaging did not demonstrate an acute infarct in any of these patients.
- None of the patients received thrombolytic therapy or underwent thrombectomy.
- 3 patients with low NIHSS scores improved to baseline at time of discharge
  - Patient with a score of 14 was discharged with only mild residual deficits relative to baseline

Table II. Imaging Findings

Patient	CT Head without Contrast	CTA	CBF < 30% vol	Tmax > 6 sec vol	MTT	MRI (hrs after CT)	MRI Findings	Treatment
1	Negative	L ICA, L M3 cutoff	0	79	symmetric	28	Negative	EC-IC bypass, dc on aspirin and Eliquis
2	Negative, old CVA	R ICA	0	161	symmetric	11	Negative	Conservative, symptoms resolved
3	Negative, old CVA	L CCA	0	99	symmetric	26	Negative	Conservative, symptoms resolved
4	Negative	L ICA	0	48	symmetric	6	Negative	Conservative, partial recovery

Patient 1


CBF
Tmax
CBF<30%: 0 ml
Tmax>6.0s: 79 ml
Mismatch volume: 79 ml
Mismatch ratio: infinite
RAPID


MTT
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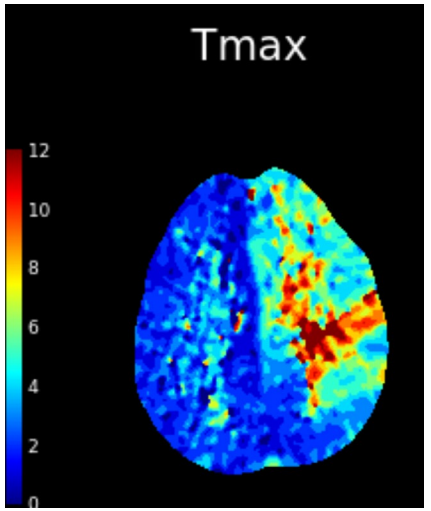
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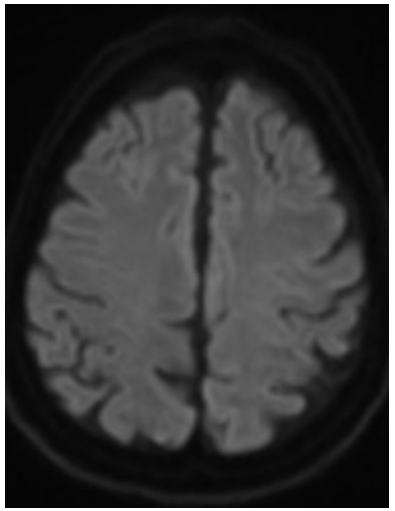
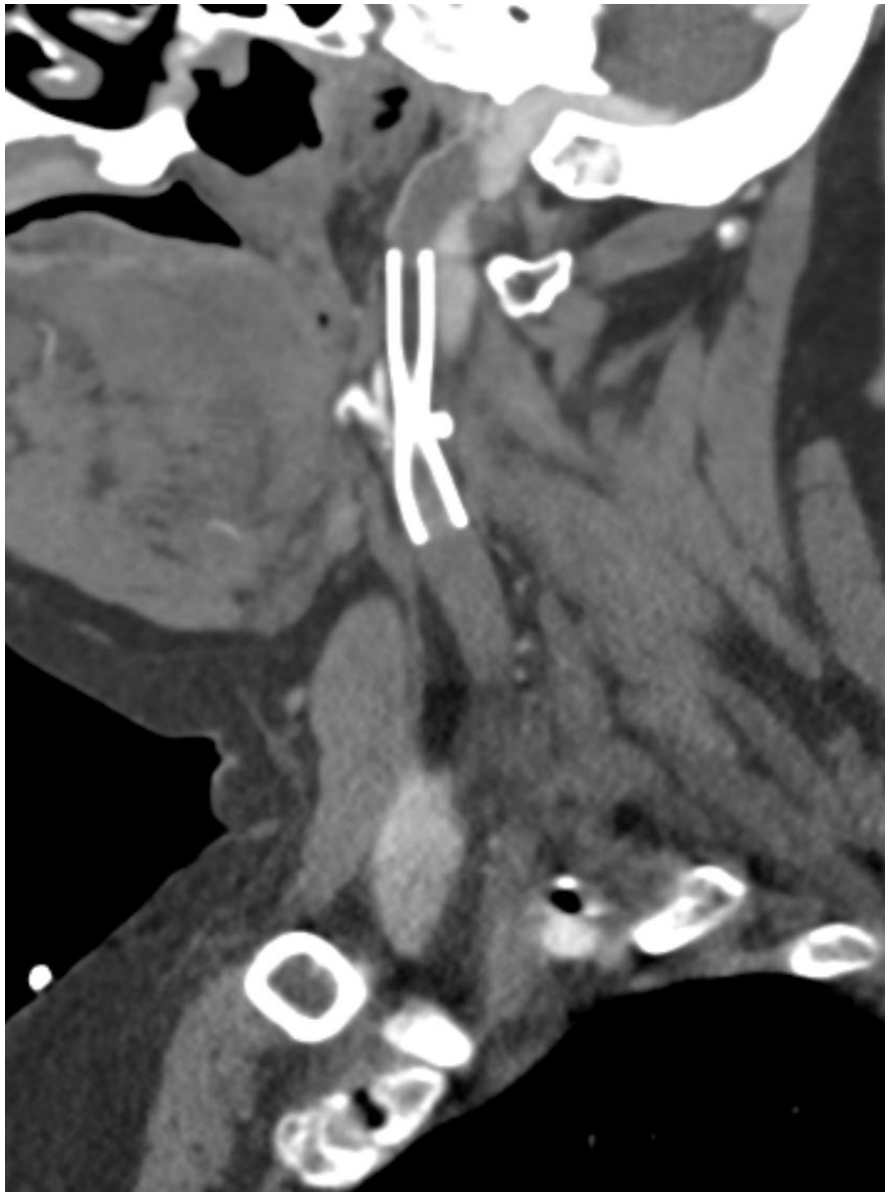
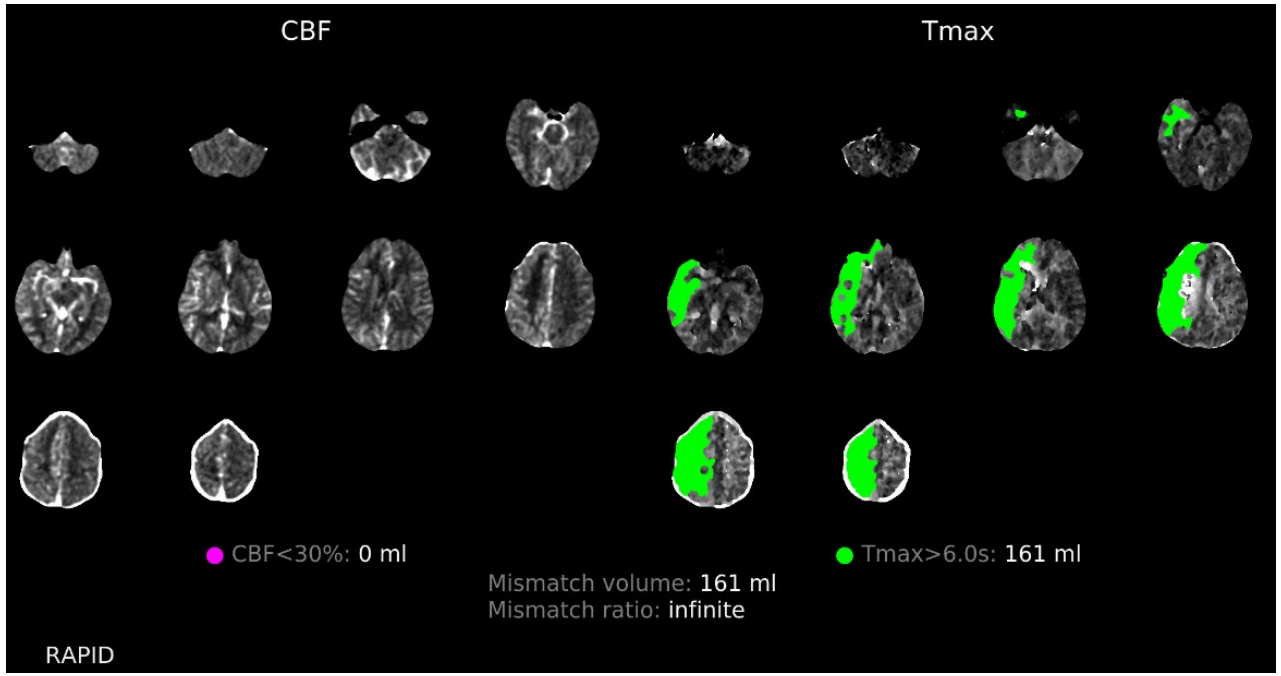
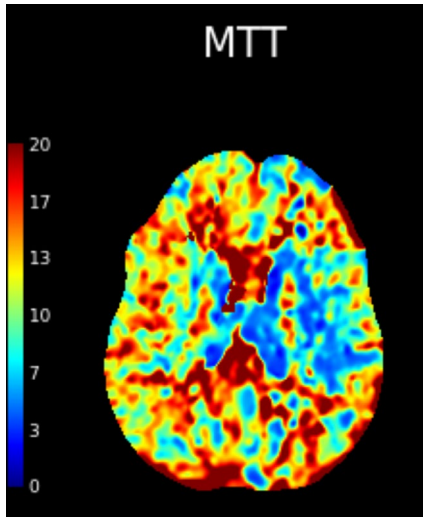


Patient 2




CBF
Tmax
CBF<30%: 0 ml
Tmax>6.0s: 161 ml
Mismatch volume: 161 ml
Mismatch ratio: infinite
RAPID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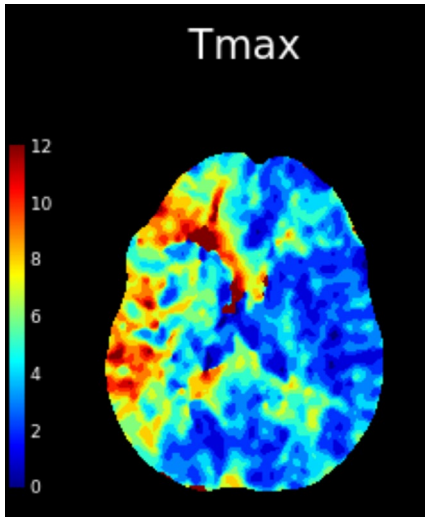
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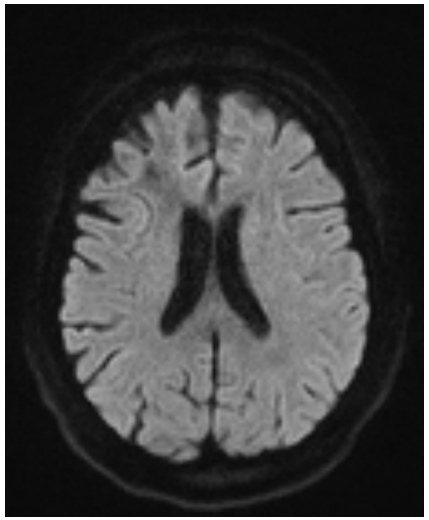
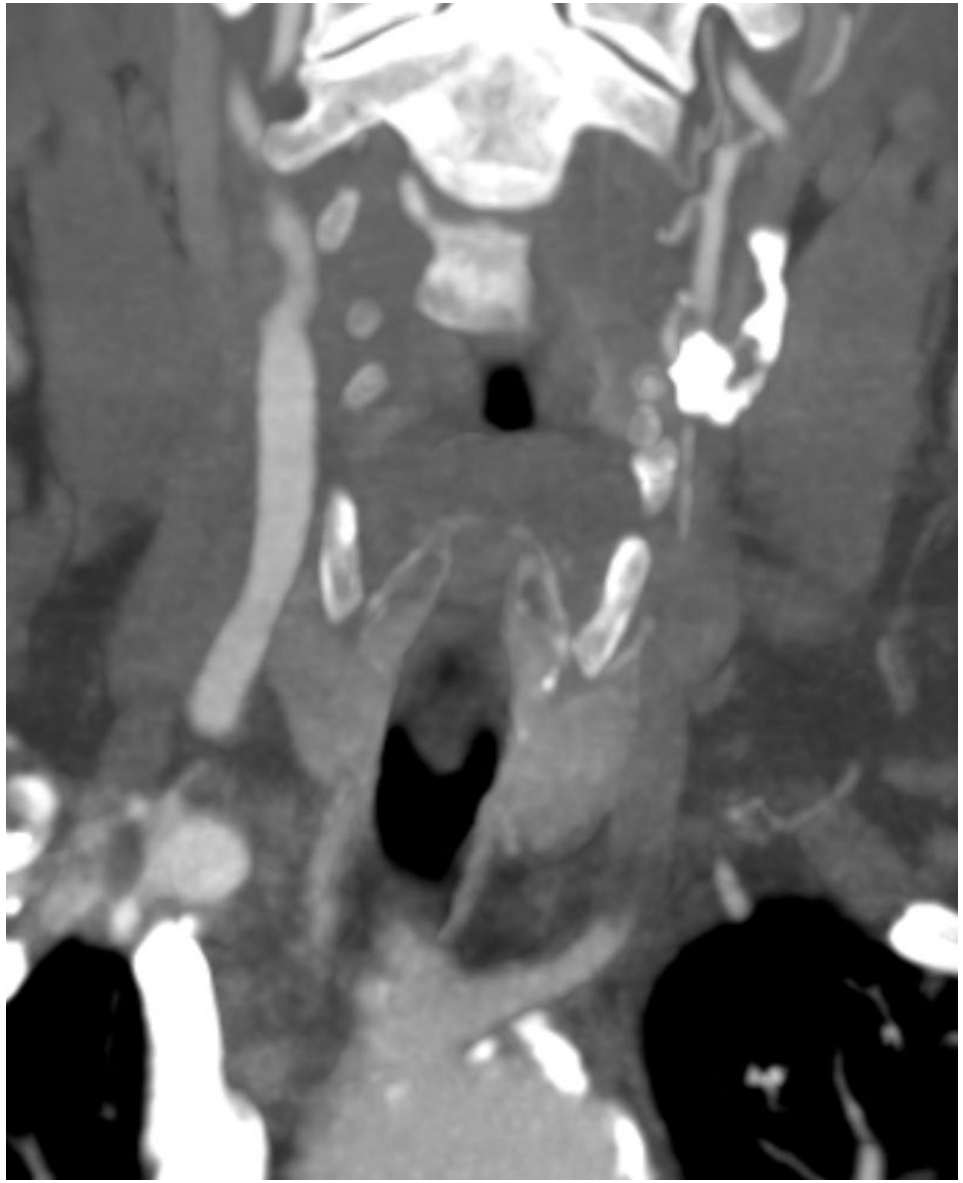
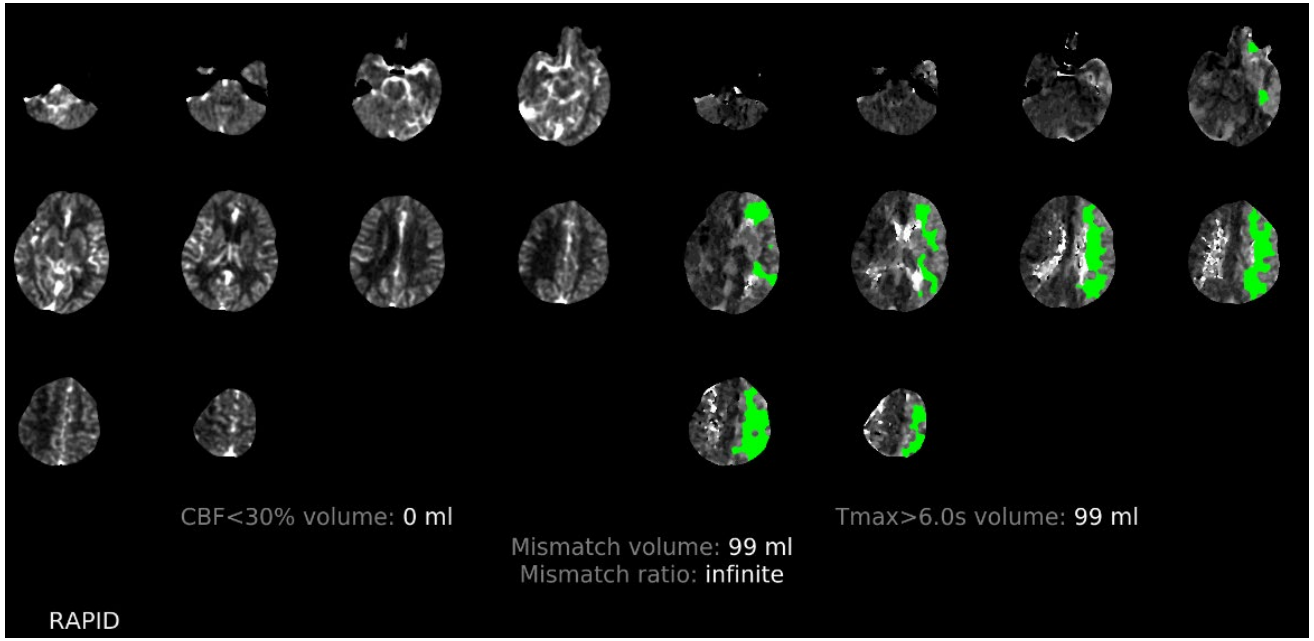
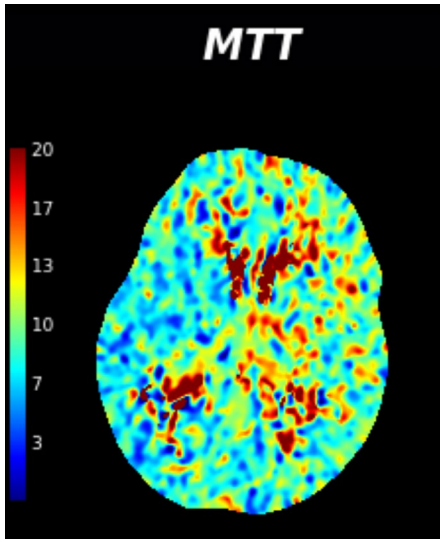


Patient 3




CBF<30% volume: 0 ml
Tmax>6.0s volume: 99 ml
Mismatch volume: 99 ml
Mismatch ratio: infinite
RAPID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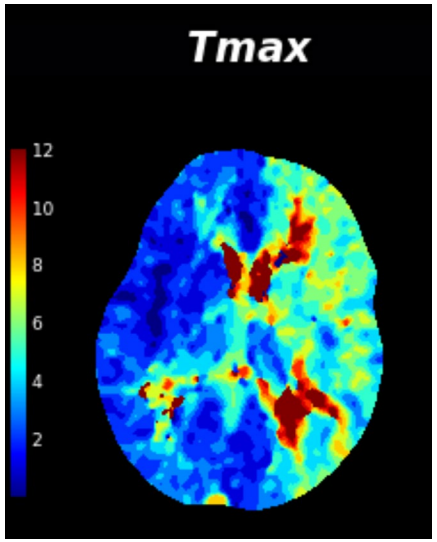
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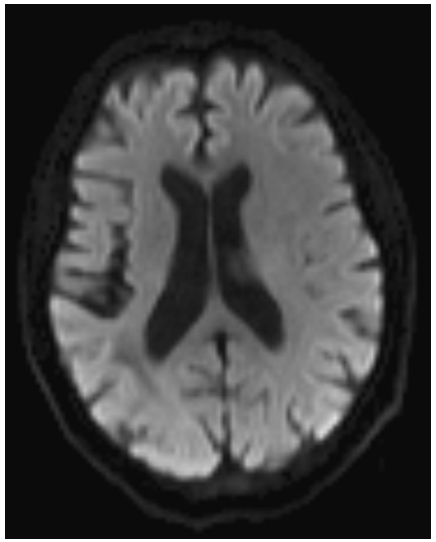
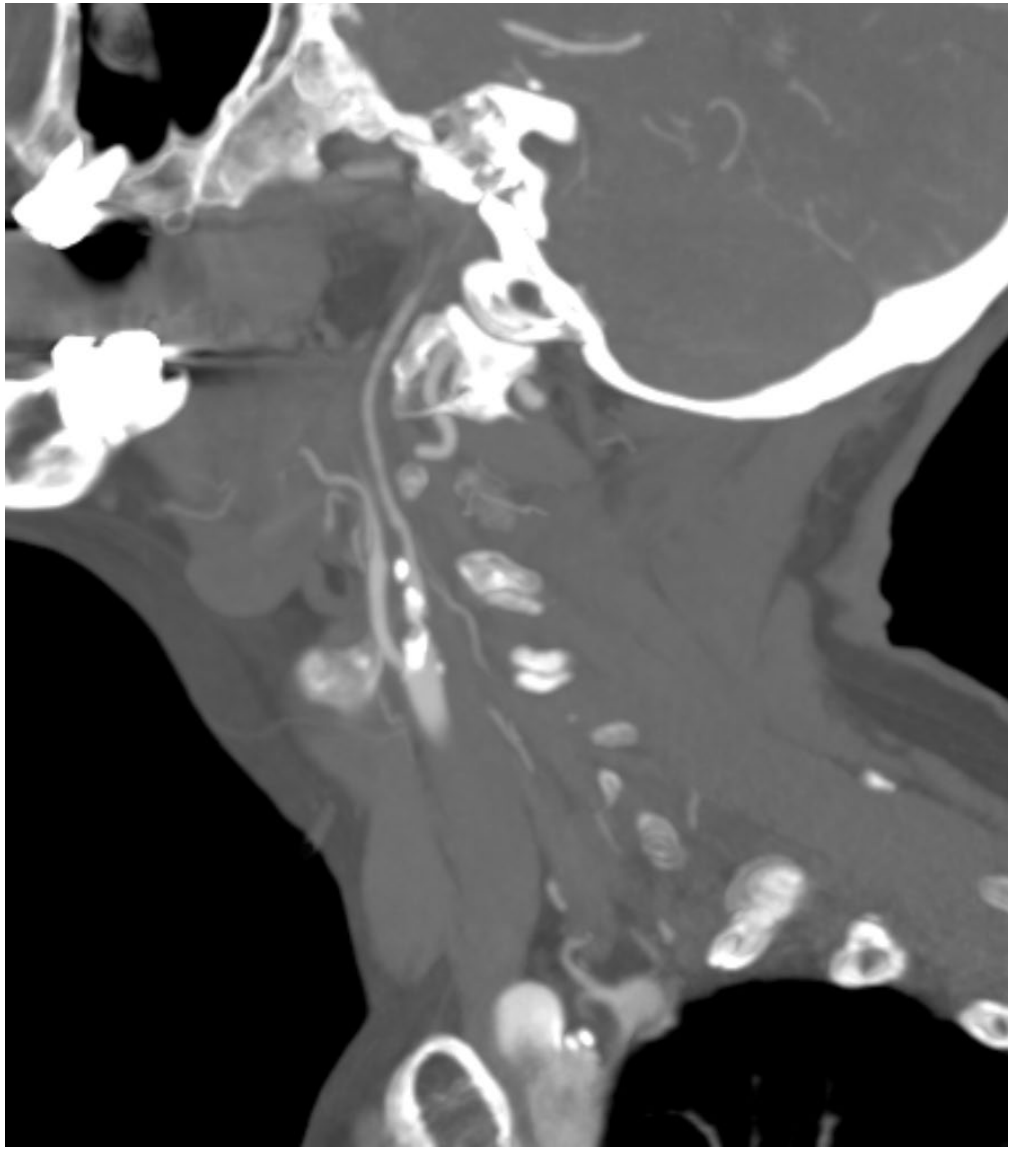
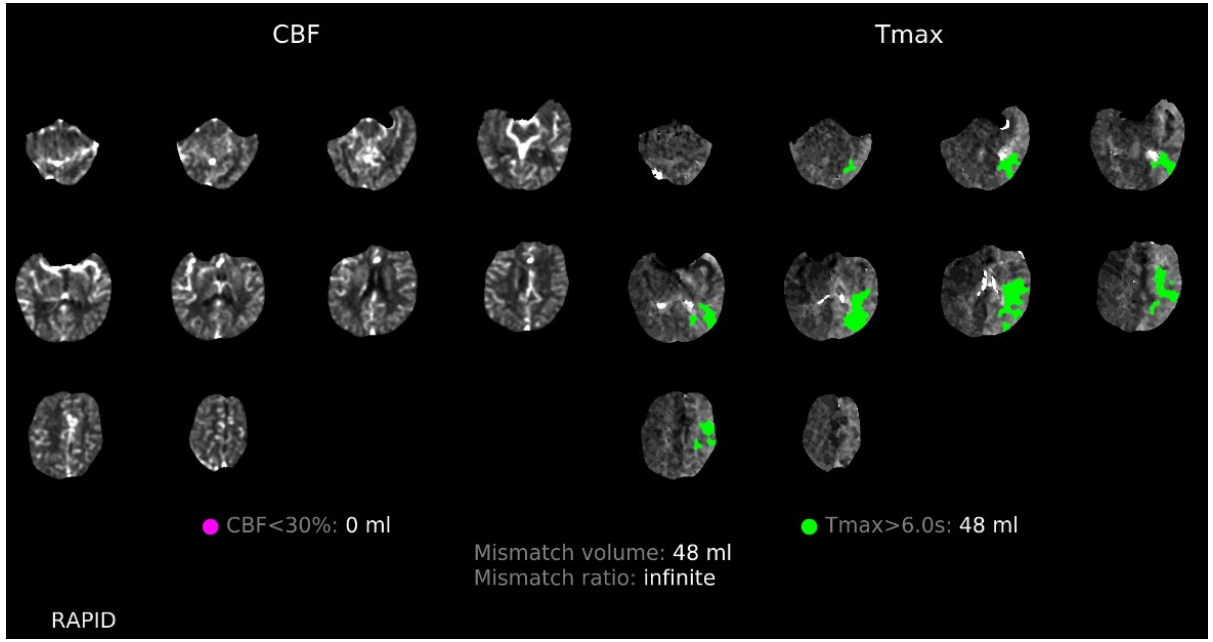
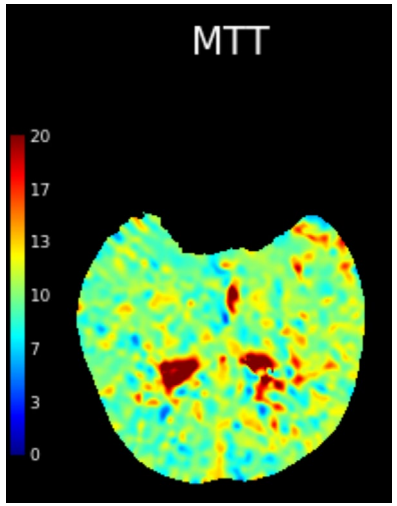


Patient 4




CBF
Tmax
CBF<30%: 0 ml
Tmax>6.0s: 48 ml
Mismatch volume: 48 ml
Mismatch ratio: infinite
RAPID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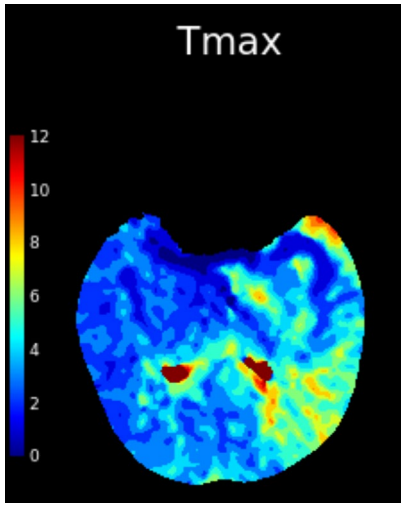
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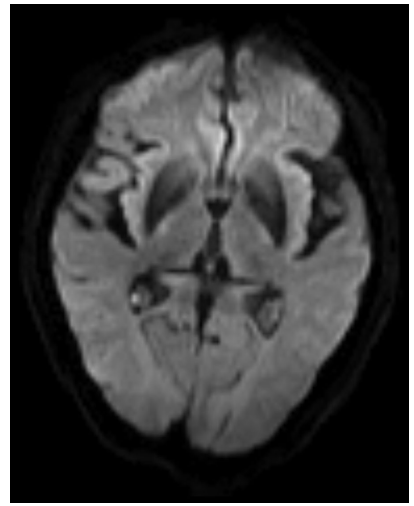

Conclusion

- Tmax elevation in the setting of collateralized common or internal carotid artery occlusion may be misinterpreted as acute ischemic penumbra.

- Tmax-MTT mismatch, where the MTT map qualitatively remains symmetric, may be useful in identifying patients who likely have collateralized occlusions.

References

1. Allmendinger AM, Tang ER, Lui YW, Spektor V. Imaging of stroke: Part 1, perfusion CT - Overview of imaging technique, interpretation pearls, and common pitfalls. *Am J Roentgenol*. 2012;198(1):52-62. doi:10.2214/AJR.10.7255
2. Kamalian S, Kamalian S, Konstas AA, et al. CT Perfusion Mean Transit Time Maps Optimally Distinguish Benign Oligemia from True “At-Risk” Ischemic Penumbra, but Thresholds Vary by Postprocessing Technique. *Am J Neuroradiol*. 2012;33(3):545-549. doi:10.3174/ajnr.A2809
3. Alves HCBR, Pacheco FT, Rocha AJ. Collateral blood vessels in acute ischemic stroke: a physiological window to predict future outcomes. *Arq Neuropsiquiatr*. 2016;74(8):662-670. doi:10.1590/0004-282X20160050
4. Galinovic I, Kochova E, Khalil A, Villringer K, Piper SK, Fiebach JB. The ratio between cerebral blood flow and Tmax predicts the quality of collaterals in acute ischemic stroke. *PLoS One*. 2018;13(1):1-9. doi:10.1371/journal.pone.0190811