CT Perfusion: The Basics

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Chief of Neuroradiology and Head & Neck Radiology
University of Michigan Health System

Outline

- Technique
- Clinical Applications
  - Stroke
  - Brain Tumors
  - Head & Neck

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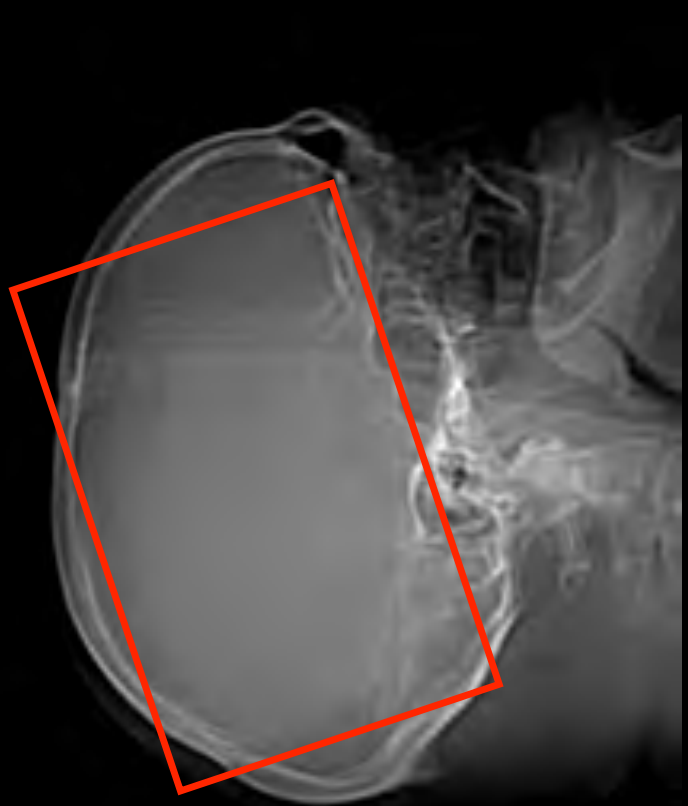
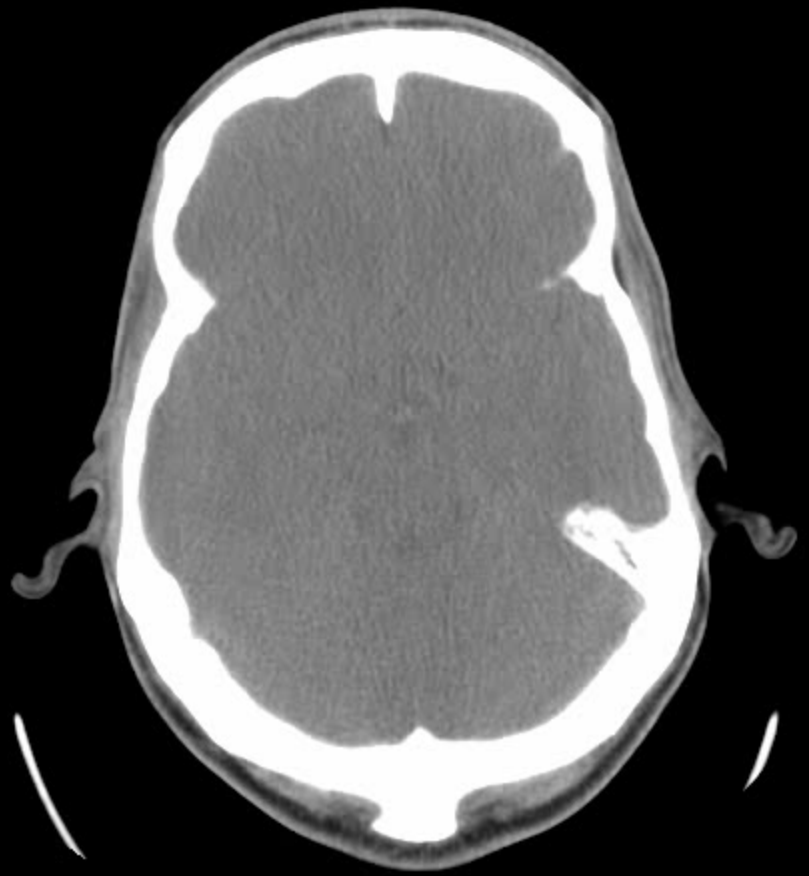
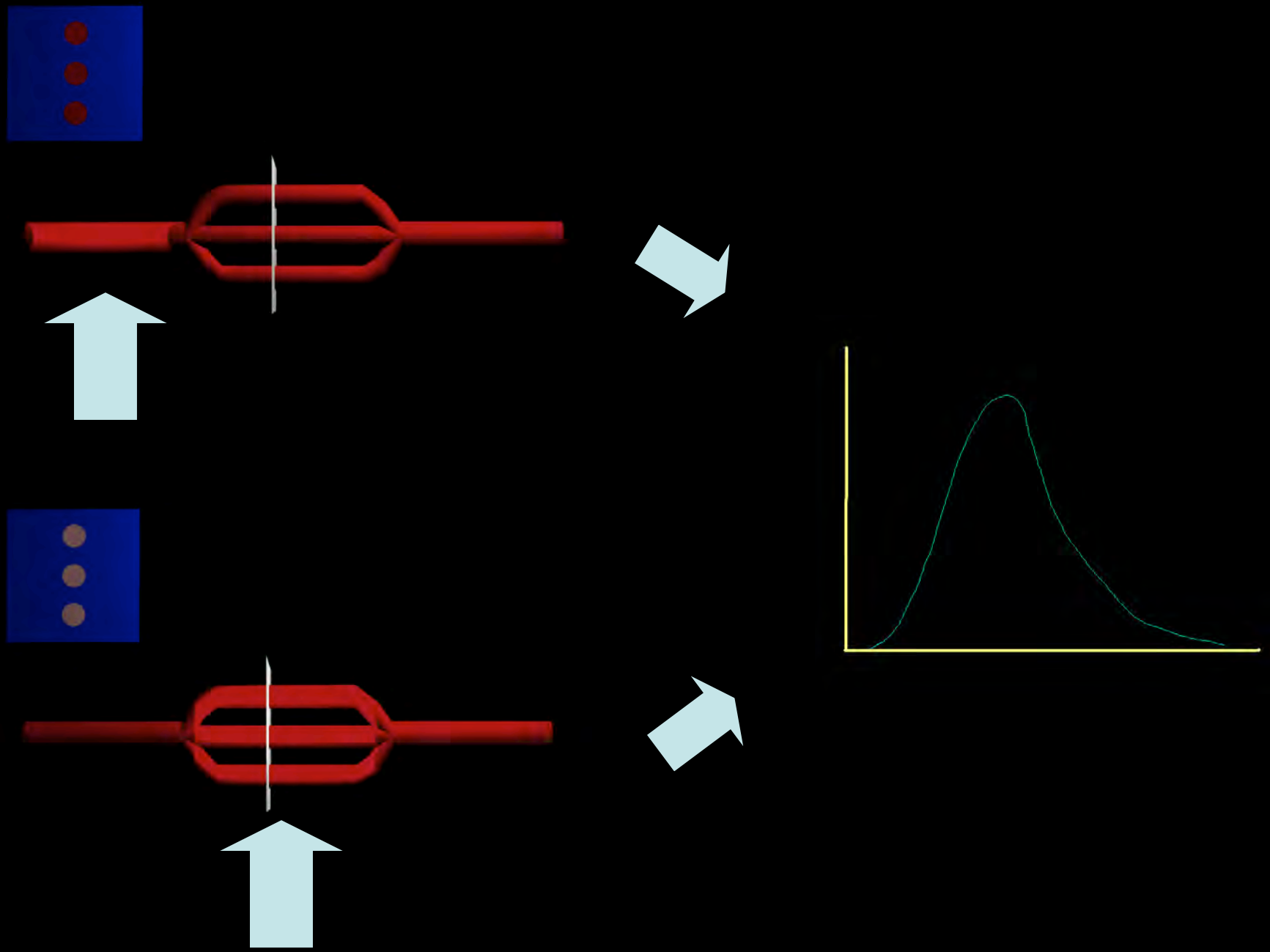
CT Perfusion Protocol





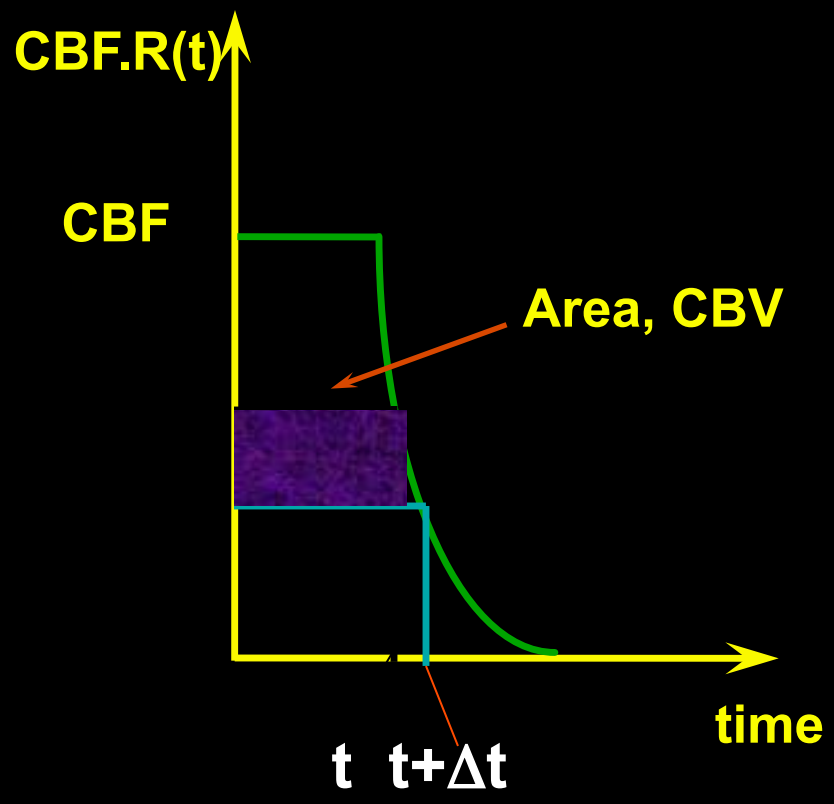
CT Perfusion

- Define ROIs for:
  - *Vein*
  - *Artery*
- Software has automated vessel selection capability



CT Perfusion – What is behind it?

$$Q(t) = CBF \cdot C_a(t) * R(t)$$



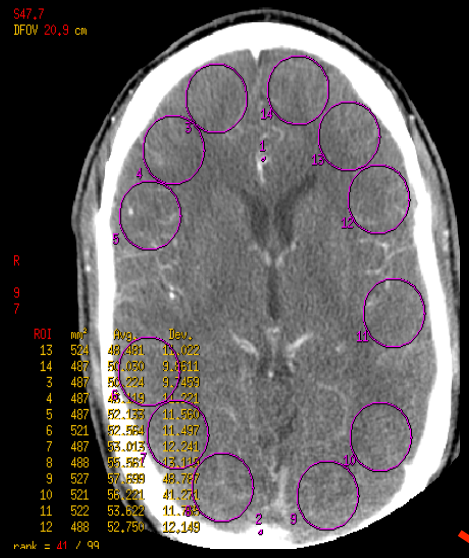
Deconvolution

- Technique described by Leon Axel, M.D., Ph.D. in 1983
- Measure Time-concentration in an input artery.
- Use mathematical process called “deconvolution” to separate effect of input from observed contrast time in tissue.

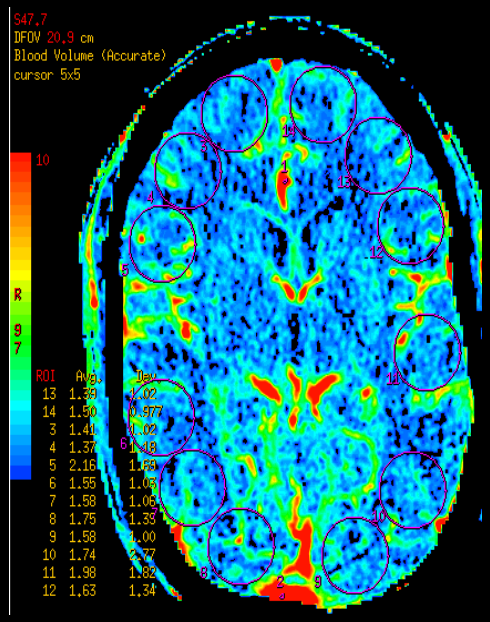
Computation

- Calculations are made based on the “central volume principle” which relates blood flow, blood volume and mean transit time.

$$BF = BV / MTT$$


S47.7
DFOV 20.9 cm
R
9
7
ROI mm² Avg. Dev.
13 524 48.491 11.022
14 487 50.050 9.3611
3 487 50.224 9.7459
4 487 48.445 11.221
5 487 52.157 11.550
6 521 52.584 11.487
7 487 53.013 12.241
8 488 53.567 12.118
9 527 57.899 10.787
10 521 56.221 11.274
11 522 53.822 11.787
12 488 52.750 12.149
rank = 41 / 99

CBV


S47.7
DFOV 20.9 cm
Blood Volume (Accurate)
cursor 5x5
10
R
9
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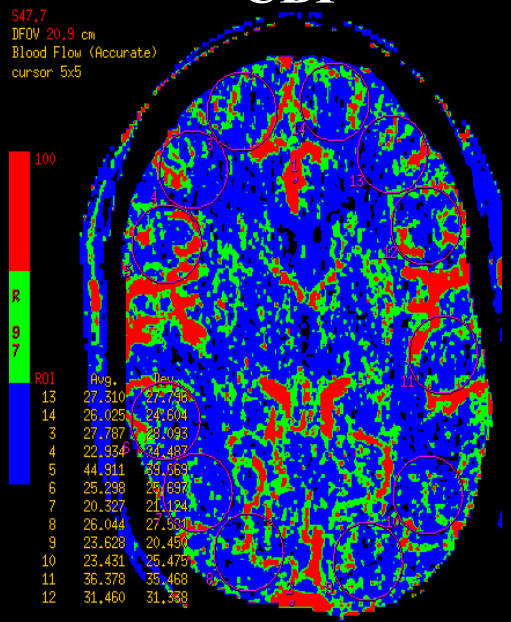
ROI Avg. Dev.
13 1.39 1.02
14 1.50 0.977
3 1.41 1.02
4 1.37 1.10
5 2.16 1.50
6 1.55 1.03
7 1.58 1.06
8 1.75 1.35
9 1.58 1.00
10 1.74 1.27
11 1.98 1.82
12 1.63 1.34

CBF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Blood Flow (Accurate)
cursor 5x5
100
R
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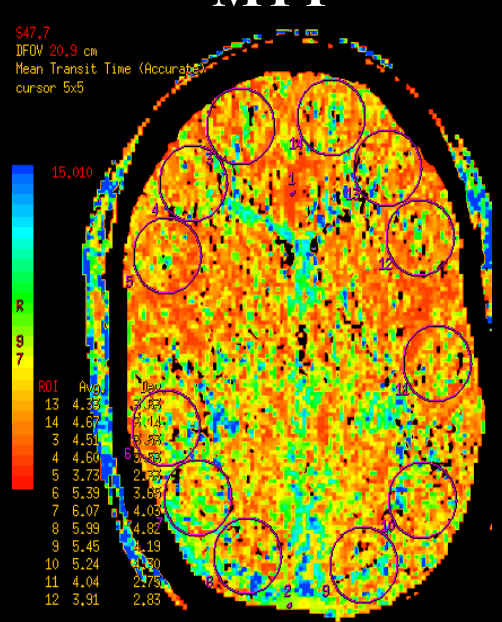
ROI Avg. Dev.
13 27.310 27.736
14 26.025 24.604
3 27.787 28.093
4 22.934 24.487
5 44.911 29.663
6 25.298 26.697
7 20.327 21.124
8 26.044 27.531
9 23.628 20.490
10 23.431 25.475
11 36.378 35.468
12 31.460 31.388

MTT


S47.7
DFOV 20.9 cm
Mean Transit Time (Accurate)
cursor 5x5
15.010
R
9
7
ROI Avg. Dev.
13 4.35 2.83
14 4.67 3.14
3 4.51 3.53
4 4.60 3.53
5 3.73 2.72
6 5.39 3.65
7 6.07 4.05
8 5.99 4.82
9 5.45 4.19
10 5.24 3.30
11 4.04 2.75
12 3.91 2.83

Technique

- Non-enhanced Brain
- CT Perfusion acquisition acquired at level of the basal ganglia
  - 8cm total coverage
  - 50cc of 370 contrast
  - 4cc/sec for 12.5 sec

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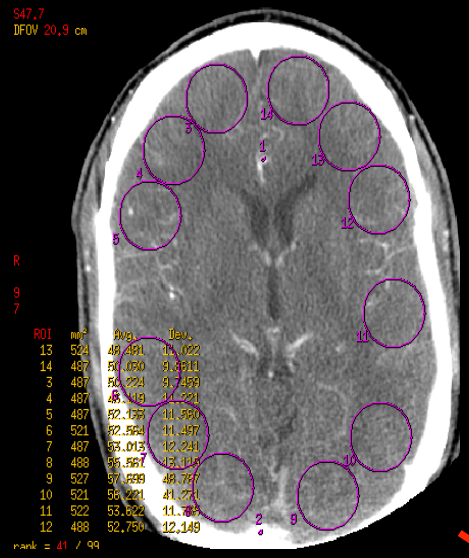
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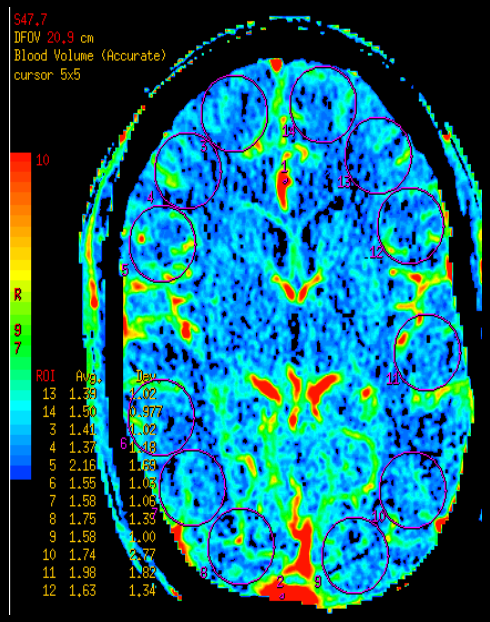
CBV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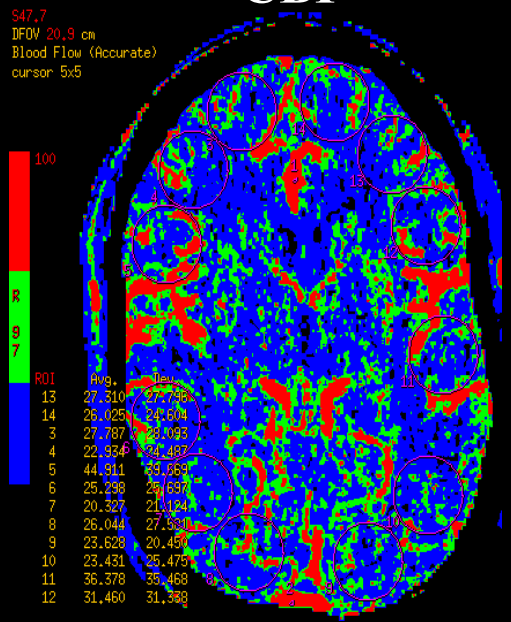
CBF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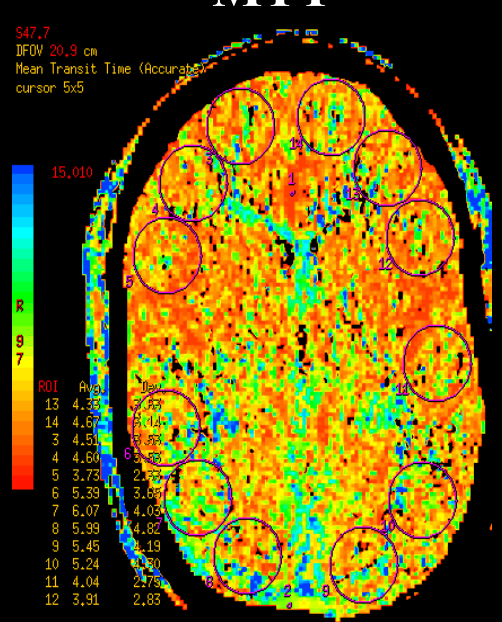
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11 4.04 2.75
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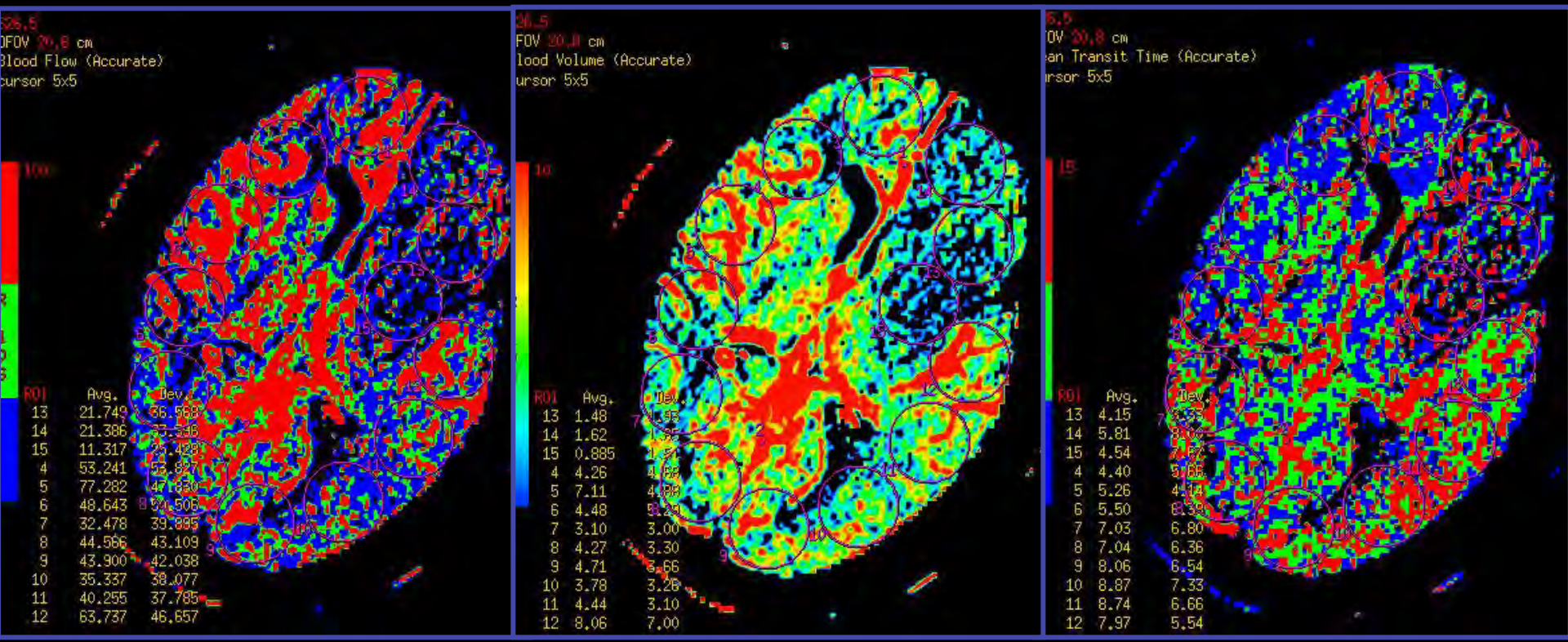
CT Perfusion

Qualitative Assessment

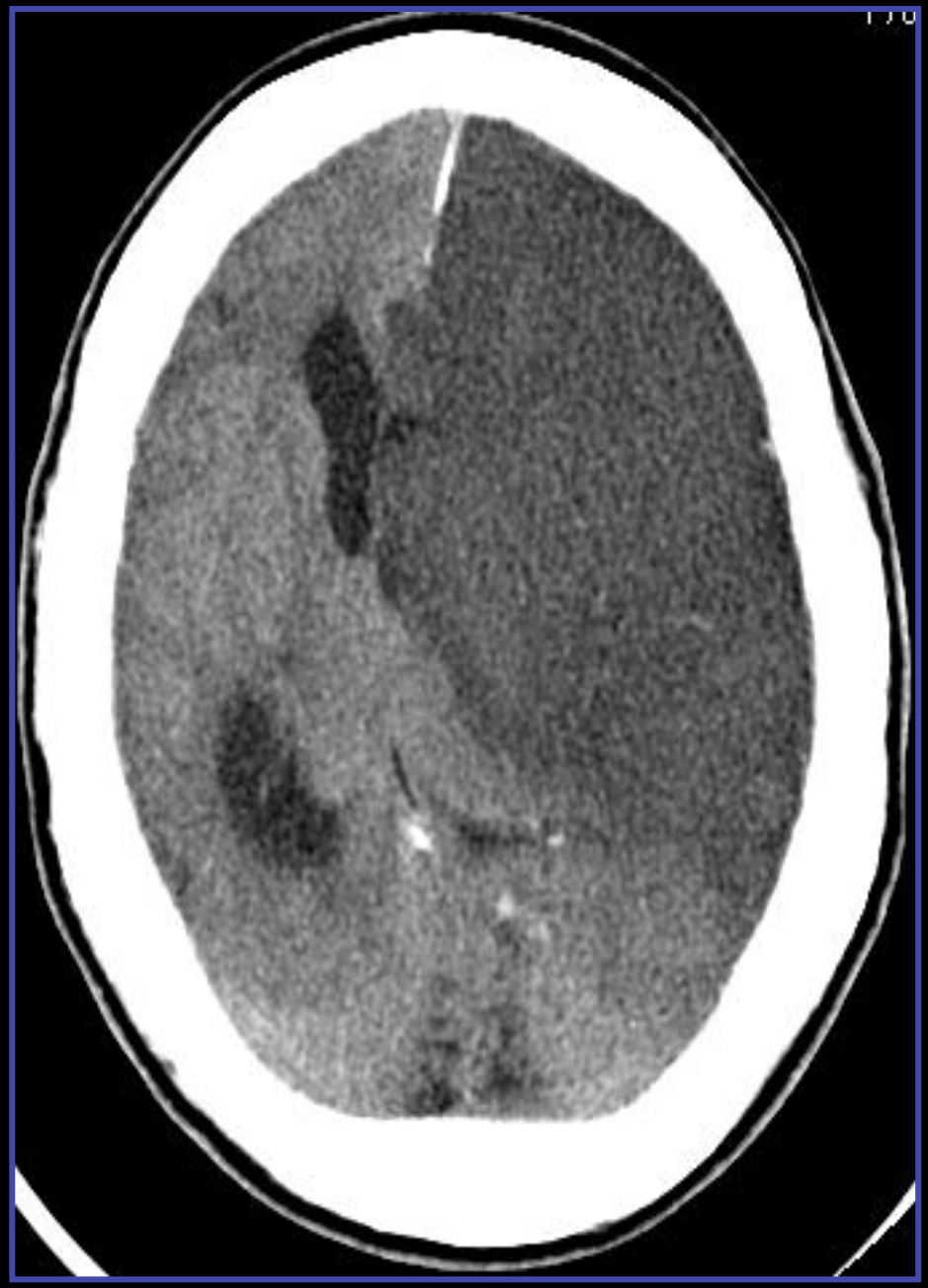
Salvageable tissue: ↓CBF, ↔↑CBV ↑ MTT

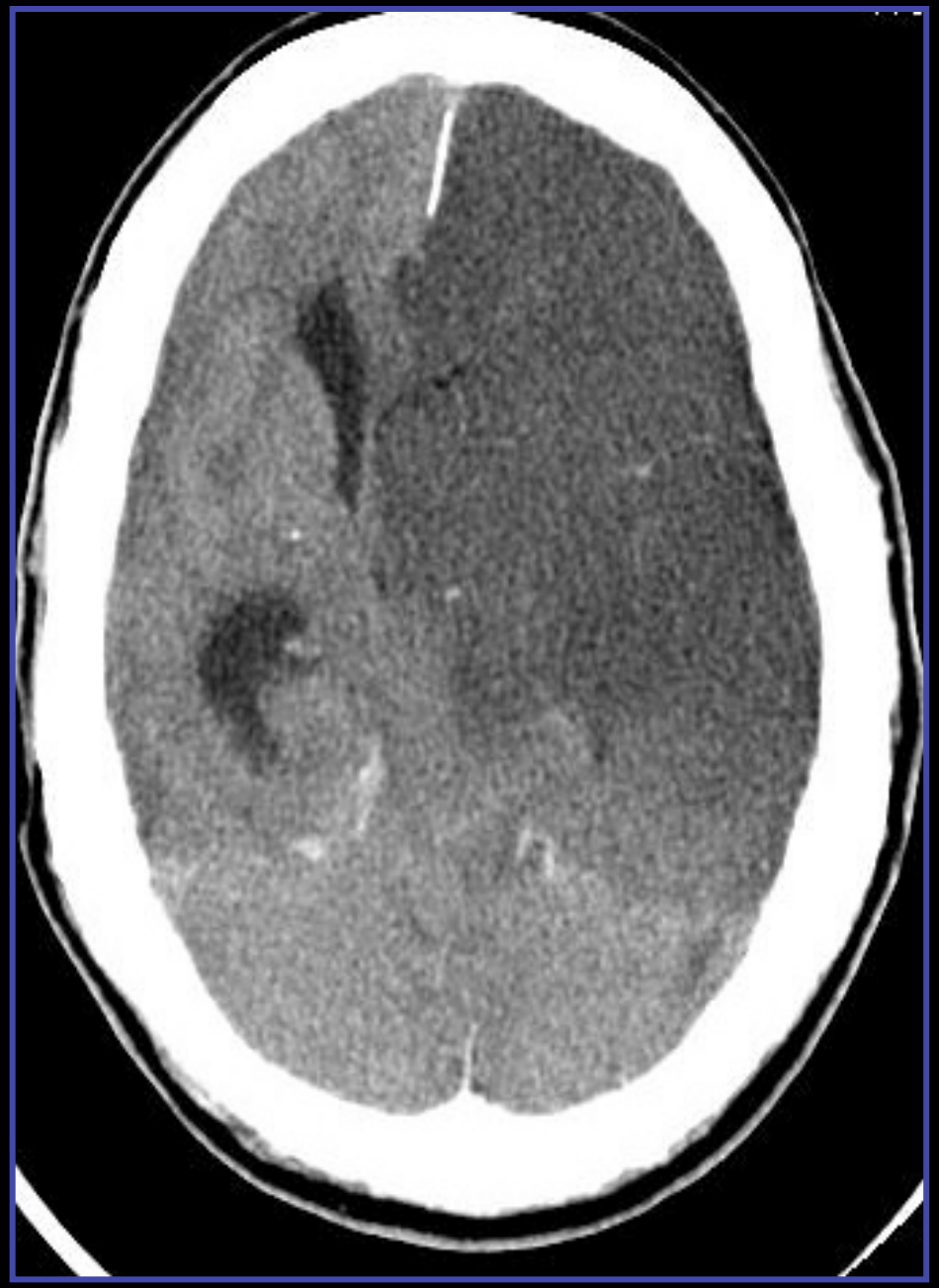
Infarct: ↓CBF, ↓ CBV and ↑ MTT

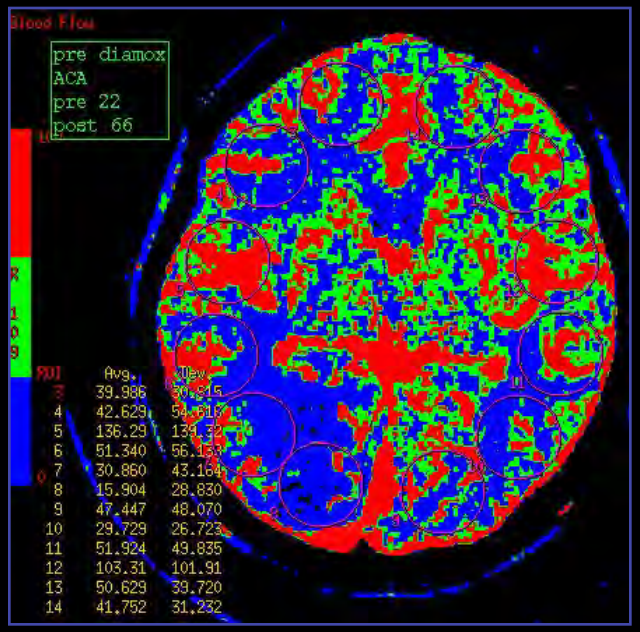
Hunter et al Radiology 2003;227:725-730

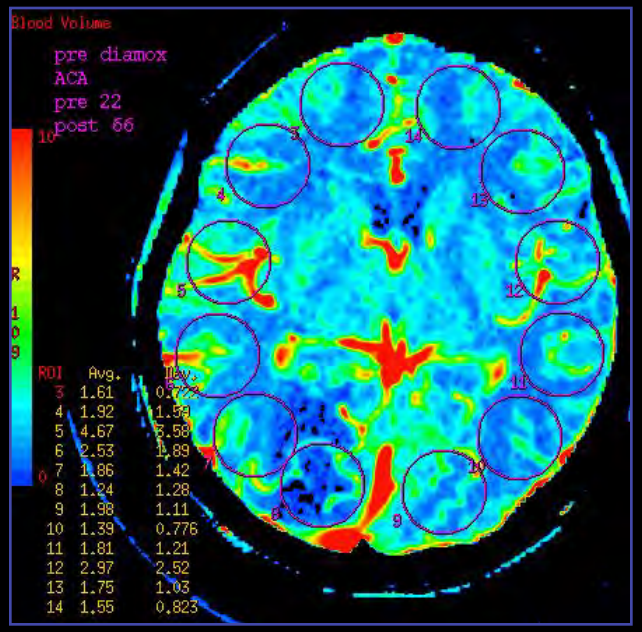


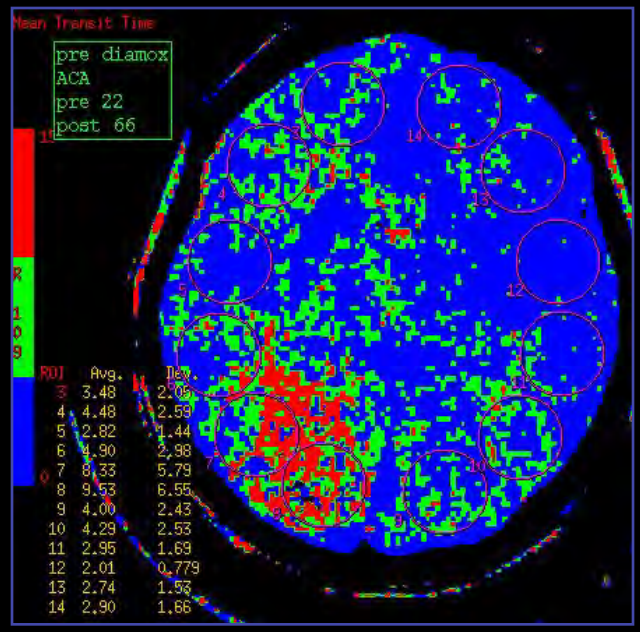
↓CBF, ↓CBV and ↑MTT in left ACA and most of left MCA territories compatible with infarction





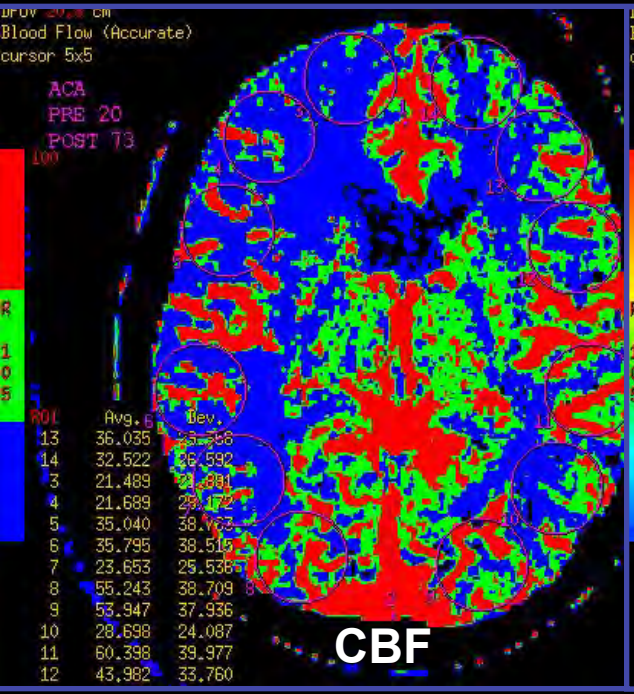


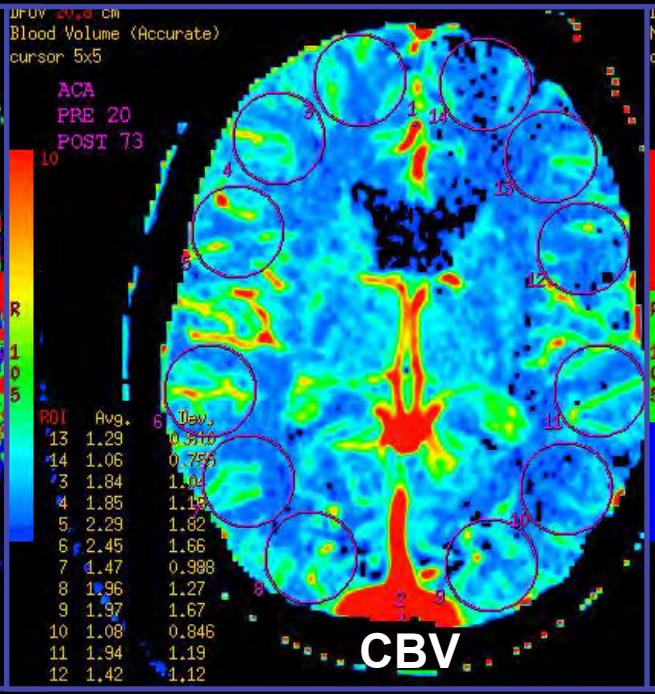


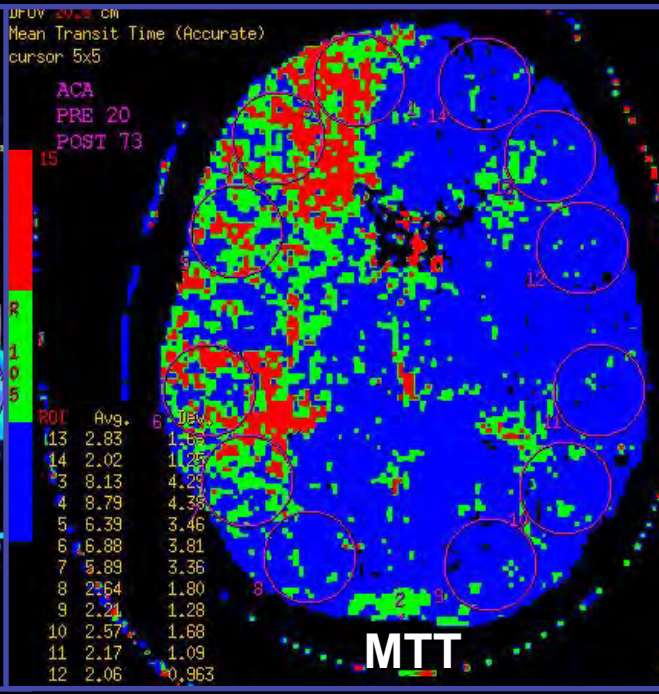


Findings compatible with right PCA infarct

- ⬇ CBF
- ⬇ CBV
- ⬆ MTT



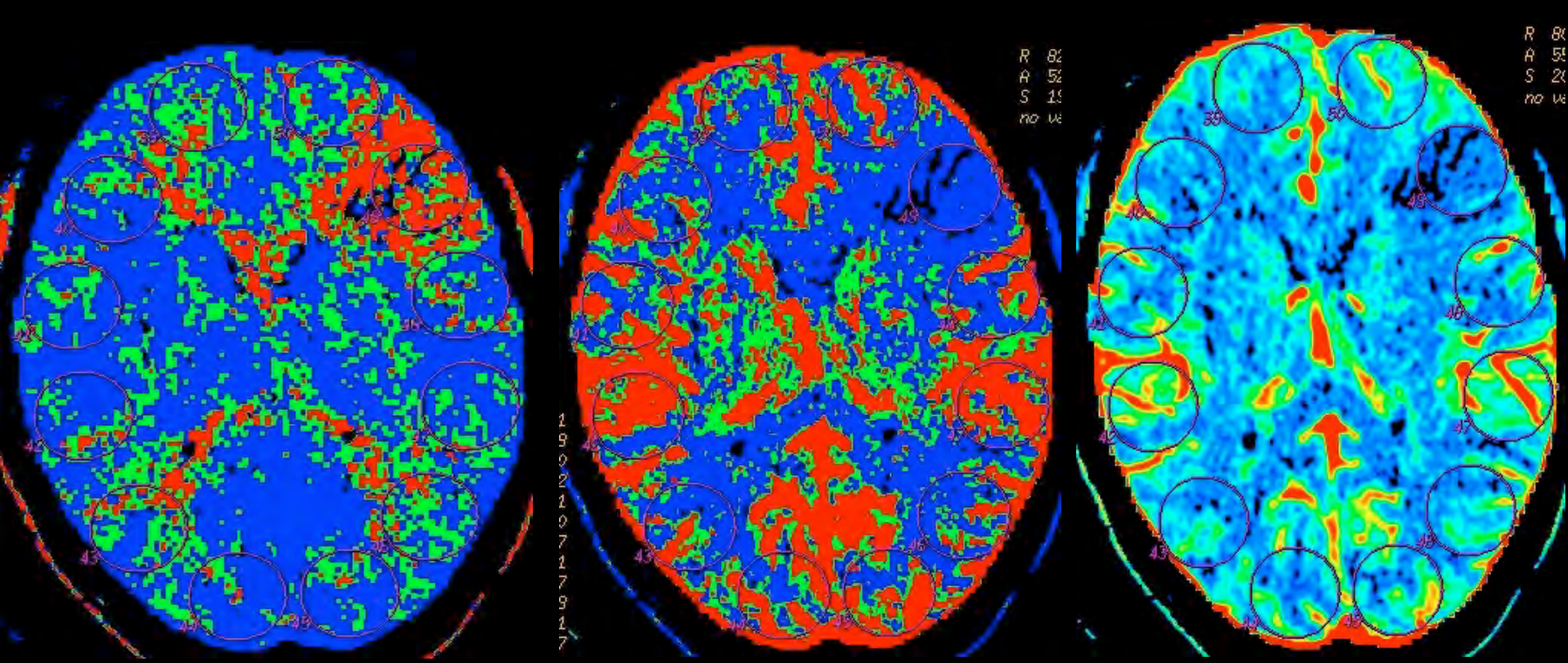




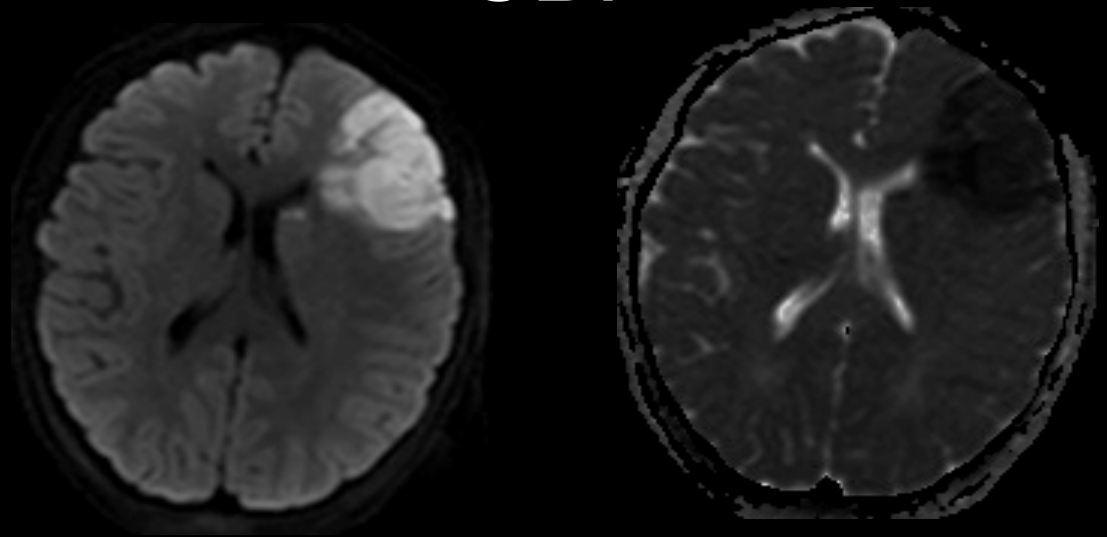
Perfusion CT changes compatible with ischemia

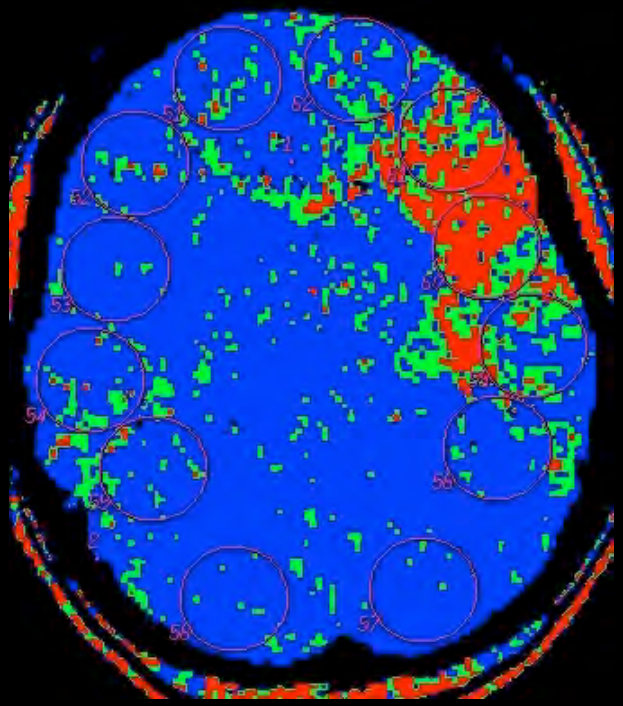
- ↓ CBF
- → CBV
- ↑ MTT

No cortical infarct on 8 mo. follow up CT

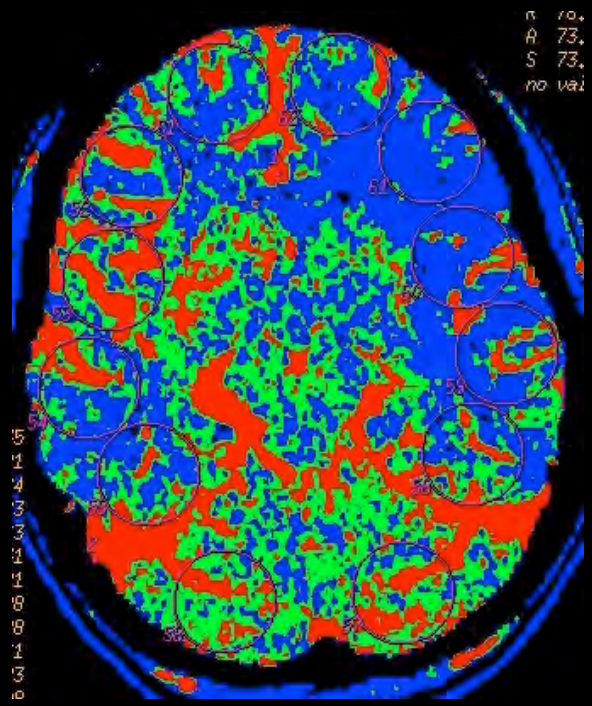


MTT CBF CBV

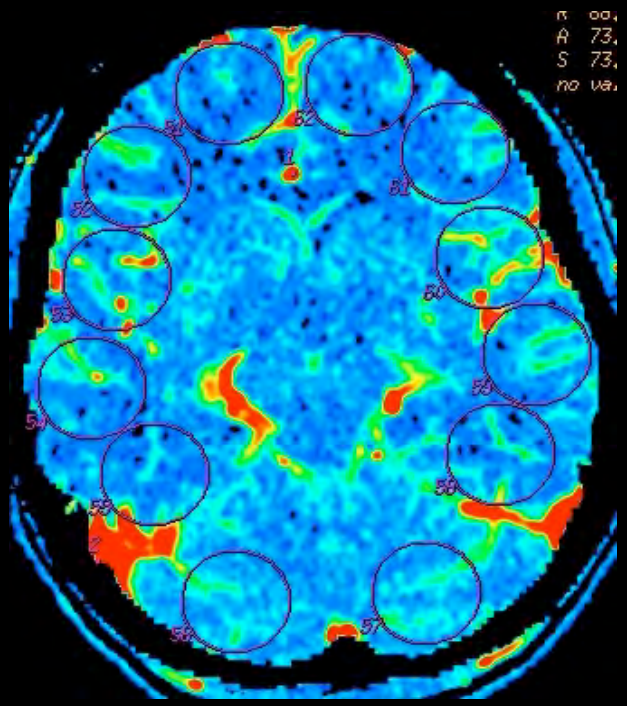




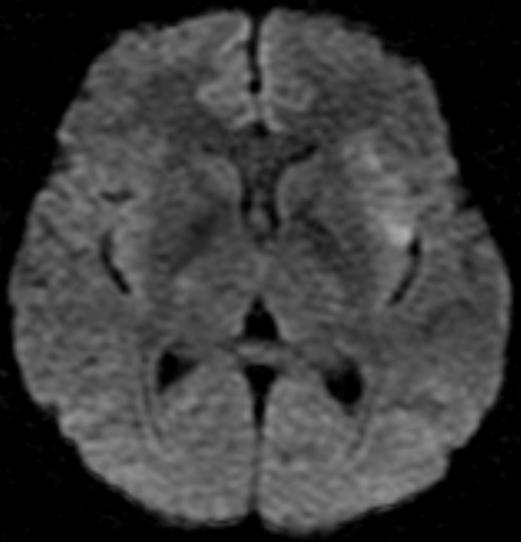
MTT

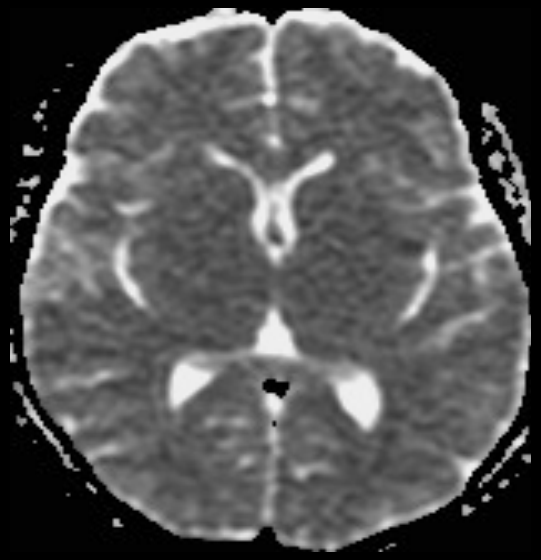


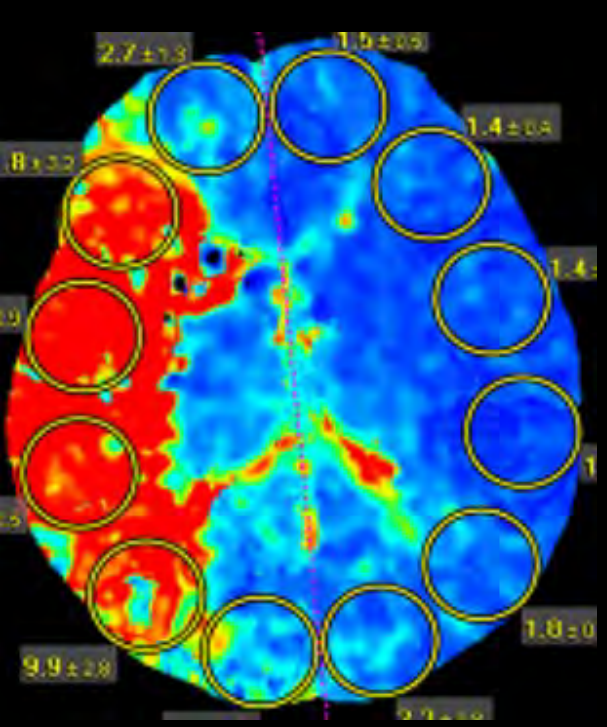
CBF



CBV







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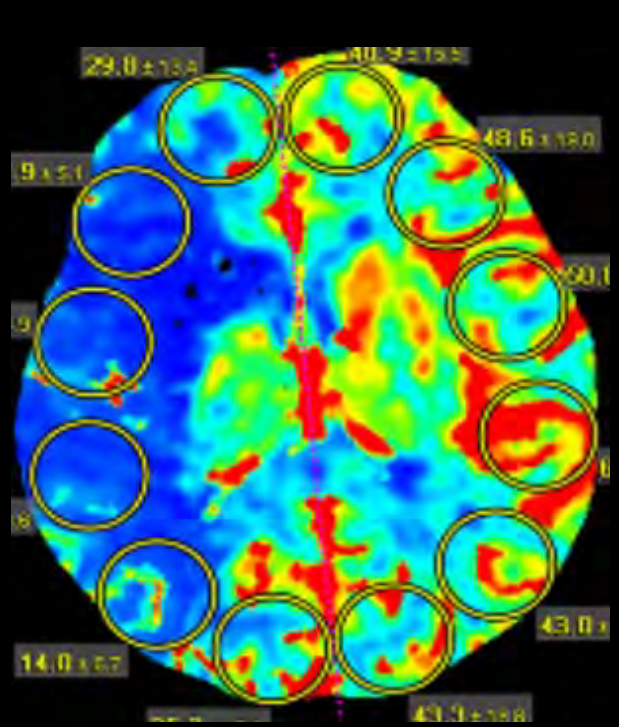
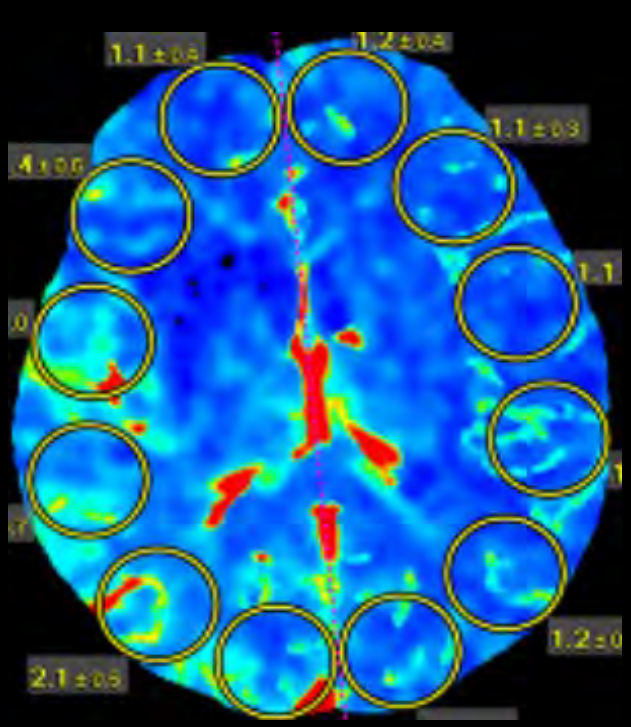
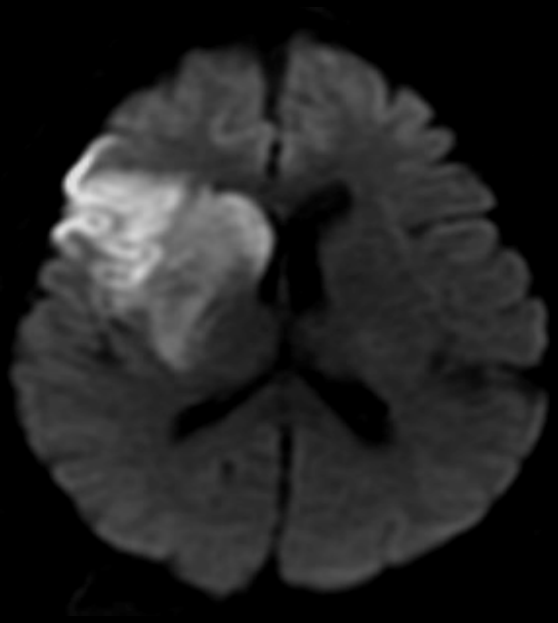


CBF



CBV



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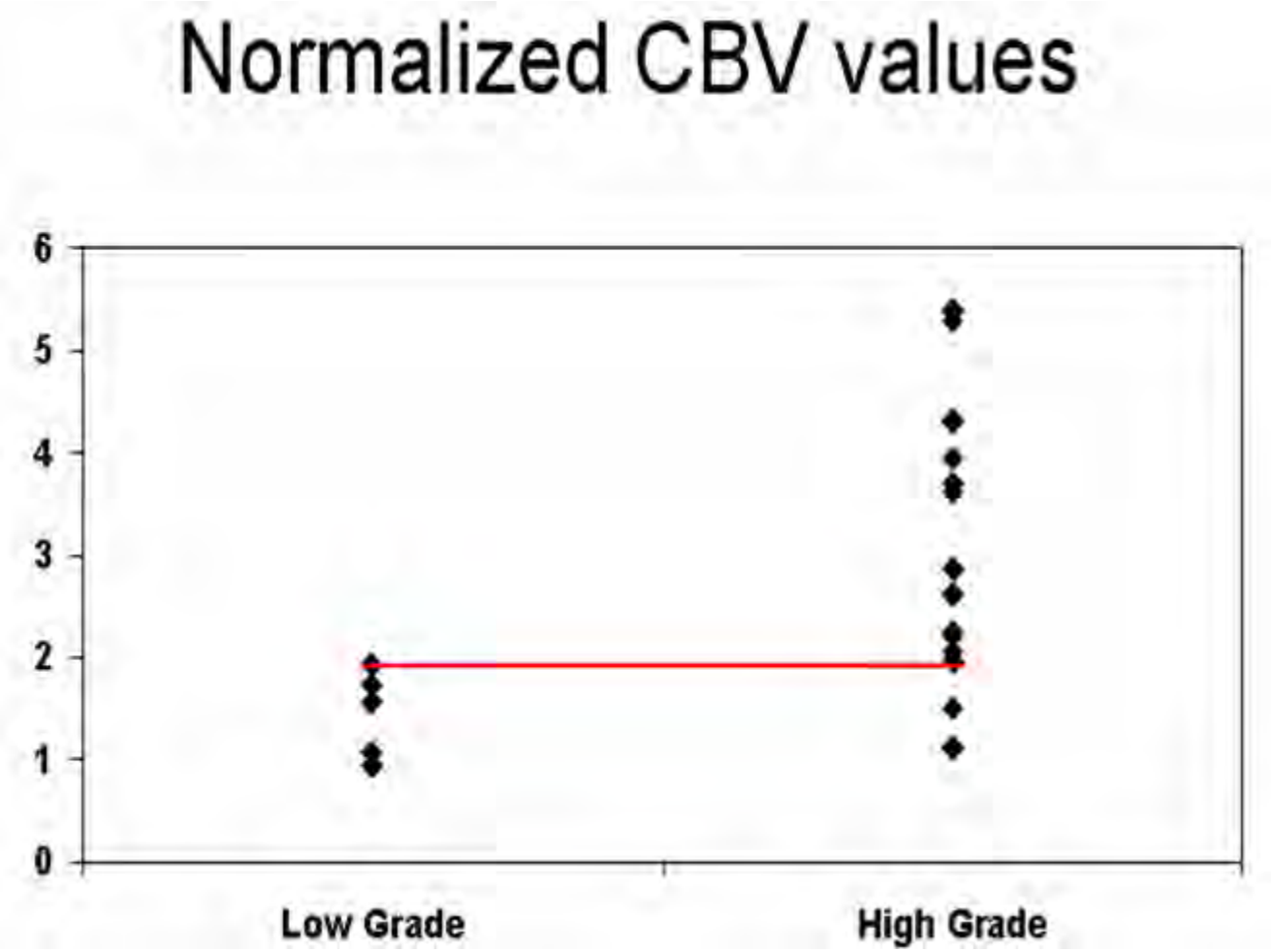
Perfusion CT Imaging: Glioma Grading

# patients	nCBV Mean (SD)	nCBF Mean (SD)	nMTT Mean (SD)
Low Grade (5)	**1.44 (0.42)**	**1.16 (0.36)**	**1.69 (1.12)**
High Grade (14)	**3.06 (1.35)**	**3.03 (2.16)**	**1.29 (0.55)**
p-value	0.005	0.045	**0.559**

Ellika S, Jain R et al. AJNR Am J Neuroradiol. 2007 Nov-Dec;28(10):1981-7.

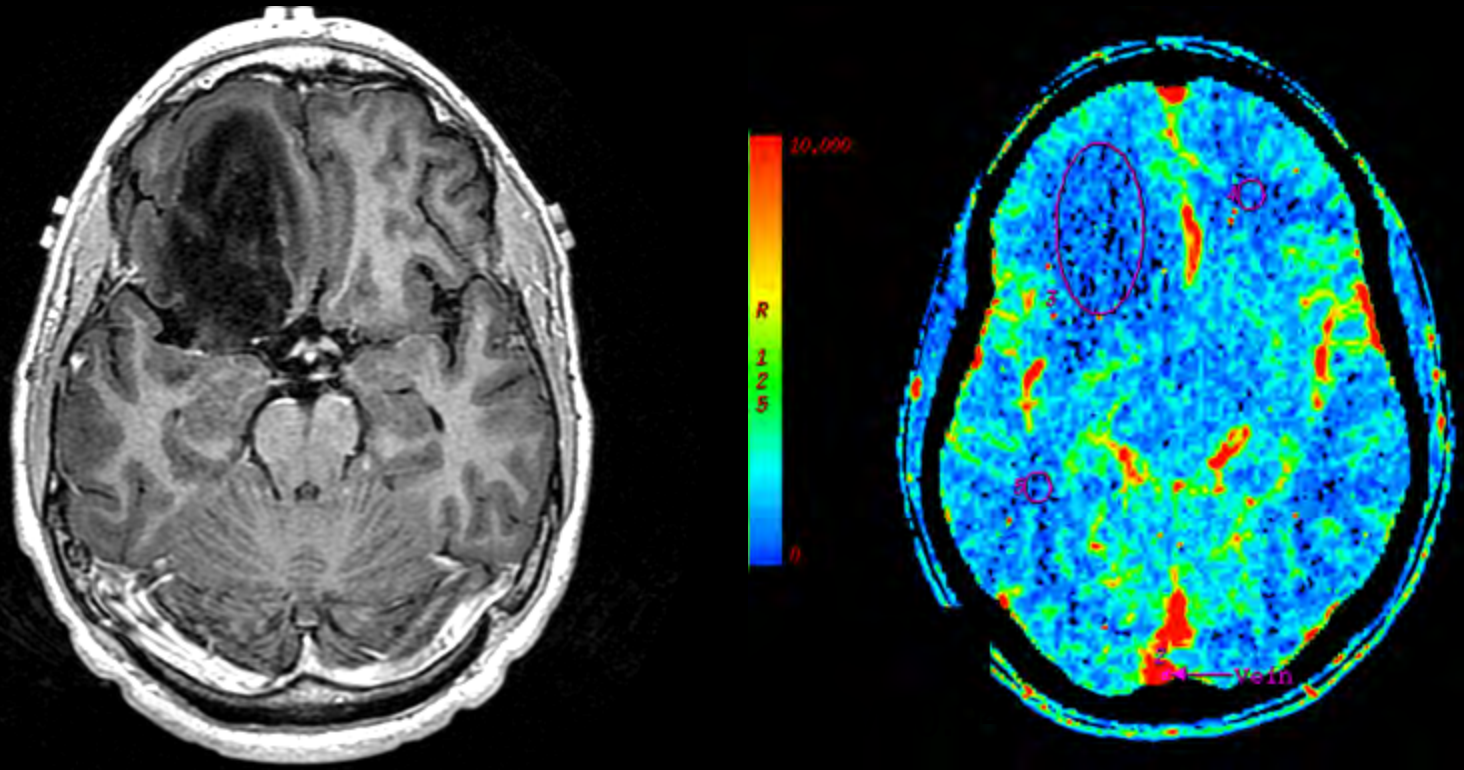
Perfusion CT Imaging: Glioma Grading



Ellika S, Jain R et al. AJNR Am J Neuroradiol. 2007 Nov-Dec;28(10):1981-7.

WHO Grade II (Low Grade Glioma)

34 yo man with WHO grade II glioma.
CBV map shows low blood volume (nCBV=0.94).



Post-gad T1WI

CBV map

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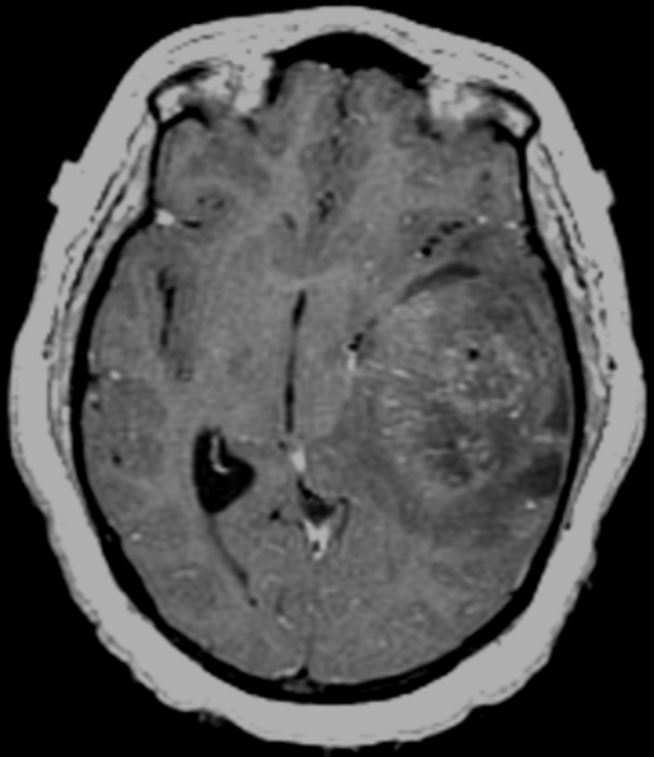
WHO Grade III (Anaplastic Astrocytoma)

WHO grade III glioma in a 39 yo woman who presented with seizure. CBV map shows higher CBV (nCBV=2.61).



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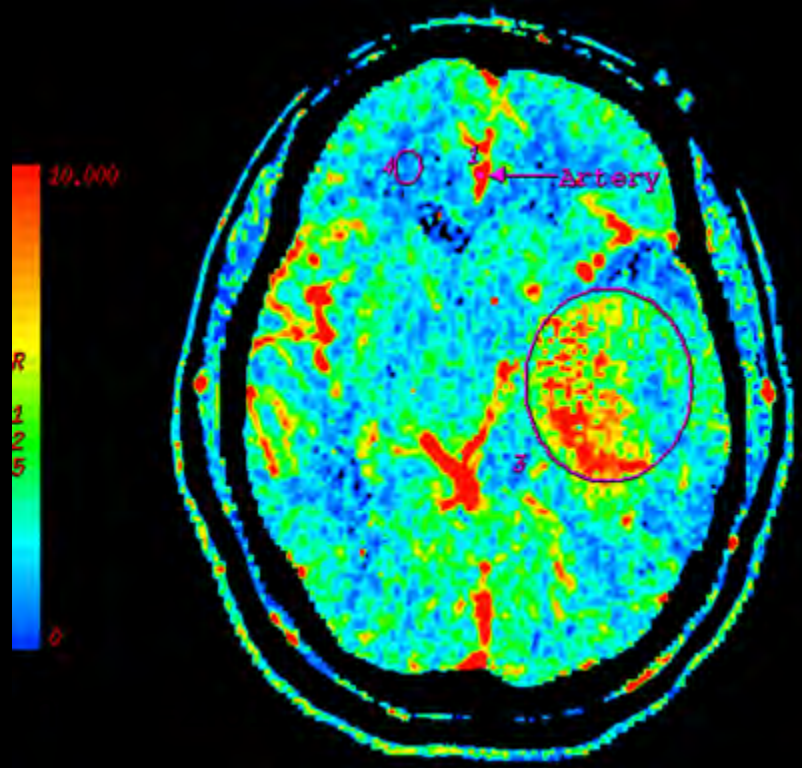

CBV map

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Perfusion CT : Recurrent Tumor vs. Radiation Necrosis

	nCBV Mean (SD)	nCBF Mean (SD)	nMTT Mean (SD)
Recurrent Tumor (RT)	**2.54 (0.22)**	**2.63 (0.34)**	**1.02 (0.09)**
Cerebral Radiation Necrosis (CRN)	**1.17 (0.15)**	**0.97 (0.08)**	**1.41 (0.09)**
p-values RT vs. CRN	**<0.0001**	**<0.0001**	**<0.0042**

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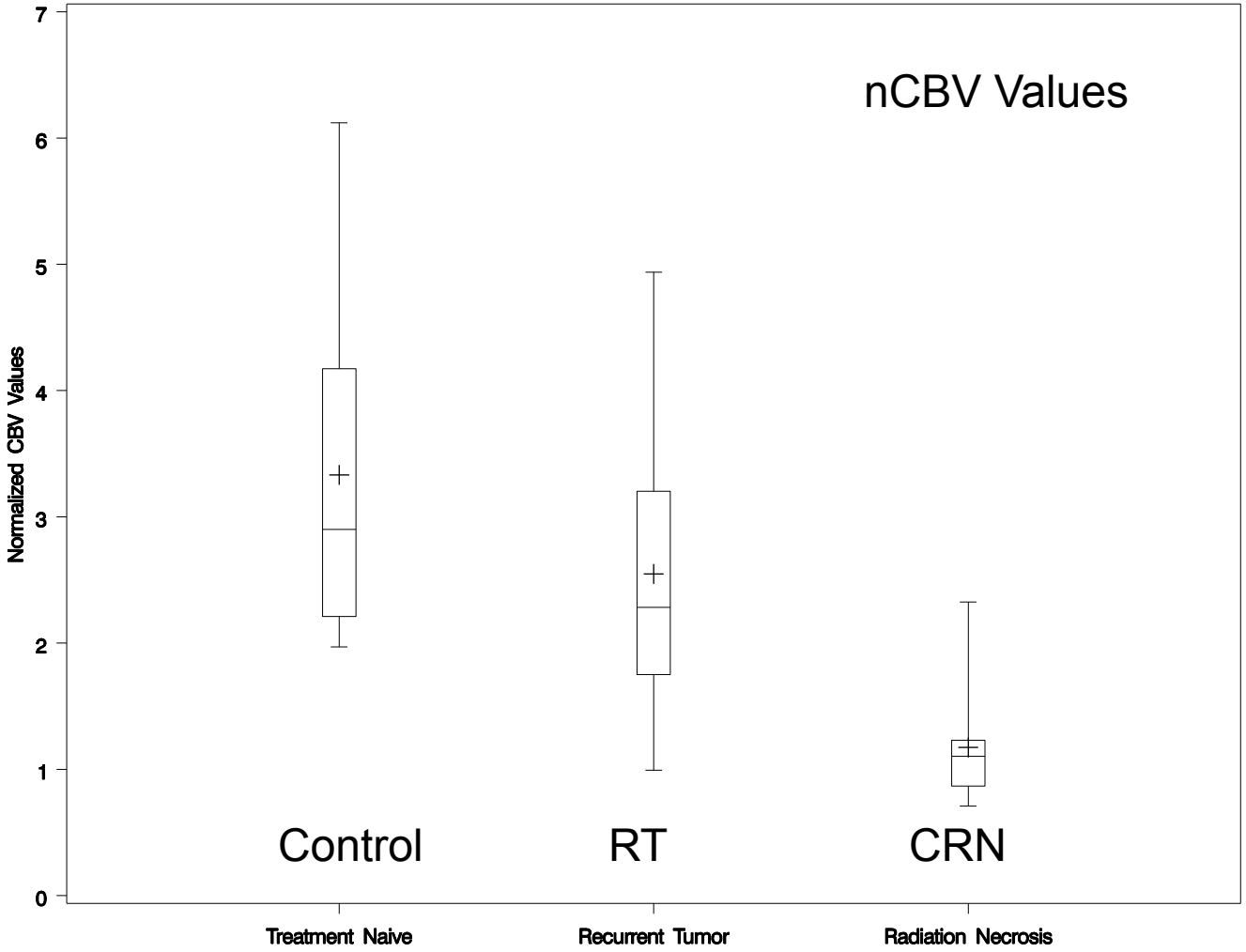
Perfusion CT Imaging: Recurrent Tumor vs. Radiation Necrosis



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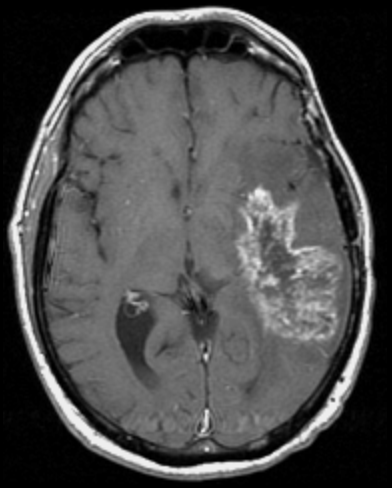
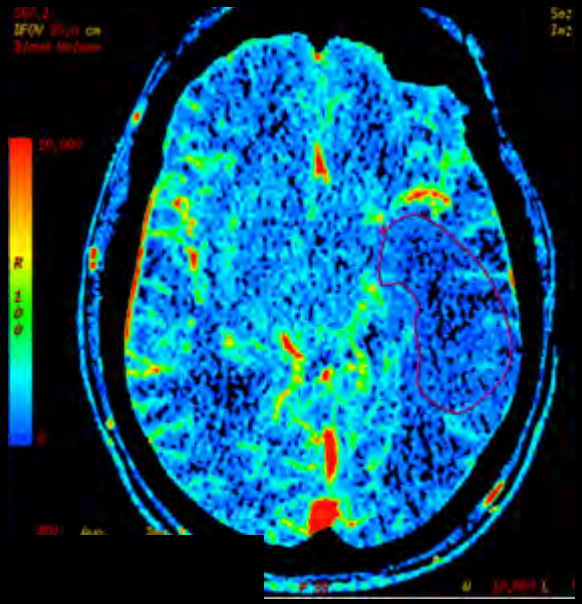
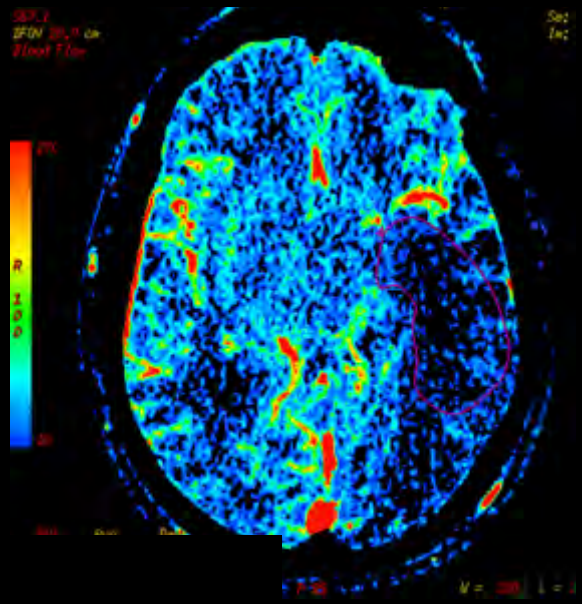
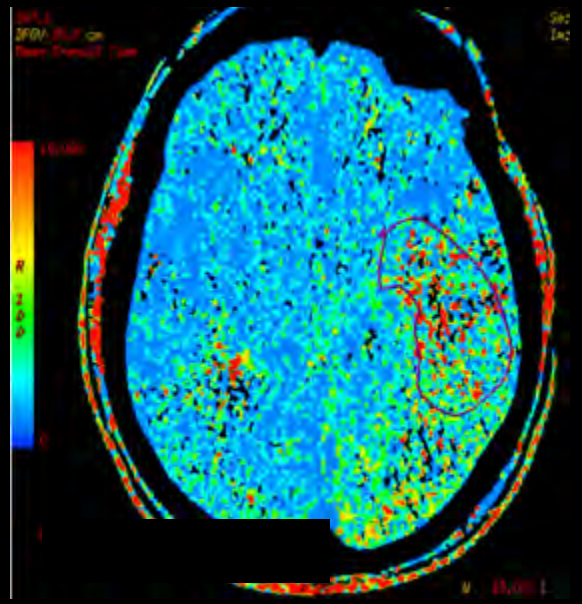


Cerebral Radiation Necrosis

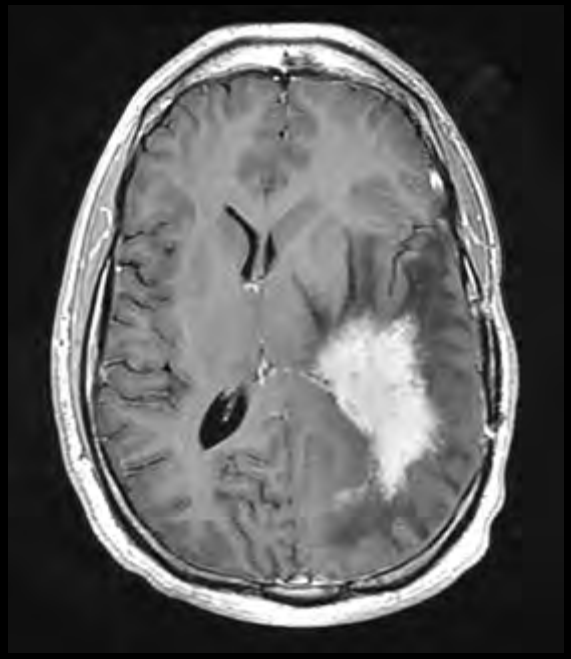
49 yo male with left temporal lobe anaplastic astrocytoma presented with a recurrent enhancing lesion 13 months after radiation therapy.





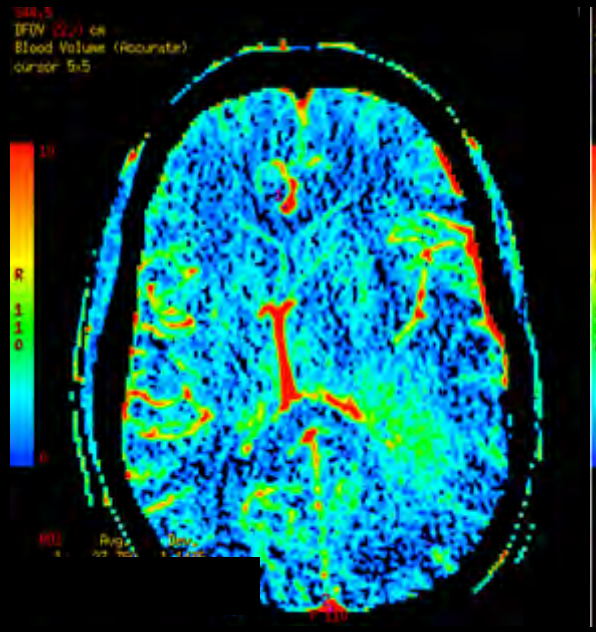


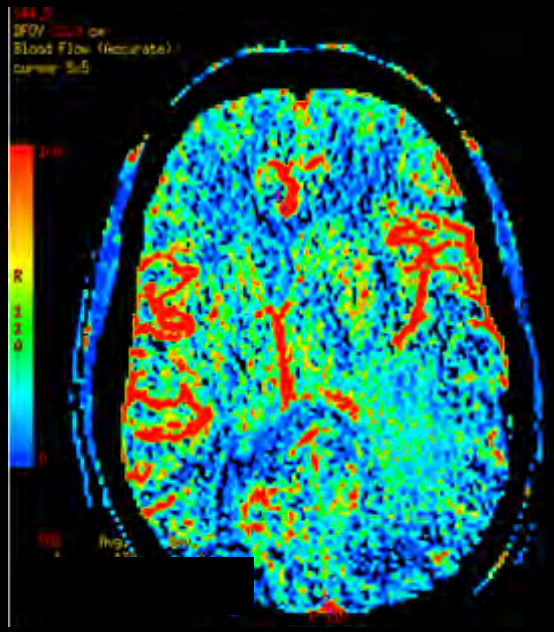
Low CBV, low CBF and high MTT consistent with cerebral radiation necrosis.

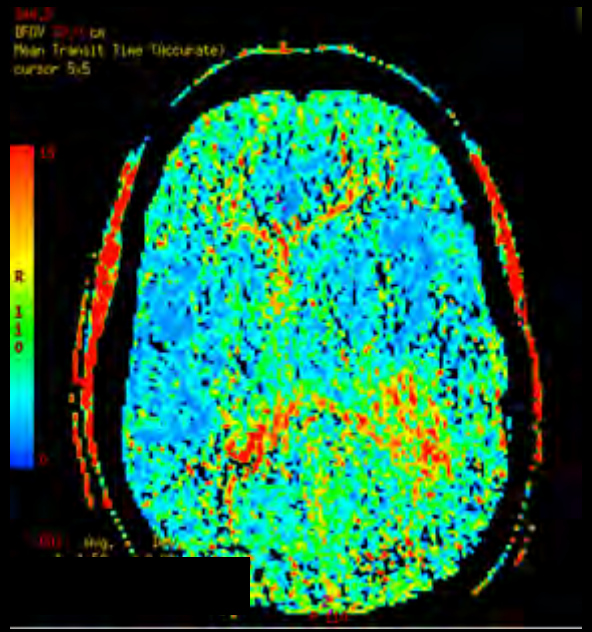


Recurrent Tumor

21 yo male with a left posterior temporal lobe astrocytoma 24 months after radiation therapy presenting with a recurrent enhancing lesion



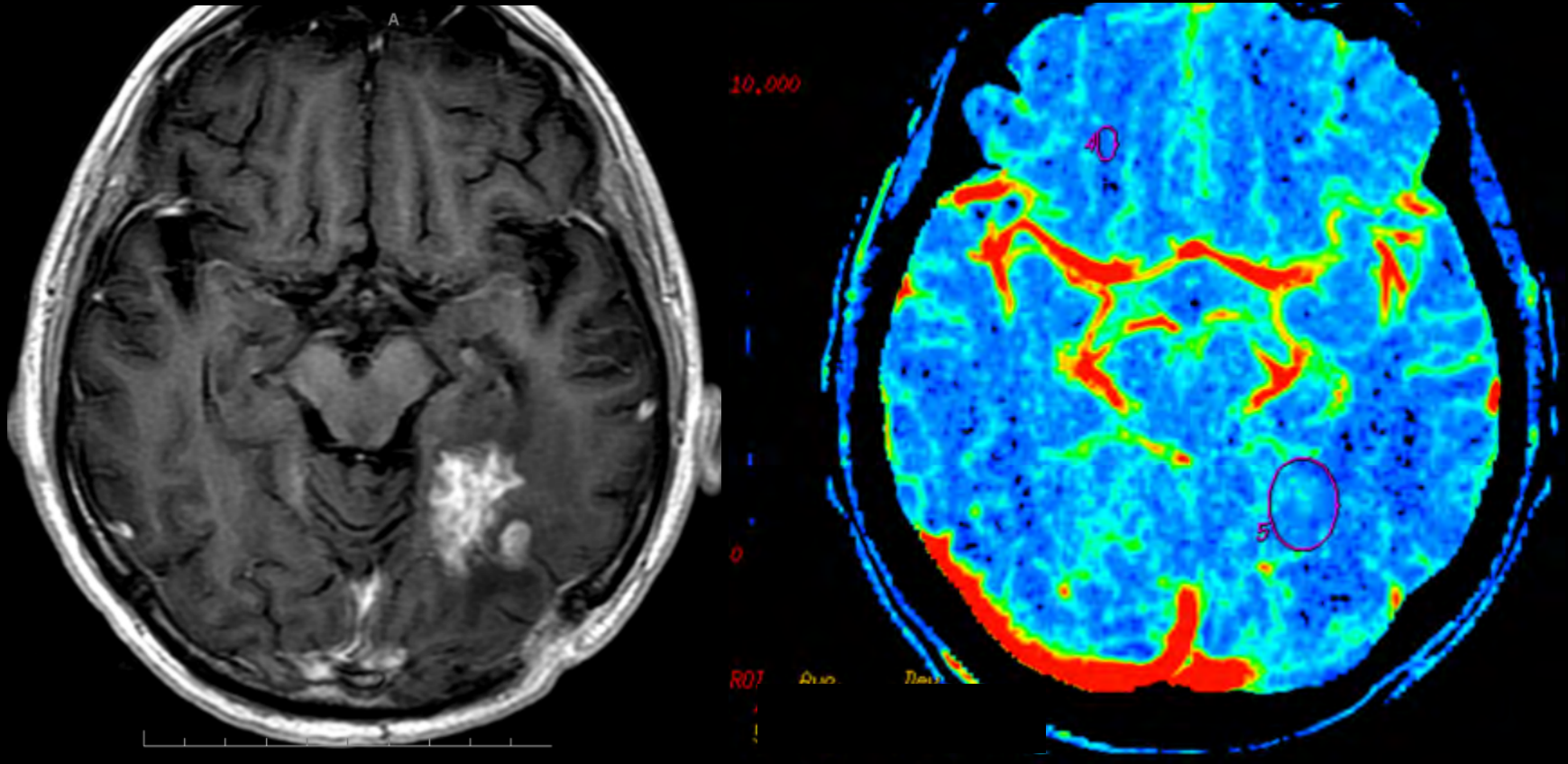




High nCBV, high nCBF and lower nMTT suggestive of recurrent tumor

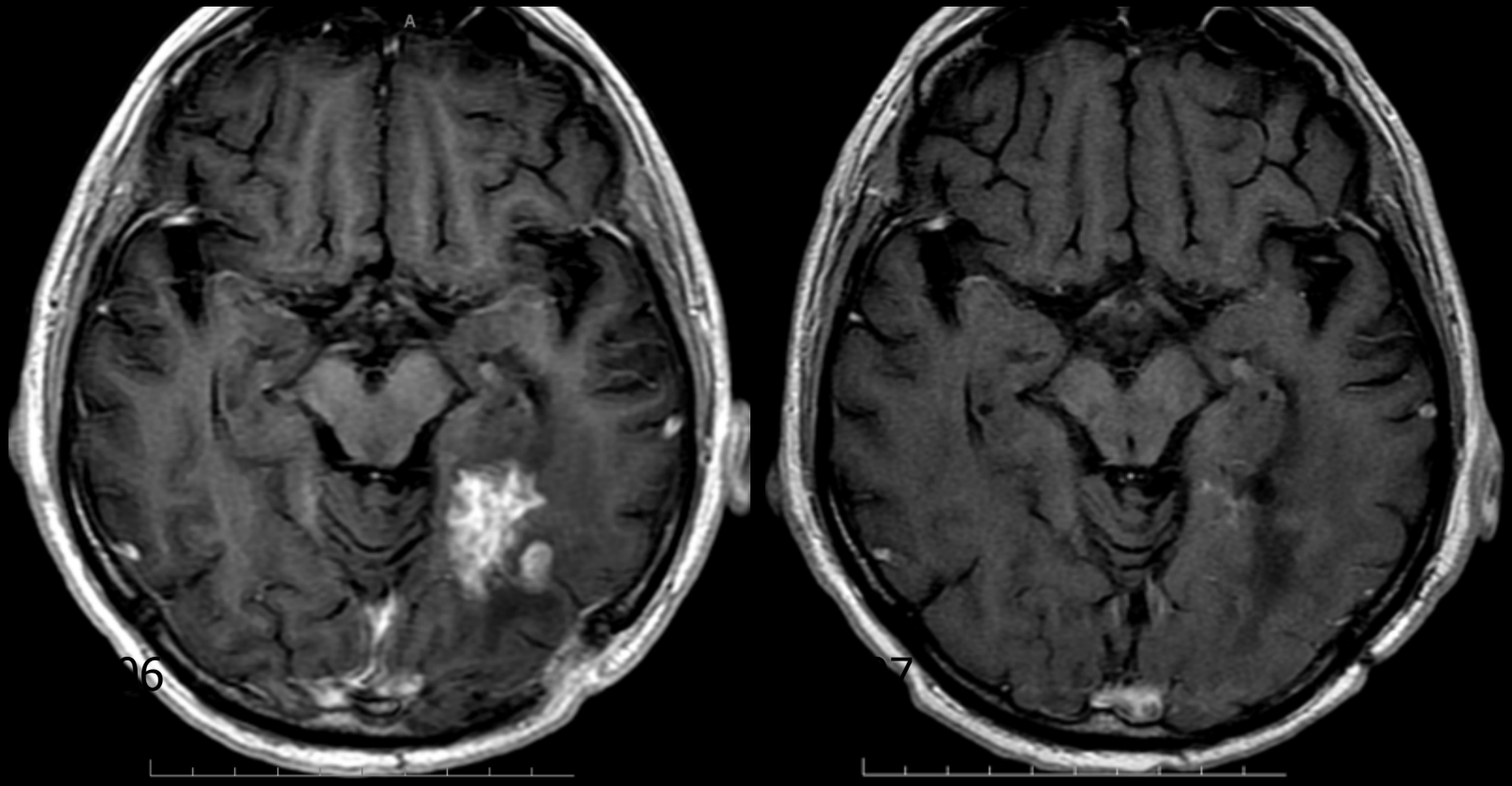
Cerebral Radiation Necrosis

50 yo male post radiation therapy for lung carcinoma metastases.
Lesion has low CBV suggesting cerebral radiation necrosis.



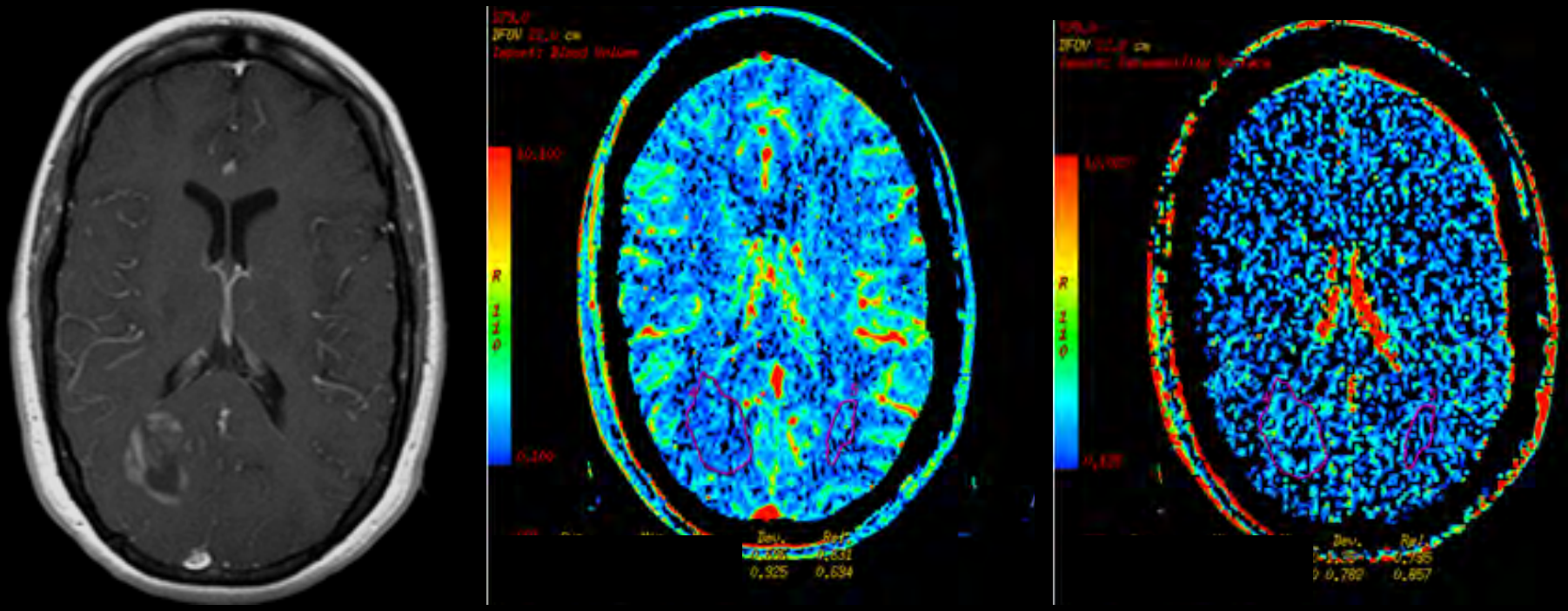
Cerebral Radiation Necrosis

Patient was treated supportively with Vitamin E and Trental, and no anti-neoplastic treatment. 8 month follow-up MR shows resolution of the lesion confirming radiation necrosis.



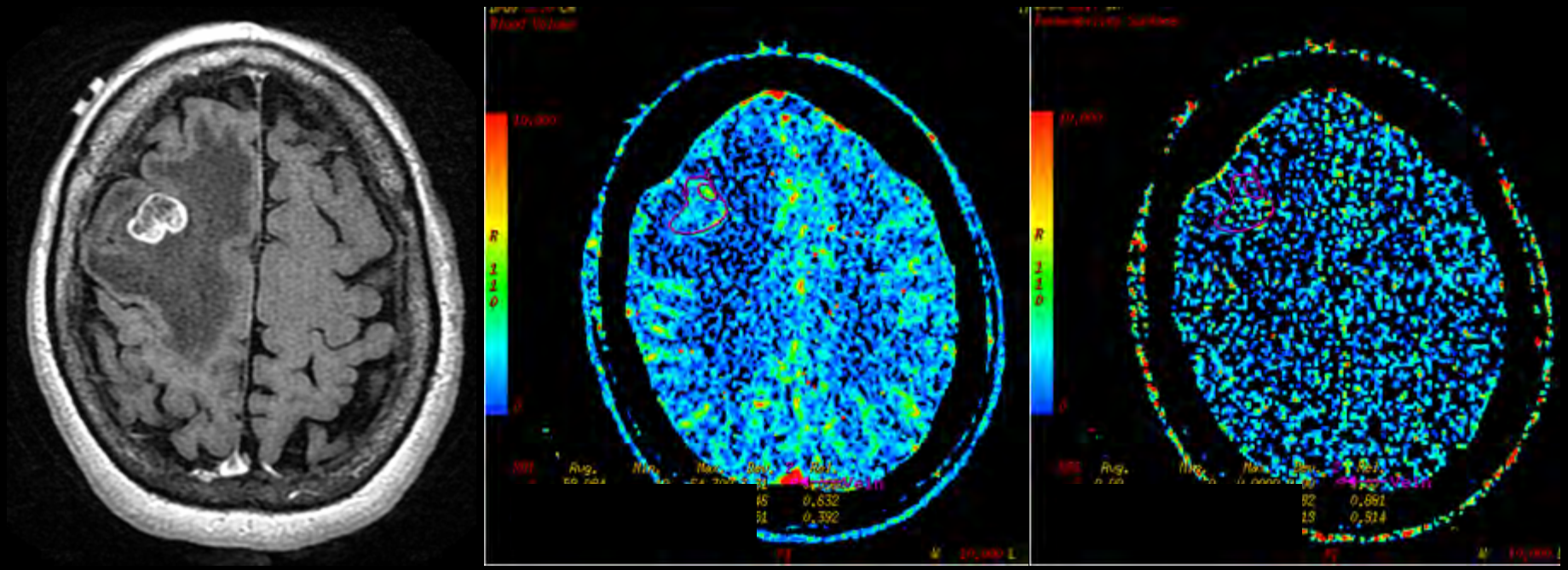
38 yo female with dizziness and headache

Low CBV suggested tumefactive MS rather than a glioma. Biopsy revealed this to be a demyelinating lesion.



63 yo female with history of multiple sclerosis and a lung mass

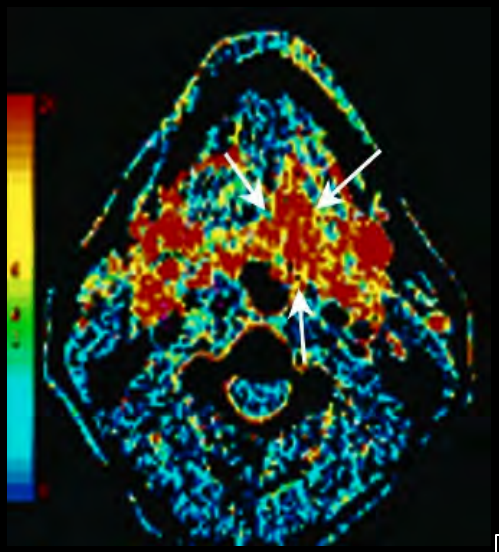
High CBV and low PS suggested neoplasm rather than TDL. Biopsy showed metastatic adenocarcinoma.



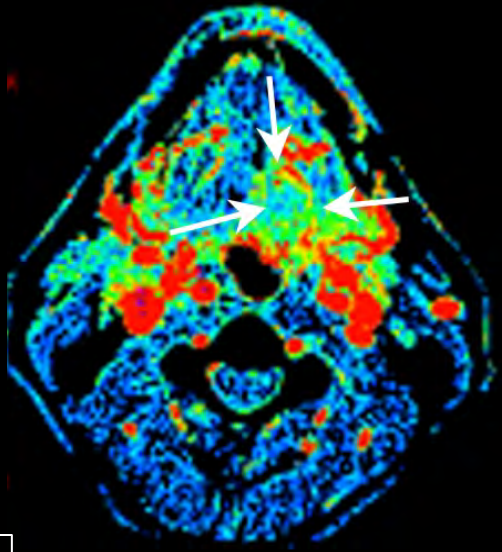
Outline

- Technique
- Clinical Applications
  - Stroke
  - Brain Tumors
  - Head & Neck

CT Perfusion



Capillary Perm



Blood Volume

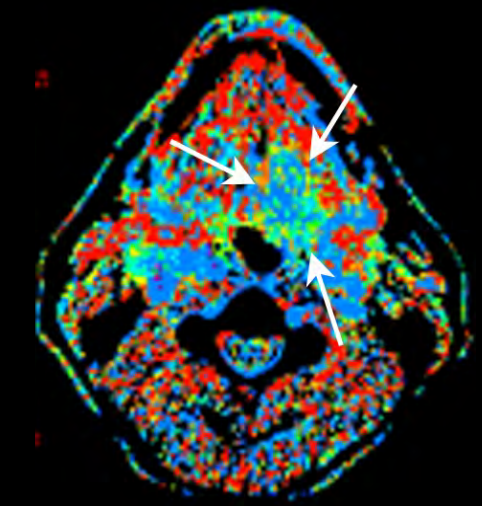
HNSCCA vs Normal Muscle

↑ CP

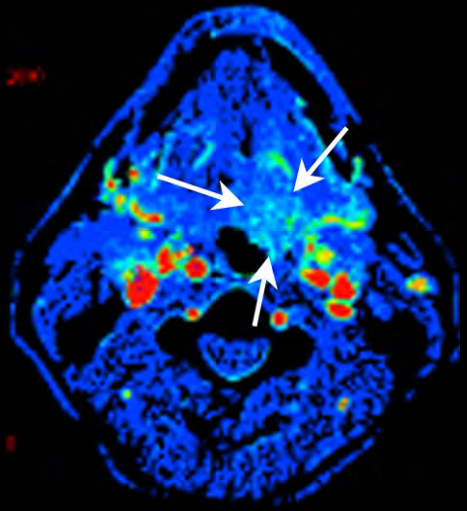
↑ BF

↑ BV

↓ MTT



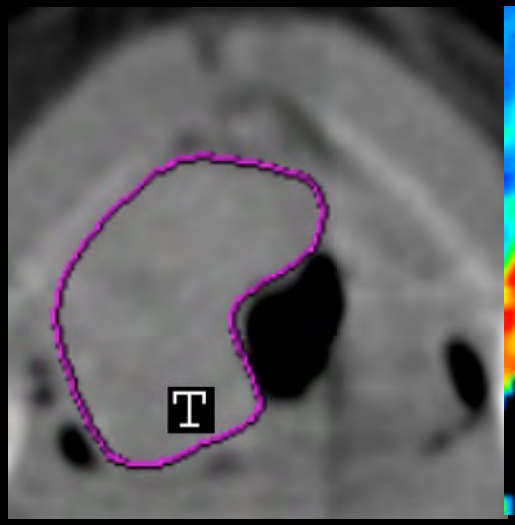
Mean Transit Time

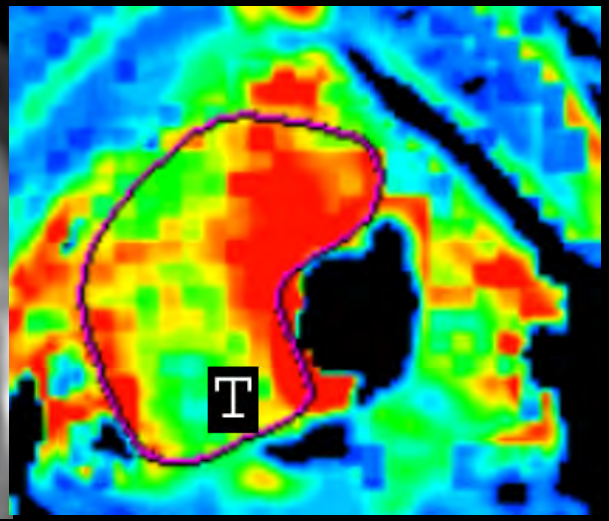


Blood Flow

CTP Perfusion vs Microvascular Density

- Intratumoral microvessl density (MVD)
  - Marker of tumor angiogenesis
  - Prognostic indicator in head and neck squamous cell carinoma (HNSCCA)
- Increased MVD
  - Advanced tumor stage
  - Locoregional and distant metastases
  - Reduced disease-free survival
  - Higher tumor oxygenation
- Requires endoscopic biopsy/tissue specimen

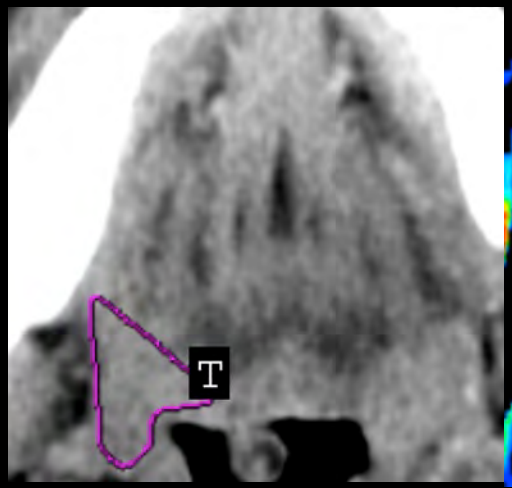


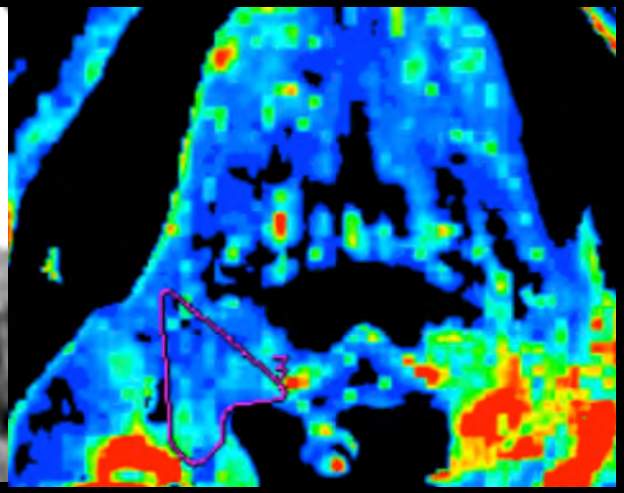


45 yo male with stage IV

Tongue Base SCCA

- Increased BF = 190.15 ml/100g/min
- Increased MVD = 47.2 vessels/mm2





57 yo female with stage III

Tongue Base SCCA

- Decreased BF = 39.13 ml/100g/min
- Decreased MVD = 19.2 vessels/mm2

Ash et al. Radiology 2009;251:422-428

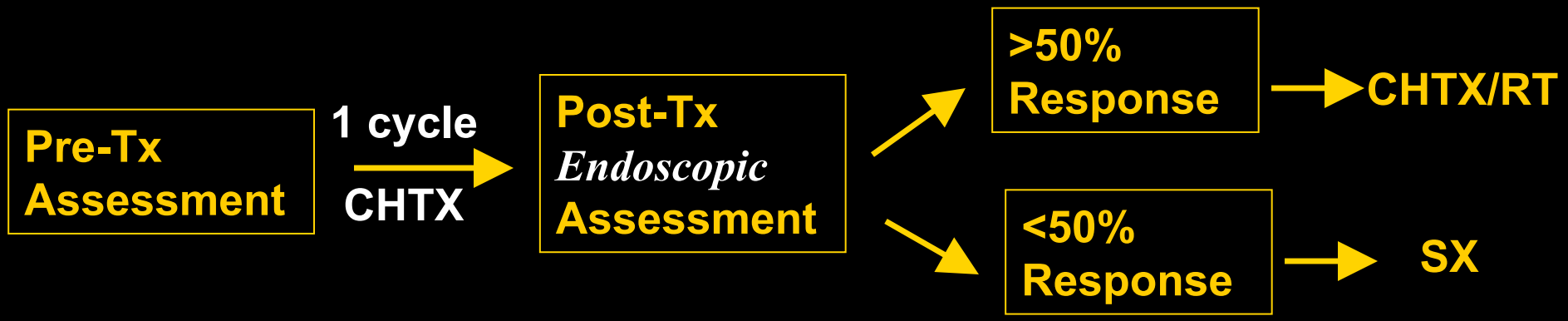
CT Perfusion

Microvascular Density

- Positive correlation
  - MVD & BF
  - MVD & BV
- No correlation
  - MVD & MTT
  - MVD & CP

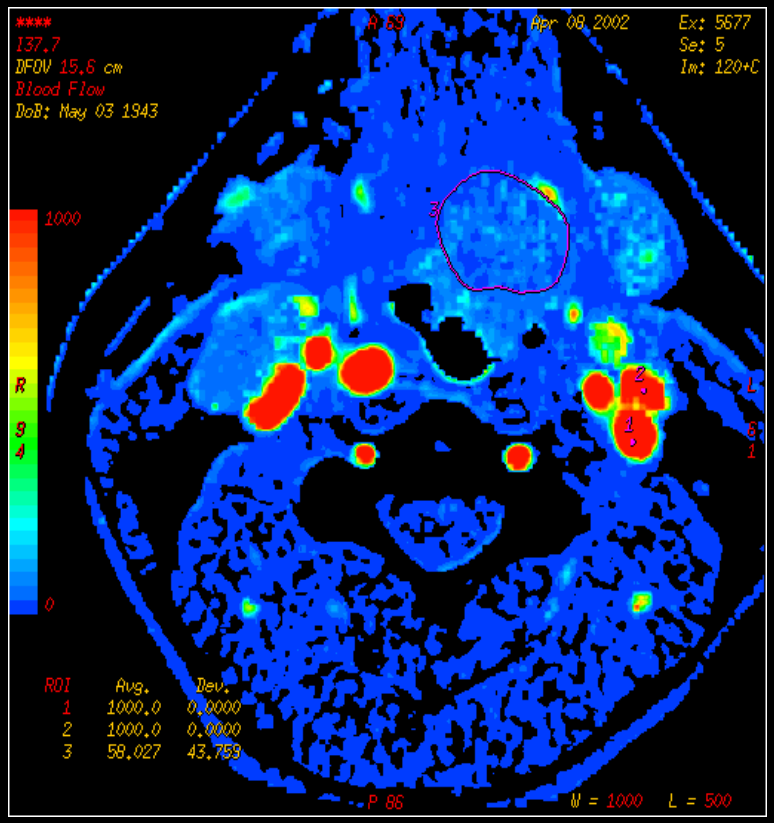
Clinical Applications

Neoadjuvant Protocol

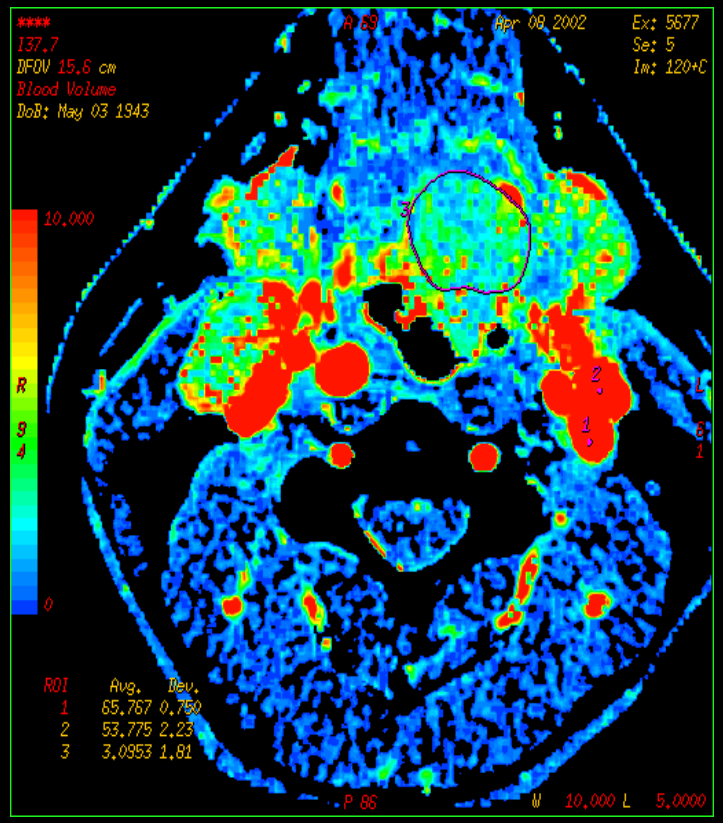


CT Perfusion

Pre-treatment Parameters



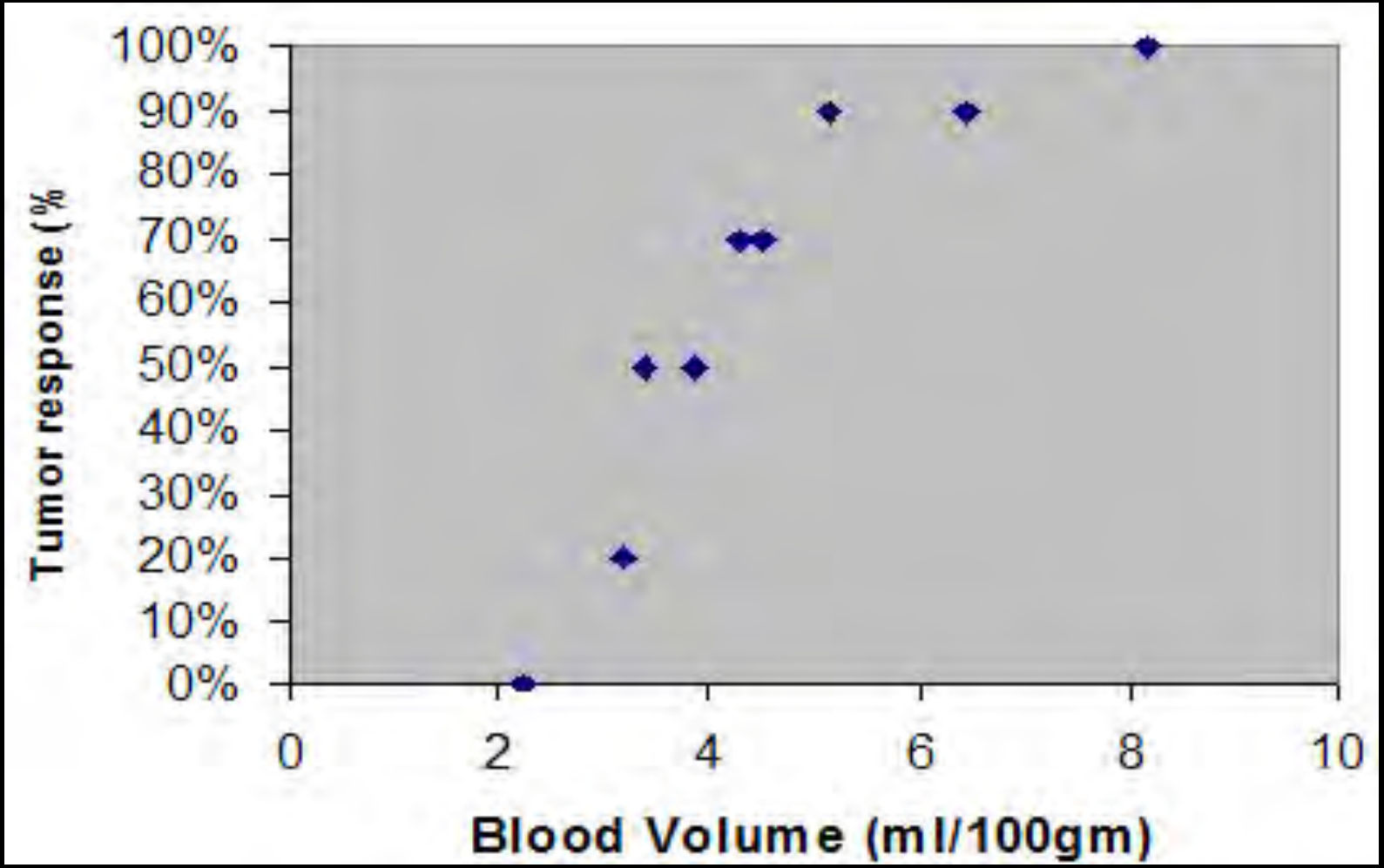
Blood Flow



Blood Volume

CT Perfusion

Pre-treatment Parameters: Blood Volume



CT Perfusion

Pre-treatment Parameters

- Pretreatment values of BV & BF were significantly correlated to >50% reduction in tumor size following induction therapy.

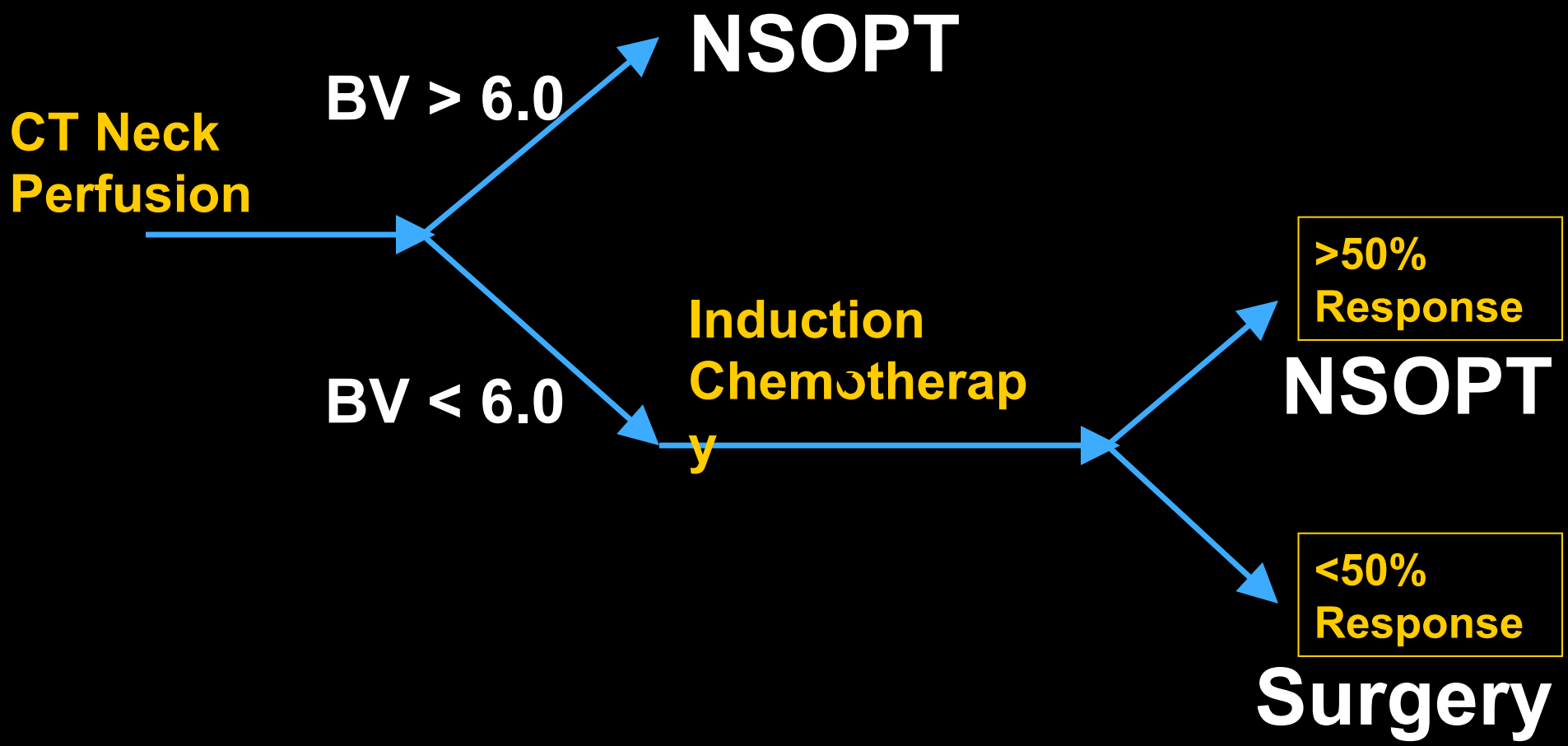
- All patient with blood volume greater than 6 mg/dl successfully responded to induction therapy.

	p-value
BF	0.03
BV	0.004
MTT	0.29
CP	0.07

Zima et al. AJNR 2007;28:328-334

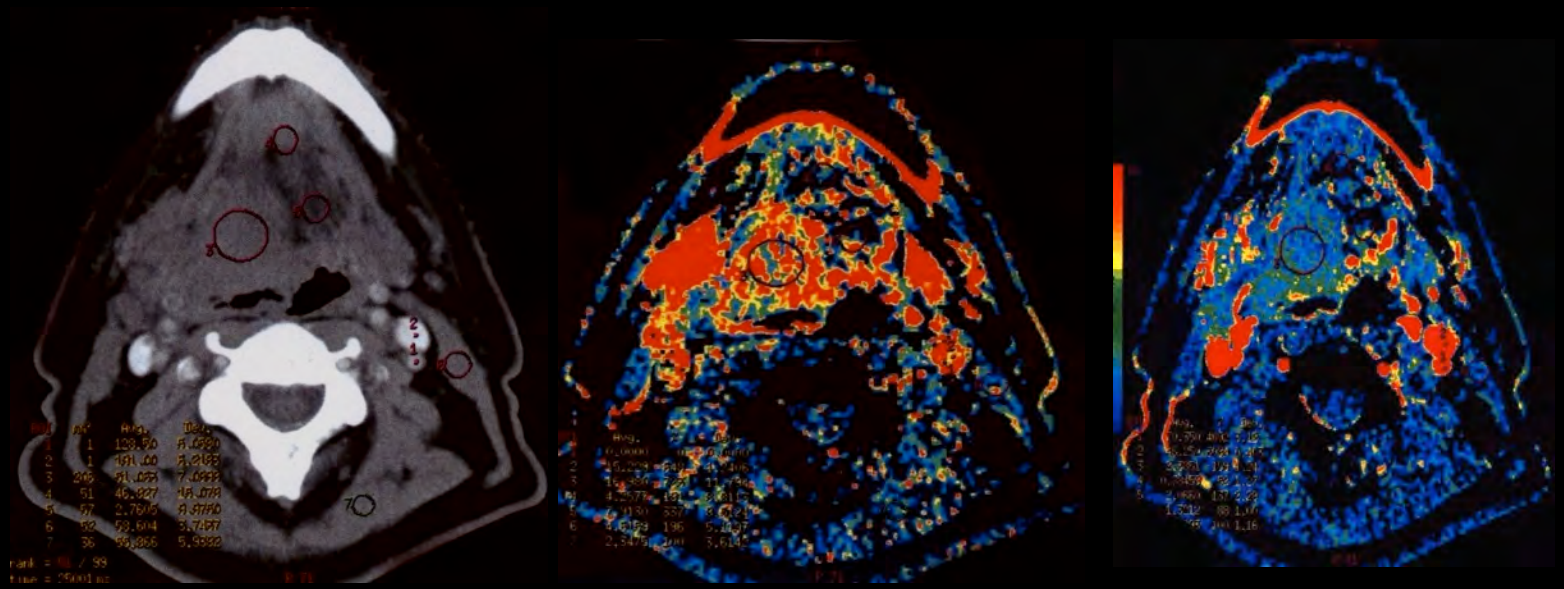
Bisdas et al. AJNR 2009;30:793-799

Proposed Organ Preservation Therapy Treatment Plan

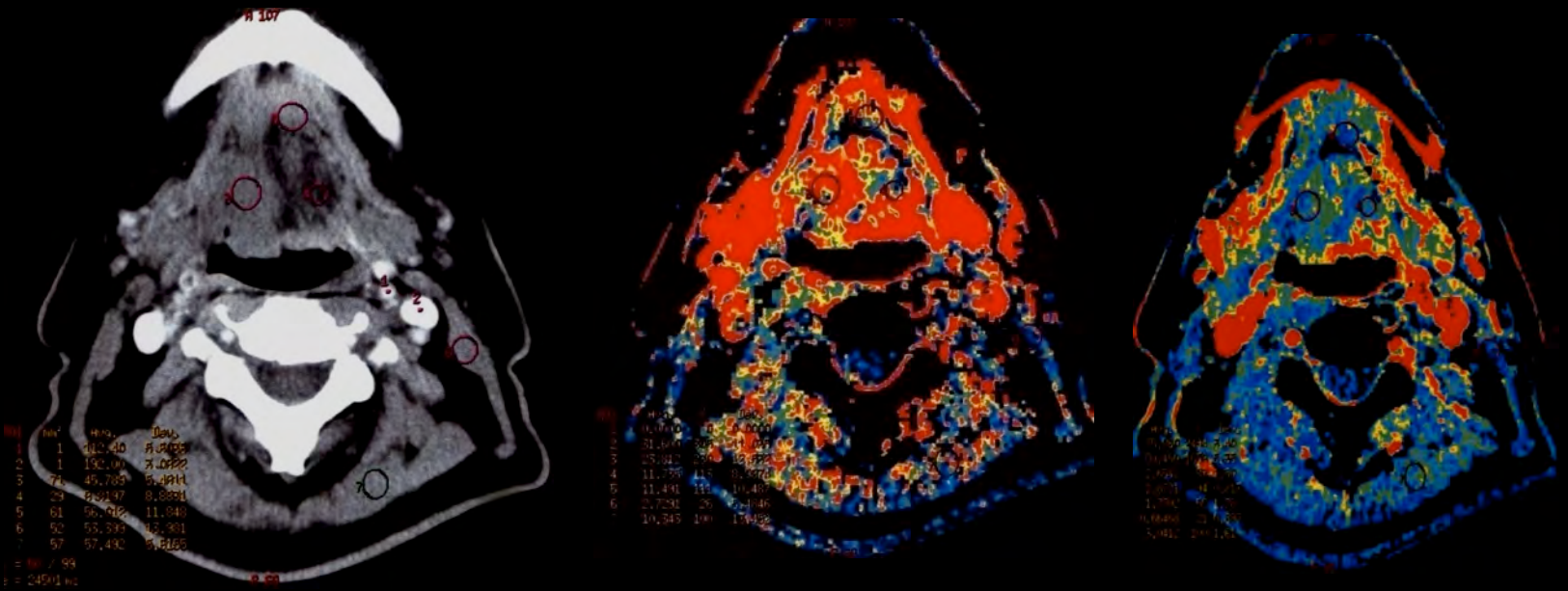


Zima et al. AJNR 2007;28:328-334

Pre-Tx

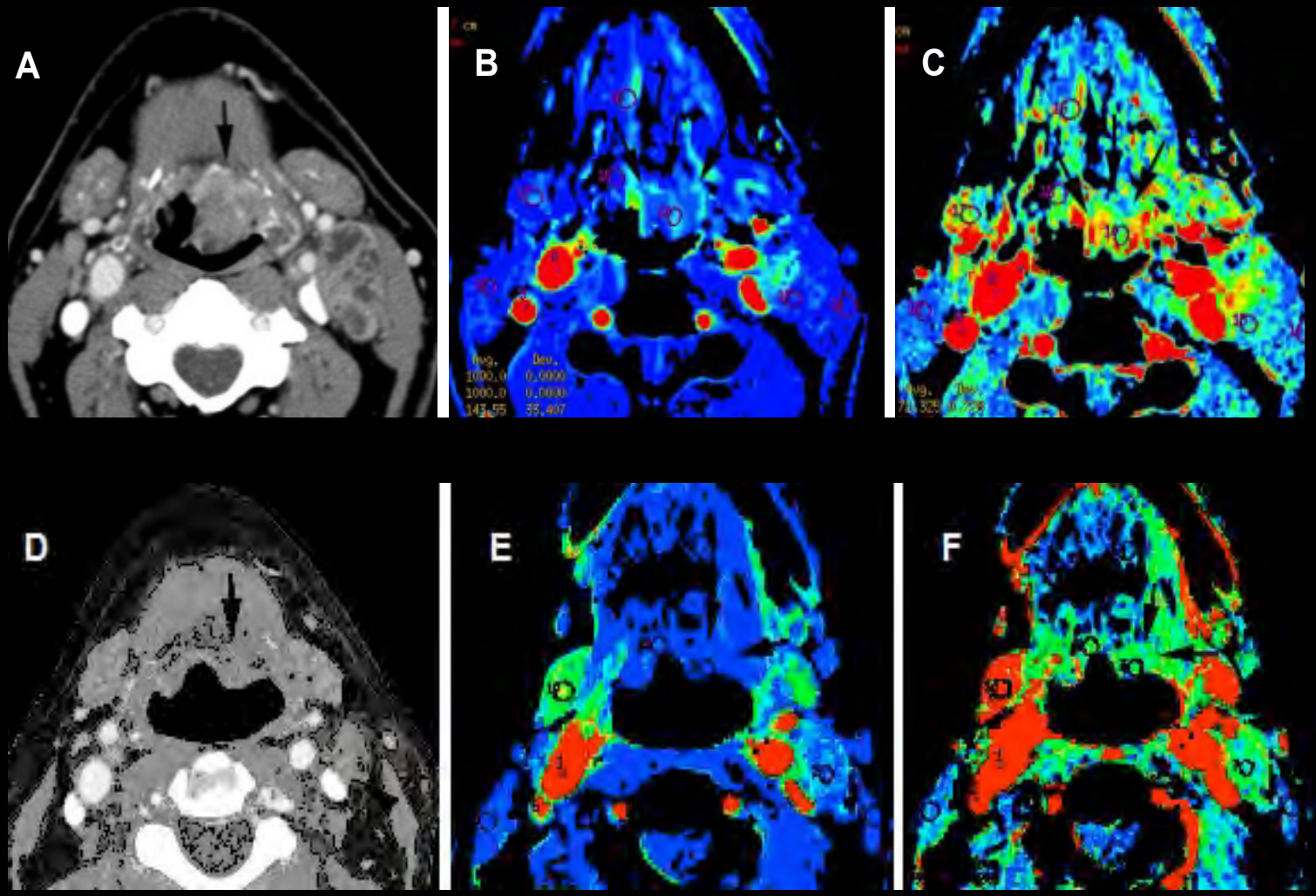


1 cycle



Pre-Tx

1
cycle



CTP vs Clinical Response

Neoadjuvant Therapy

CTP Parameter	Kappa Value
Blood Volume	0.73
Blood Flow	0.37
Capillary Perm	0.37
MTT	0.37

Gandhi et al. AJNR 2006;27:101-106

CTP vs Clinical Response

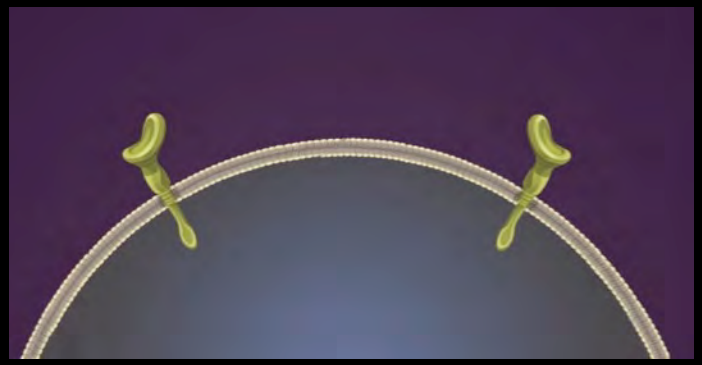
Concommitant Therapy Monitoring

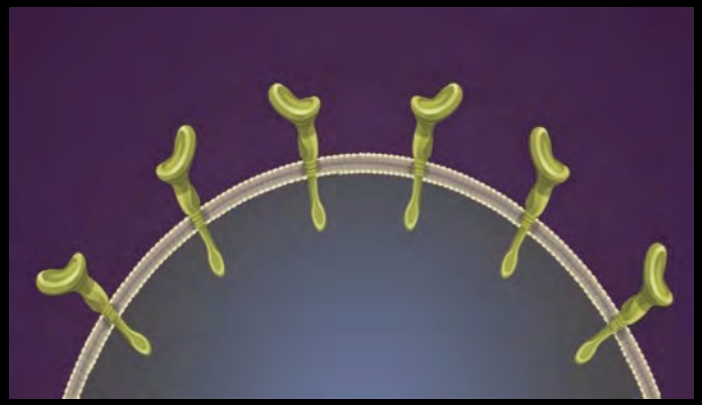
40y & 70gy

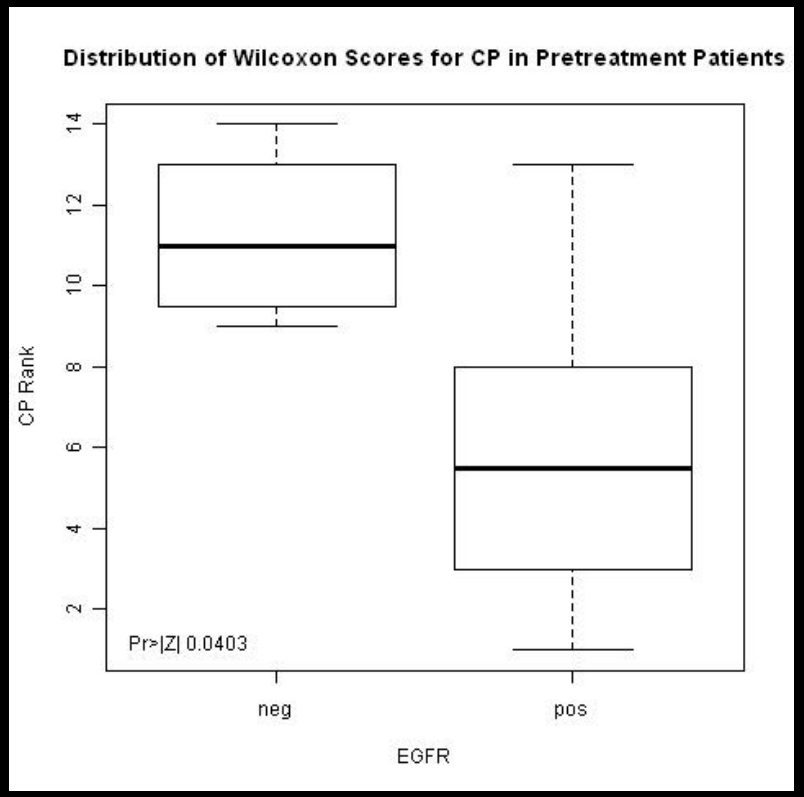
- Decreased BV suggests responders (40Gy)
- No change or increase BV indicates non-responders

Surlan-Popovic et al. AJNR 2010;31:570-575

Correlation with EGFR Biomarker







Outline

- Technique
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  - Stroke
  - Brain Tumors
  - Head & Neck
- Radiation Dose Update

FDA Alert: 10/8/09

At least 206 patients in an 18-month period received extremely high radiation doses during perfusion CT imaging. Patients were expected to receive a dose of 0.5 Gy (max) to their head but instead received 3-4 Gy.

Resulted in hair loss and skin erythema. Possibility of long term effects

CT unit had been set at incorrect levels for 18 months, after the hospital made an error while reconfiguring the scanner.

FDA Alert: 12/8/09

- FDA has identified at least 50 additional patients who were exposed to excess radiation during CT perfusion scans
- Cases involved more than one CT vendor
- If patient doses are higher than the expected level, but not high enough to produce obvious signs of radiation injury, the problem may go undetected and unreported, putting patients at increased risk for long-term radiation effects including cataracts.

FDA Alert: 12/8/09

1. Assess whether patients who underwent CT perfusion scans received excess radiation
2. Review radiation dosing protocols for all CT perfusion studies to ensure that the correct dosing is planned for each study
3. Implement quality control procedures to ensure that dosing protocols are followed every time and the planned amount of radiation is administered.
4. Technologists check the CT scanner display panel before performing a study to make sure that amount of radiation to be delivered is at the appropriate level for the individual patient.
5. If more than one study is performed on a patient during one imaging session, practitioners should adjust the dose of radiation so it is appropriate for each study

level, causing a **CT radiation overdose**. Now, patients who were affected by the excess **CT scan radiation** have filed lawsuits against Cedars-Sinai and the makers of the CT machine, GE Healthcare Inc. and GE Healthcare Technologies.

FREE CASE EVALUATION

Send your CT Brain Scan Radiation claim to a Lawyer who will review your case at **NO COST** or obligation.

CLICK HERE

CT Brain Perfusion Scan Radiation Overdose

According to an FDA alert, at least 206 patients in an 18-month period received extremely high radiation doses when they were undergoing perfusion CT imaging. Specifically, the FDA says that the patients were expected to receive a dose of 0.5 Gy (maximum) to their head but instead received 3-4 Gy.

An article in *The New York Times* (October 15, 2009) notes that Cedars-Sinai Hospital disclosed that it had accidentally exposed patients to high doses of radiation. Meanwhile, in an incident unrelated to the FDA CT scan alert at Cedars-Sinai, at Mad River Community Hospital in Arcata, California, an x-ray technician has lost her state license for reportedly putting a 2½ year old through more than an hour of CT scans, according to the same article in *The New York Times*.

The FDA alert notes that some patients experienced hair loss and erythema (redness of the skin). However, also of concern is that overexposure to radiation that is not at doses high enough to produce obvious signs of radiation injury may put patients at risk for long-term radiation effects. Furthermore, there is a concern that the problem may be more widespread than just one facility.

"While this event involved a single kind of diagnostic test at one facility, the magnitude of these

Exposure, Increases Oversight

Washington, DC: In the wake of a radiation scare where more than 300 patients undergoing **CT scans** and other medical procedures in four hospitals were given too much radiation, the US Food and Drug Administration (FDA) has announced it will step up oversight for the potentially dangerous procedure. [Read More]

Health scans seen as risky in wake of ct radiation overdose case

Miami, FL: Medical science has provided modern man with many tests to better facilitate preventative health care, yet some of these tests - notably the **CT brain scan** - may potentially be more harmful to the patient in the long run. [Read More]

CT Scan Overdose Victims Have Rights

Los Angeles, CA: It seems that somebody at Cedars-Sinai Medical Center made a serious error when the hospital's CT Scanner was recalibrated in February 2008. Dozens of patients booked for diagnostic brains scans were blasted with **megadoses of radiation** – doses usually reserved for treating brain tumors. [Read More]

MORE CT BRAIN SCAN RADIATION

CT Brain Scan Radiation Overdose Legal Help

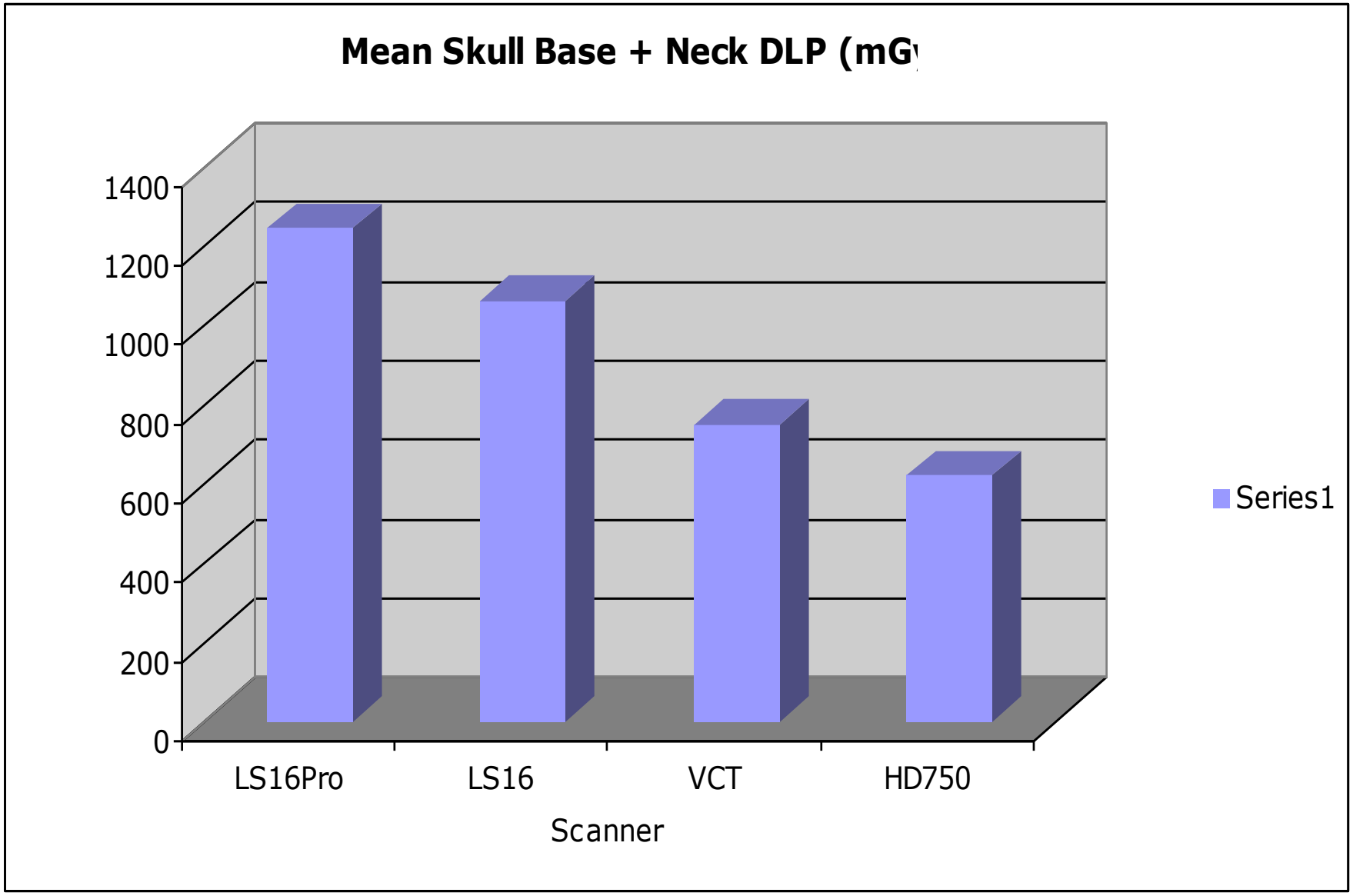
If you or a loved one has suffered an adverse health event resulting from CT brain perfusion scanning, please click the link below and your complaint will be sent to a lawyer who may evaluate your claim at no cost or obligation.

Please click here for a free evaluation of your CT Brain Scan Radiation case

Lawsuit in Alabama CT Perfusion Case: 12/15/09

Attorneys in Huntsville, AL, have filed suit in federal court on behalf of a patient who allegedly received excessive radiation during a CT perfusion head scan for suspected stroke.

The lawsuit represents more than 300 patients, including many of the 260 patients who allegedly received CT overdoses at Cedars-Sinai Medical Center in Los Angeles.


Mean Skull Base + Neck DLP (mG
1400
1200
1000
800
600
400
200
0
LS16Pro
LS16
VCT
HD750
Scanner
Series1

Scanner #	Measured head phantom (mGy)	Randon patient head dose from scanner display (mGy)	Acceptable dose range for brain perfusion according to FDA (mGy)
CT 2	387	309	<500
CT 4	355	317	<500
CT 6	389	311	<500

FDA requirement for perfusion study: less than 500 mGy

120 mm acute stroke volume shuttle

0.4 s rotation

40 mm detector coverage

5 mm thickness

pitch 0.984:1, 39.37 mm/rot

coverage time 45.7 s

27 shuttle passes

80 kV

490 mA

CTDI= 617.30 perfusion

CTDI= 45.92 non-contrast head

Total CTDI 663.22 mGy

300 mA	350 mA
CTDI=378 perfusion	CTDI=441 perfusion
Total CTDI 424 mGy	Total CTDI 487 mGy

80 mm shuttle axial

0.4 s rotation

40 mm detector coverage

5 mm, 8i

coverage time=46.6s

17 passes

80 kV

500 mA

CTDI= 222.57 perfusion

CTDI= 45.92 non-contrast head

Total CTDI 268.49 mGy

40 mm cine

1.0 s rotation

40 mm detector coverage

5 mm, 8i

coverage time=50s

80 kV

200 mA

CTDI= 654.76 perfusion

CTDI= 45.92 non-contrast head

Total CTDI 700.68 mGy

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