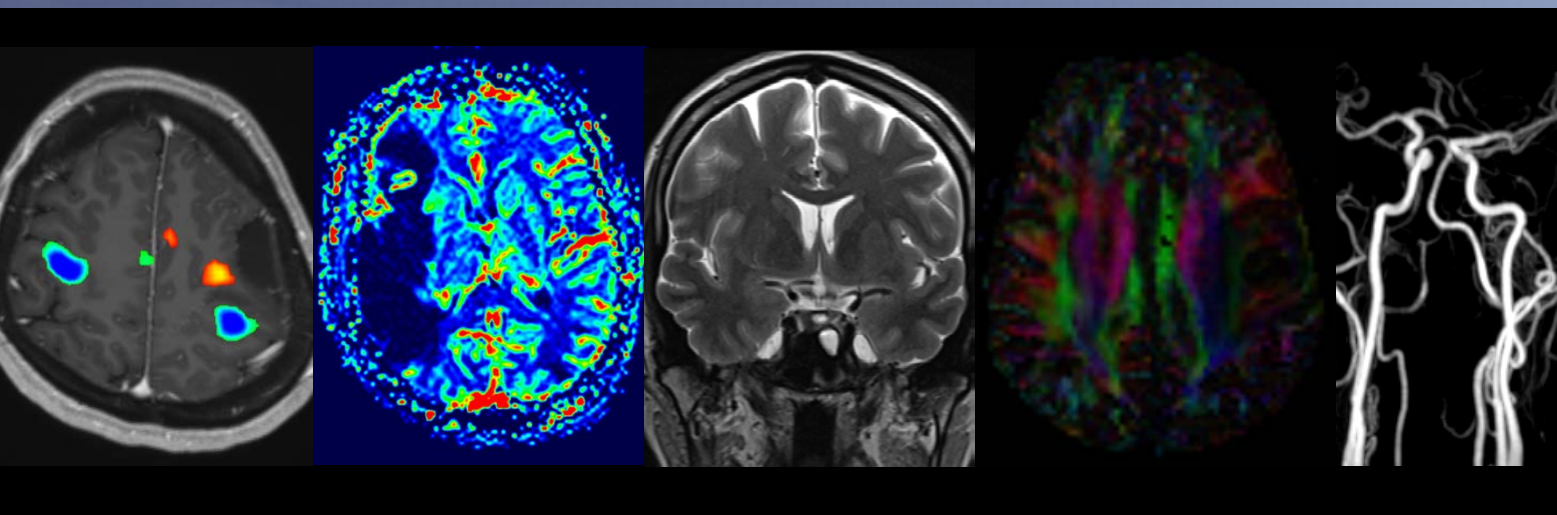
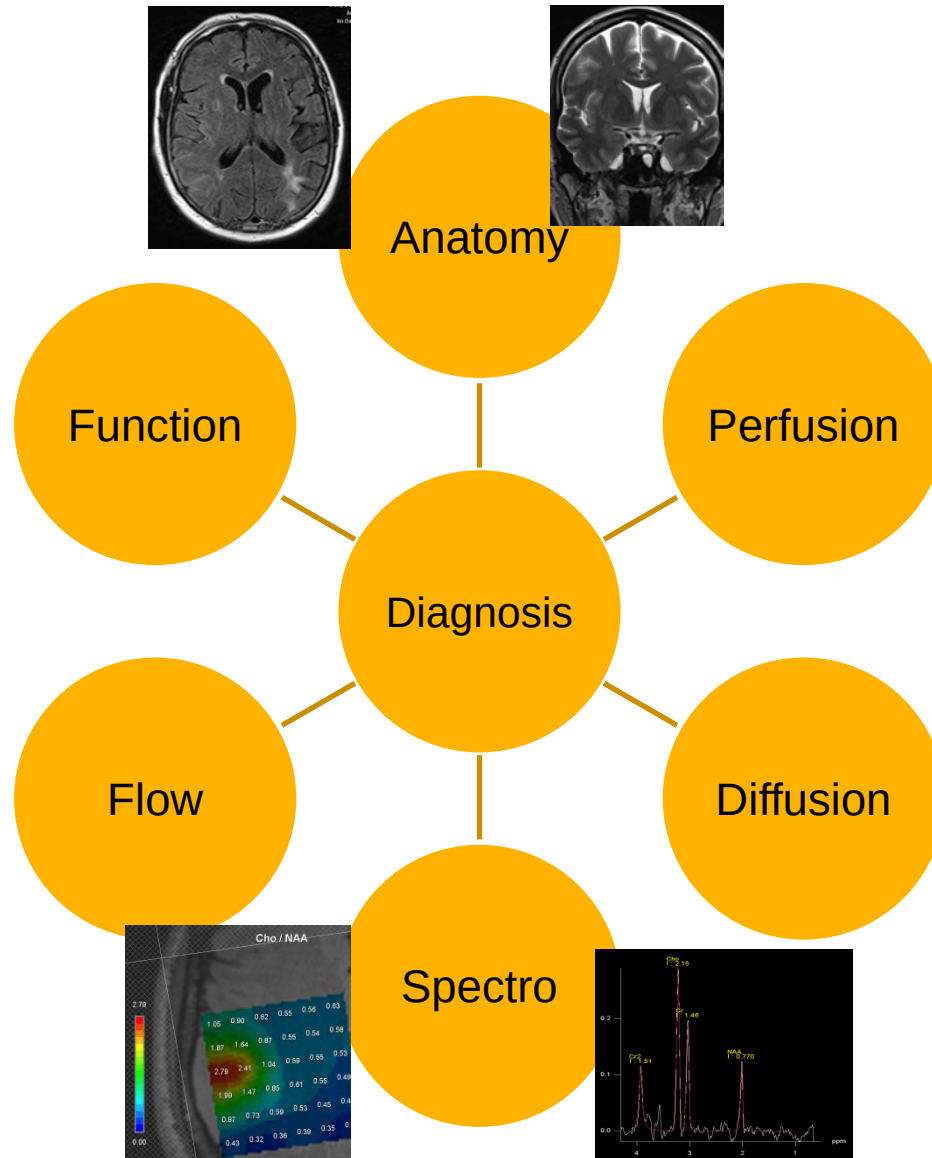




Advanced MR techniques in neuroimaging *clinical applications and examples*

Georg Bier

MR applications



MAGNETIC RESONANCE IMAGING

- A short introduction -

DEVELOPMENT OF MRI



MAGNETIC RESONANCE IMAGING

- A short introduction -



MAGNETIC RESONANCE IMAGING

- *contraindications* -

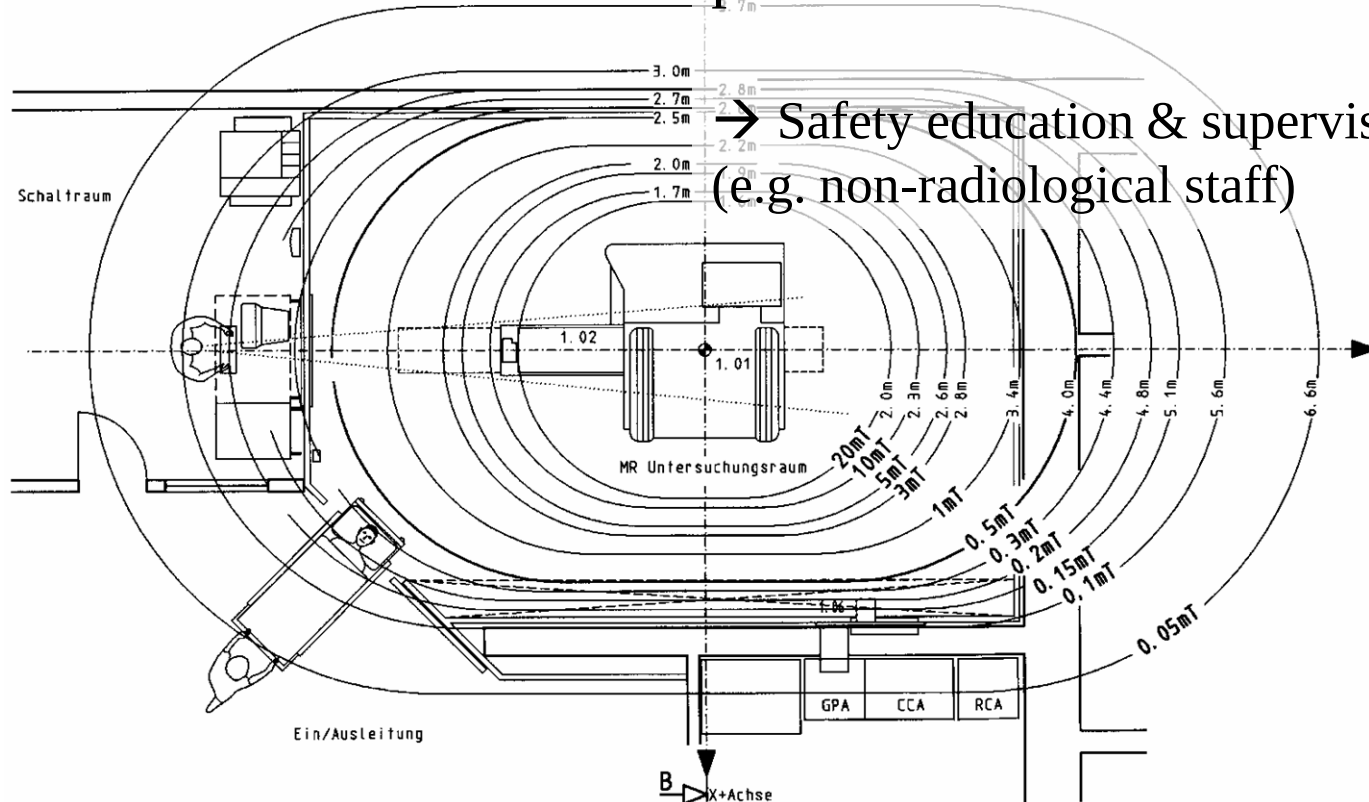


SAFETY ASPECTS - B_0 -field

The B_0 -field is the most dangerous

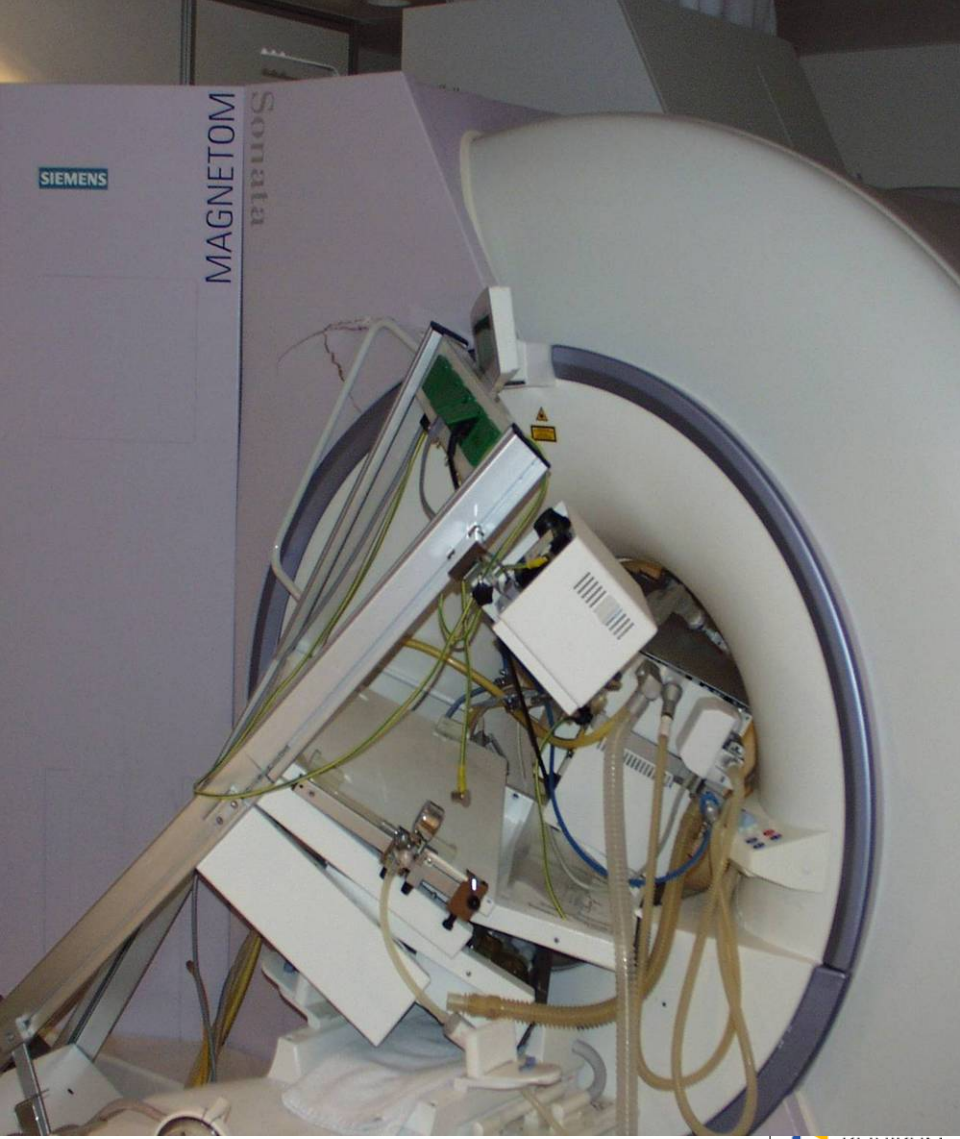
part in the MR room

→ Safety education & supervision
(e.g. non-radiological staff)



MAGNETRESONANZTOMOGRAPHIE

- Sicherheitsaspekte-





failblog.org

Quenching – what happens when you press the red button



MR scanner explosion

2015, Oradell, New Jersey, USA





Tübingen, 06/2016

MRI unit

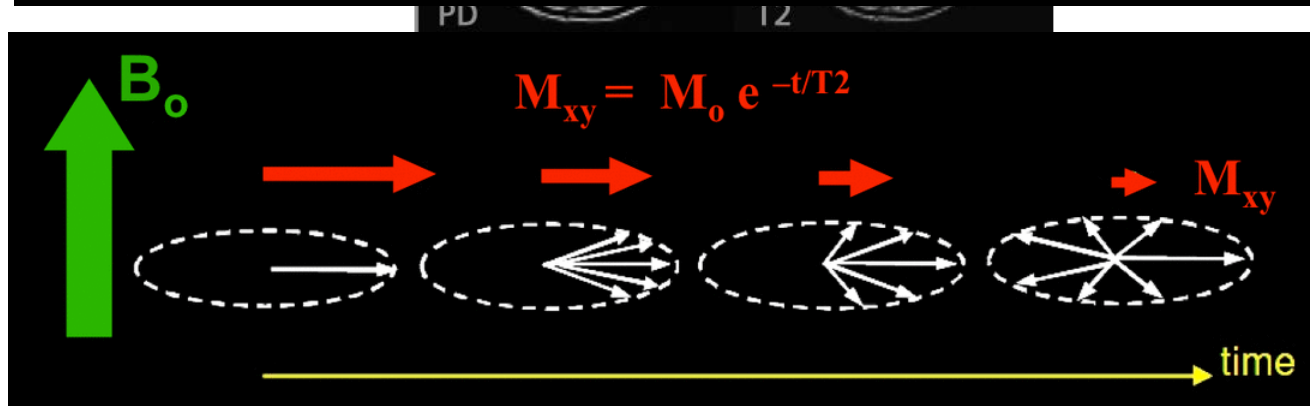
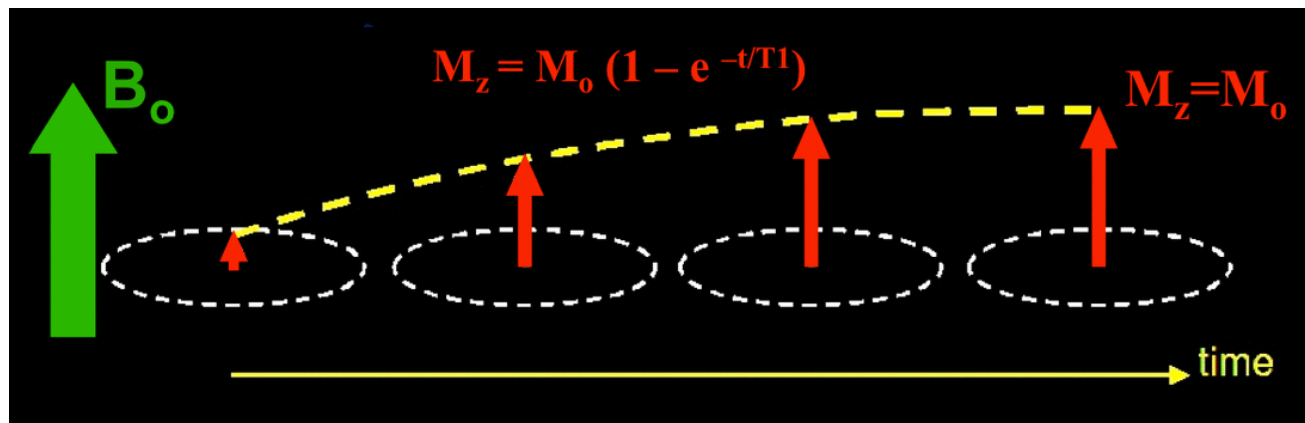


Head and neck coil

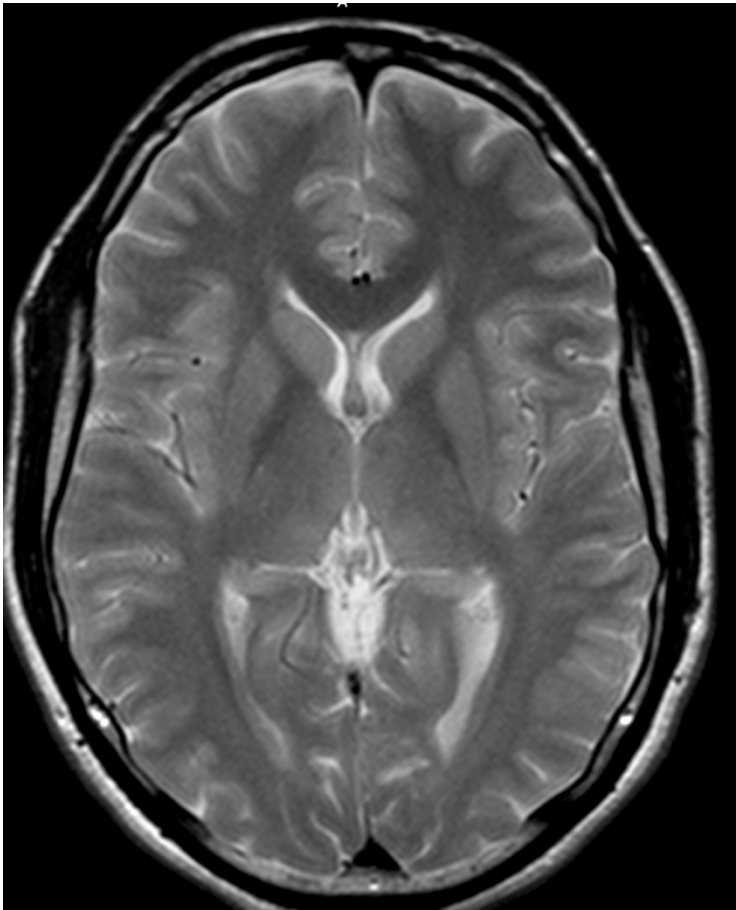


Images

- Image depends on T1 and T2 relaxation time of tissue type

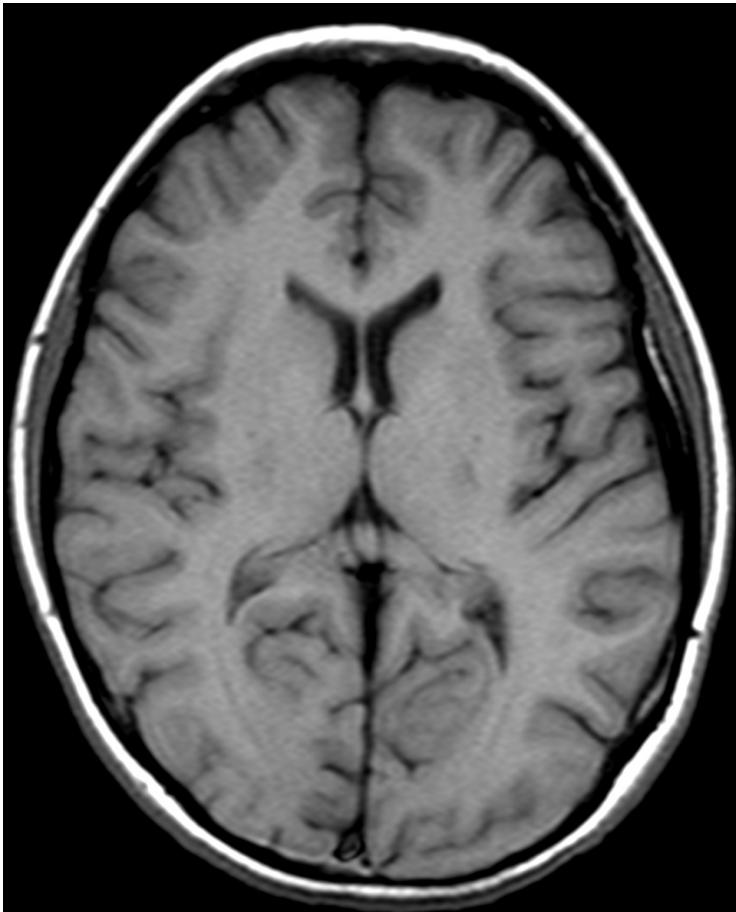


T2 weighted image (T2w)



- CSF (fluid) hyperintense
- Edema hyperintense
- Fat hyperintense

T1 weighted image (T1w)



- CSF (fluid) hypointense
- Fat strong hyperintense
- Blood hyperintense
- White/gray matter inverse to T2w

Contrast enhanced T1w

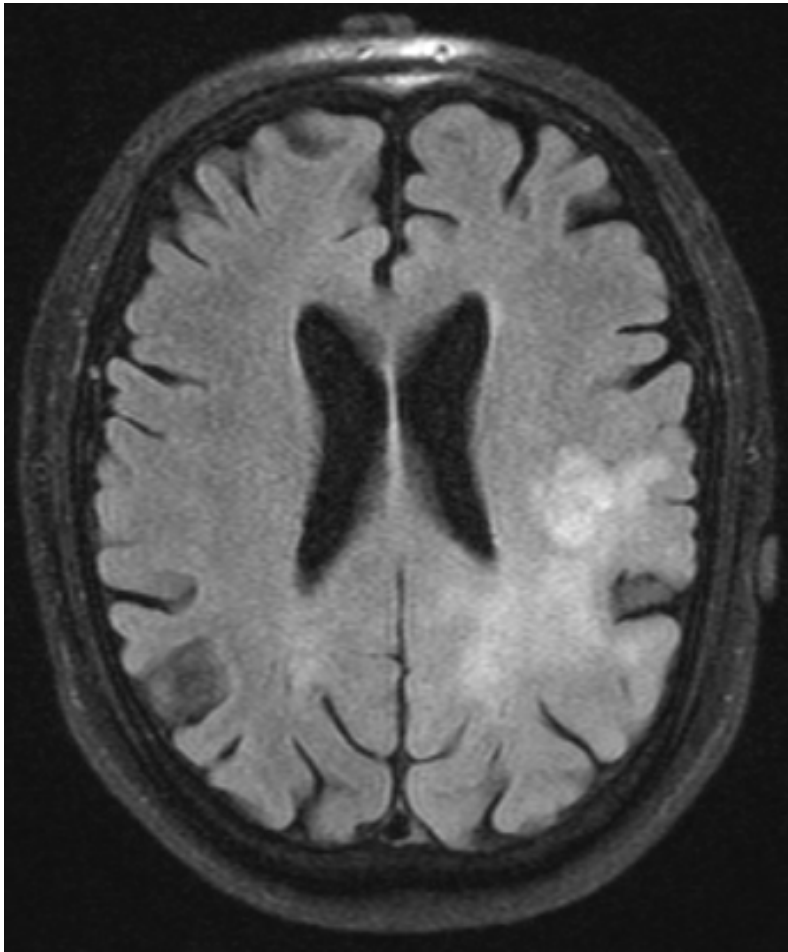


T1w without contrast



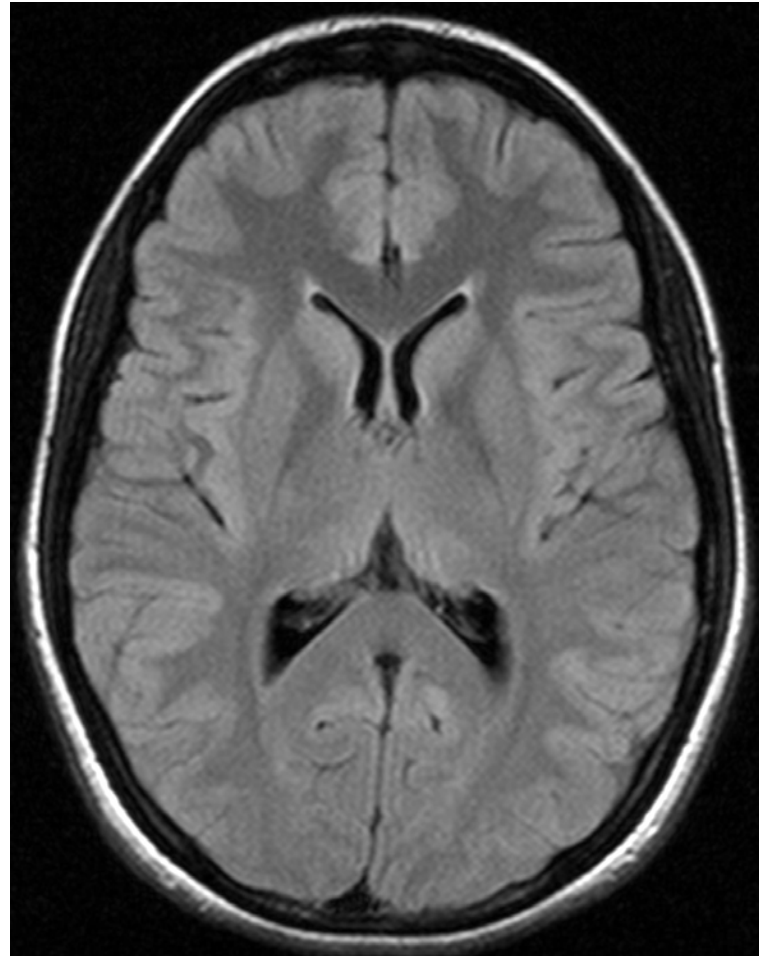
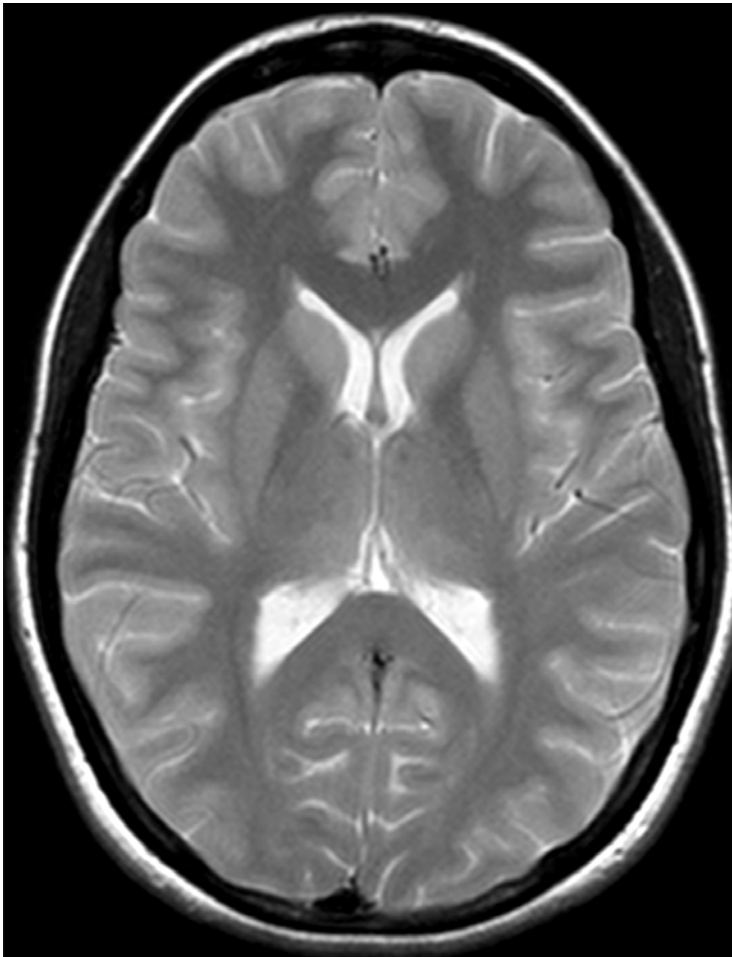
Contrast enhanced T1w

Fluid attenuated inversion recovery (FLAIR)

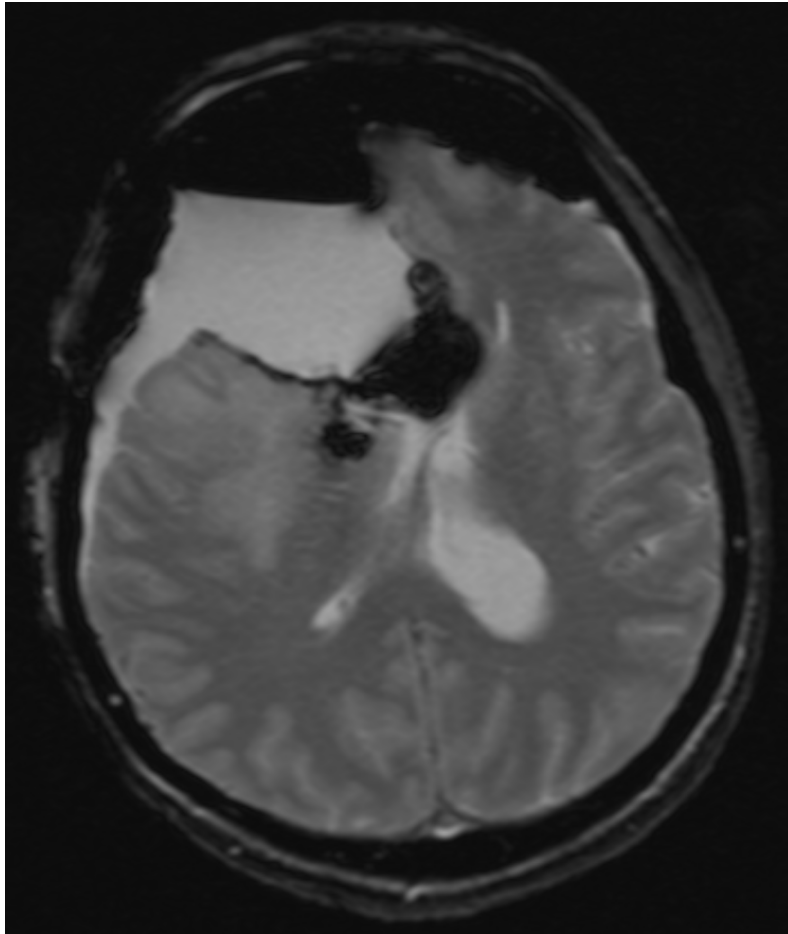


- T2w image
- Suppression of CSF
- Superior tissue T2 lesion detectability

Fluid attenuated inversion recovery (FLAIR)

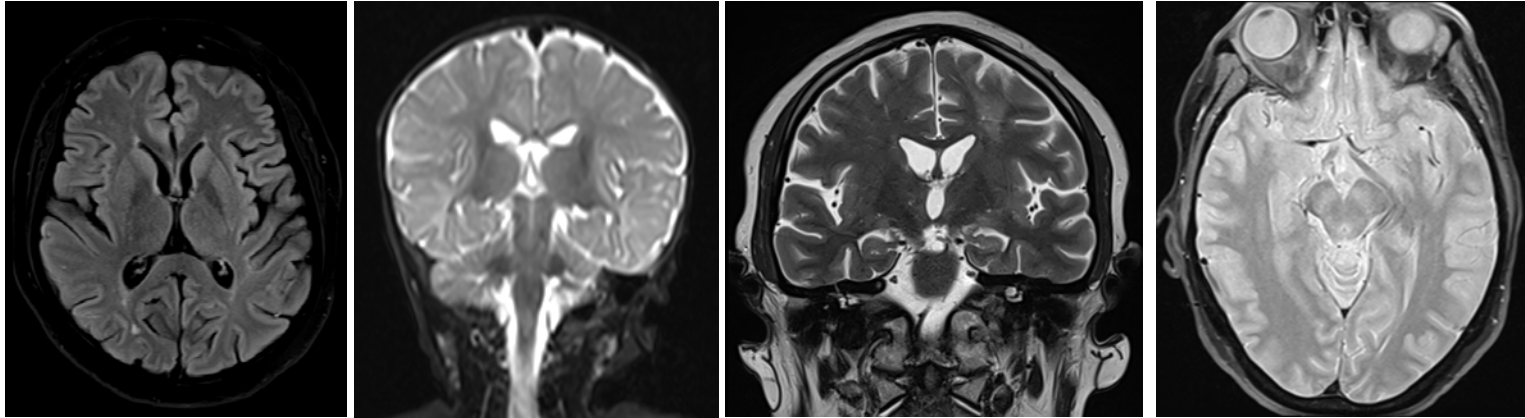


T2 * weighted image



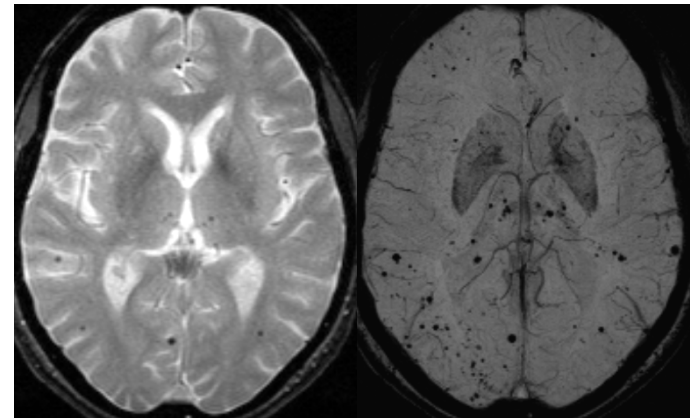
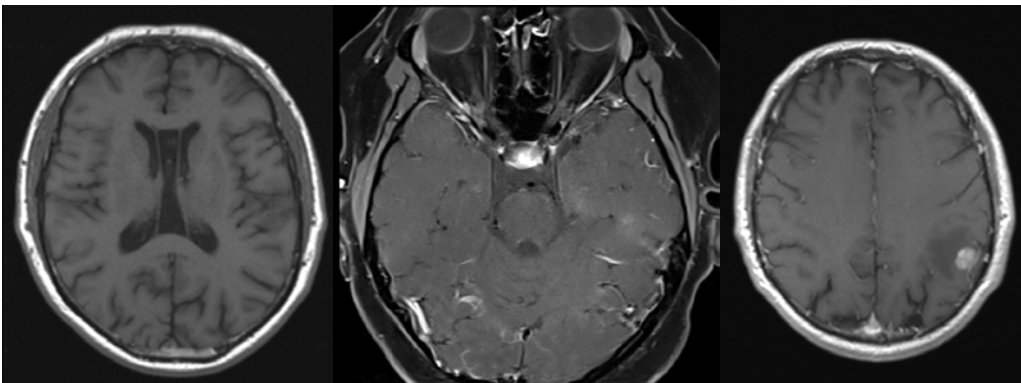
- Susceptibility artifact weighted (paramagnetic)
- Blood: Oxy-Hb, Deoxy-Hb, Met-Hb, Hemosiderine
- HYPOintense

Quiz: Basic sequences

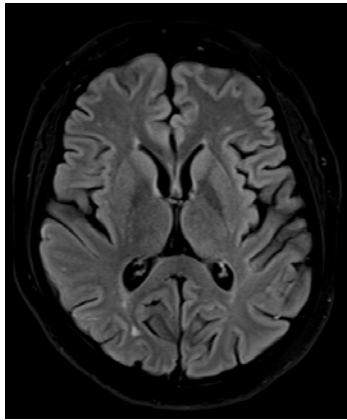


T1, T2, T2*, PD ?

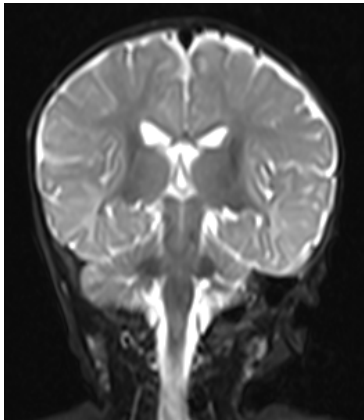
fs, IR, CE



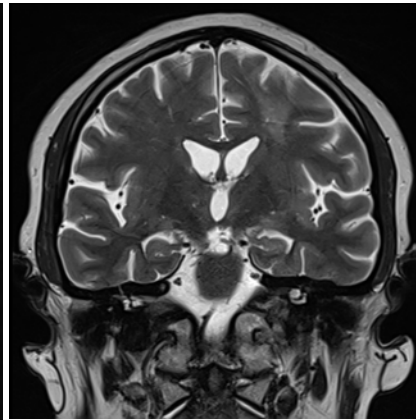
Quiz: Basic sequences



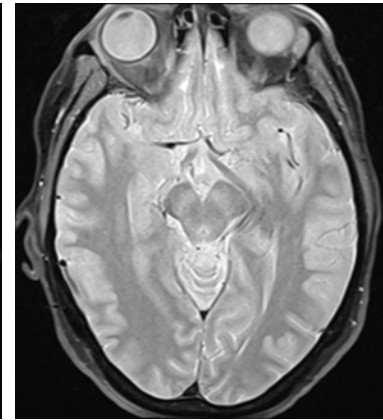
fs-FLAIR



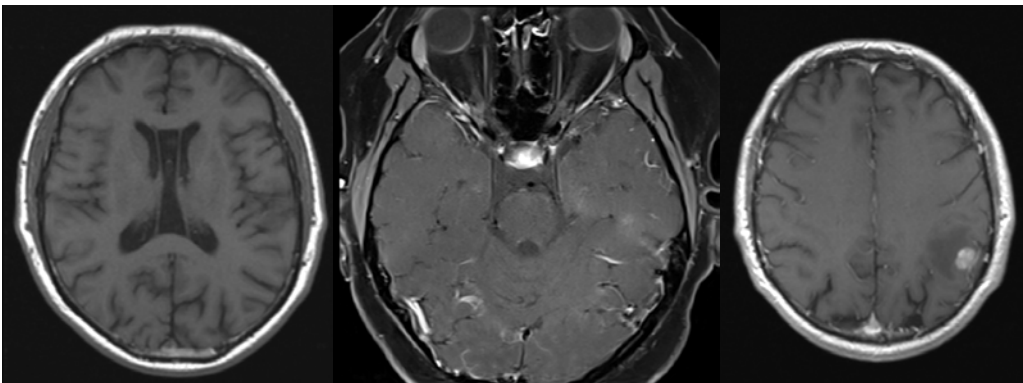
T2-STIR
(infant!)



T2



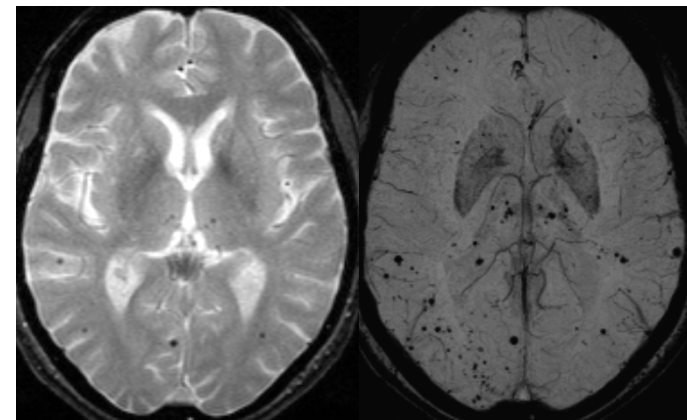
PD



T1

fs-T1 CE

T1 CE



T2*

SWI

there are even more: IR-T1, DIR, ...

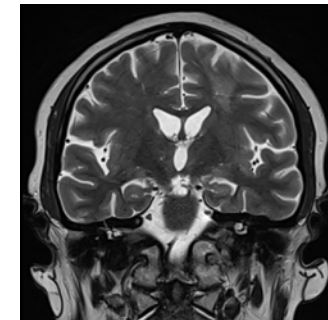
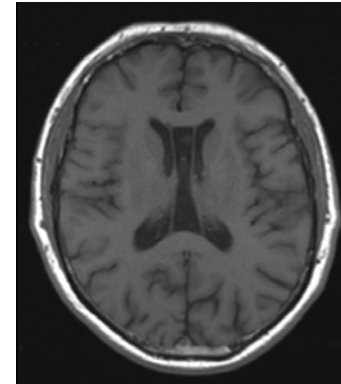
Basic sequences

T1: for CE, blood, calcifications
fat bright, water dark,
WM higher intensity than GM

T2: „water sensitive“, edema
fat bright, water bright
GM higher intensity than WM

T2*: iron/hemosiderin, air

CE: inflammation, tumor



MR applications: Flow

Without contrast: phase contrast (venous, CSF)
 time of flight (arterial or venous)

With contrast: high resolution MRA (arterial,
 venous)
 time resolved MRA (arterial and
 venous)

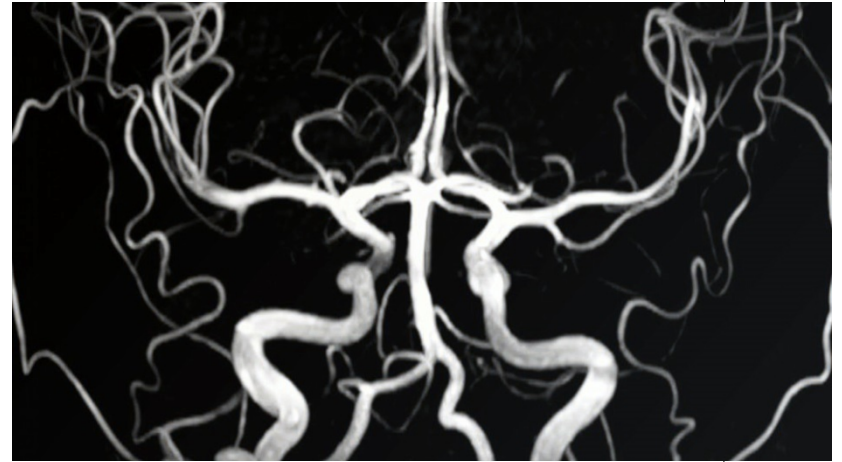
MR applications: Flow – TOF Angiography

Advantages

- Can be repeated
- No contrast agent needed

Disadvantages

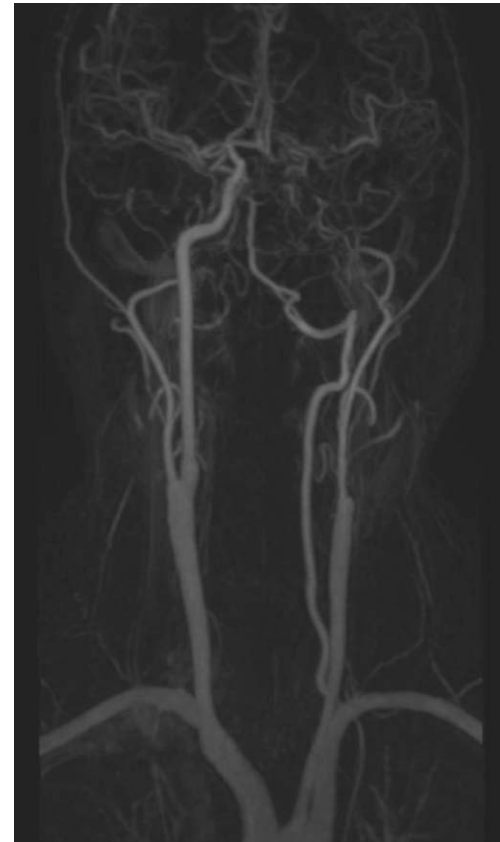
- Long measurement time
- Insensitive to in plane flow
- T1 hyperintense thrombus can mimic flow



MR applications: Flow – CE-MRA

MR-angiography

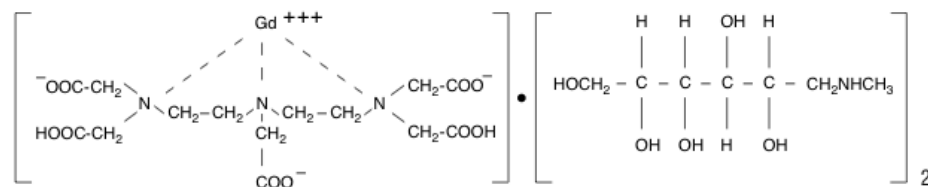
- High spatial resolution for detection of vascular anomalies
- Central k-space at the beginning
- Bolus tracking technique





Contrast agents

MAGNEVIST[®] Injection is a 0.5-mol/L solution of 1-deoxy-1-(methylamino)-D-glucitol dihydrogen [*N,N*-bis[2-[bis(carboxymethyl)amino]ethyl]-glycinato-(5⁻)-]gadolinatate(2⁻)(2:1) with a molecular weight of 938, an empirical formula of C₂₈H₅₄GdN₅O₂₀, and has the following structural formula:



Each mL of MAGNEVIST[®] Injection contains 469.01 mg gadopentetate dimeglumine, 0.99 mg meglumine, 0.40 mg diethylenetriamine pentaacetic acid and water for injection. MAGNEVIST[®] Injection contains no antimicrobial preservative.

Adverse reactions after application of Gd-DTPA (in 5 Mio usages)*:

- Reaction at the site of injection	n = 87
- Vomiting	n = 207
- Flush	n = 70
- Urticaria	n = 278
- Seizure	n = 16
- Glottal edema	n = 5
- Anaphylactic shock	n = 13
- Death	n = 1

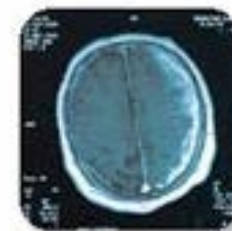
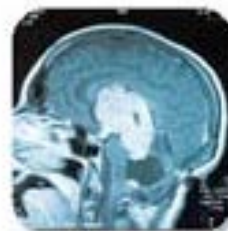
(*Advances in MRI contrast. 1993;2 : 12-19)

Contrast agents

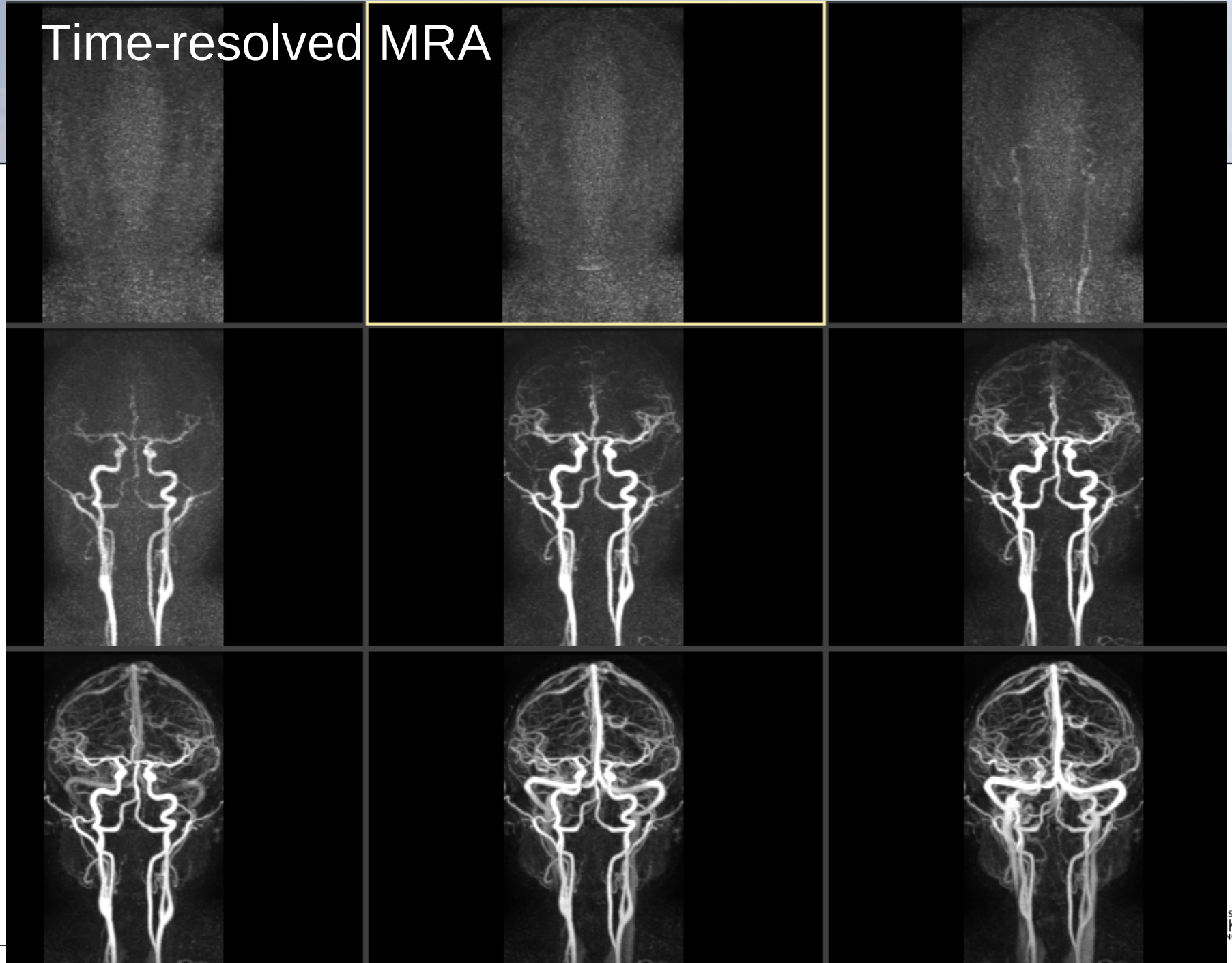
Gd (z.B. Gadovist, Magnevist)

(Fe) (z.B. Resovist)

Mn (z.B. Teslascan)



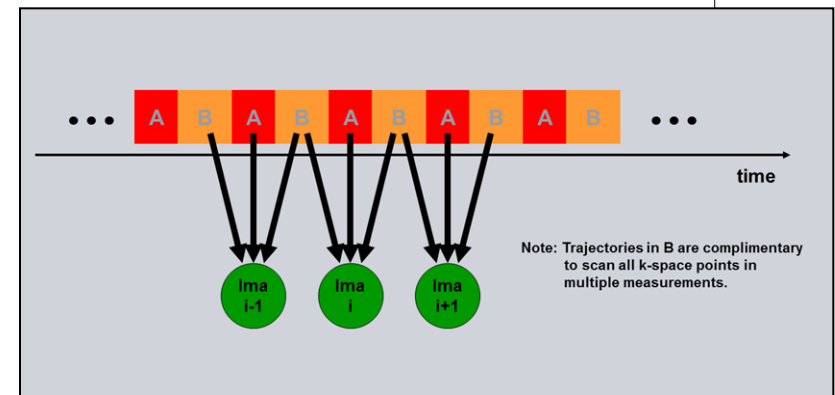
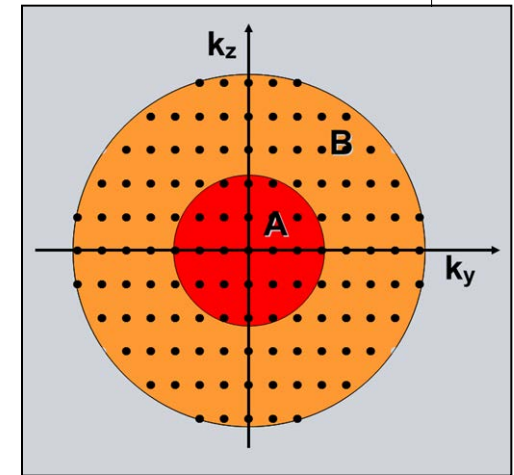
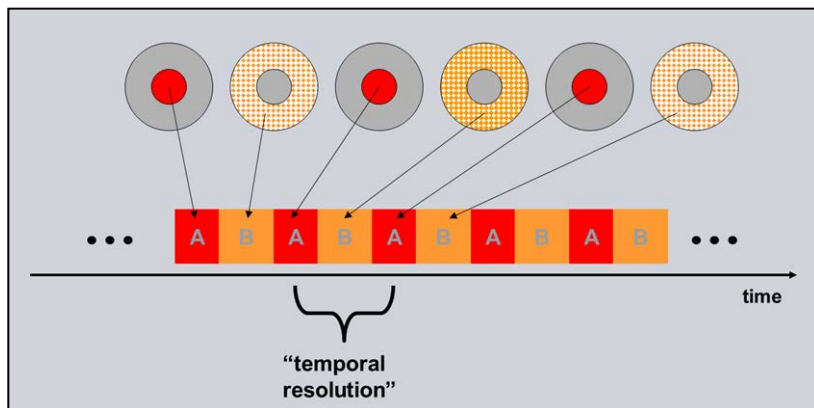
Time-resolved MRA



MR applications: Flow – Time-resolved MRA

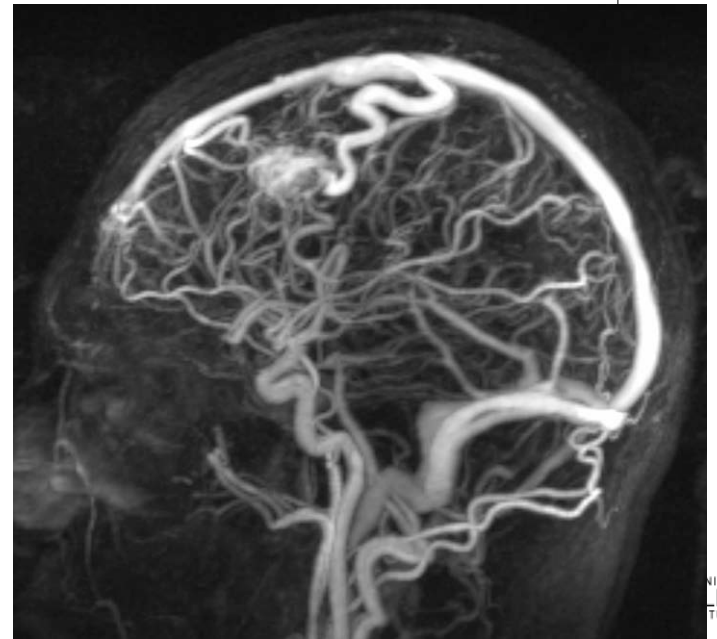
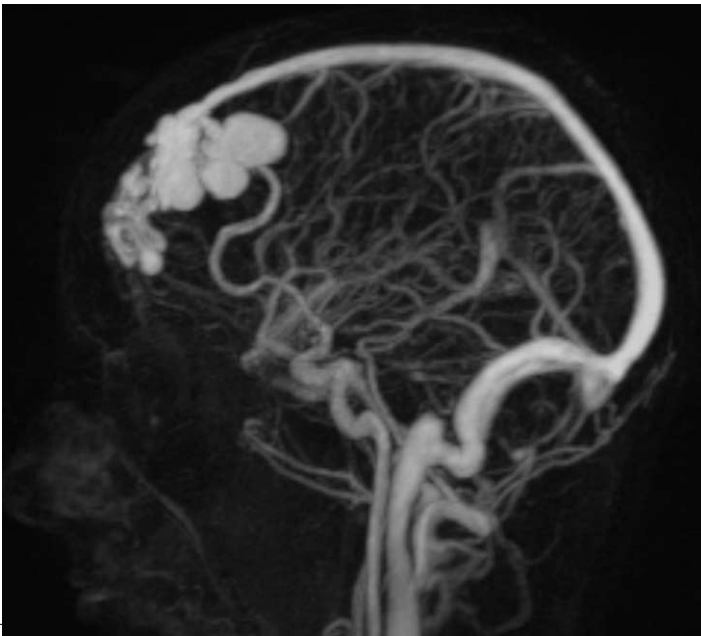
„4D MRA“

- Dynamic filling of the vessels
- Hemodynamic information



MR applications: Flow – Time-resolved MRA

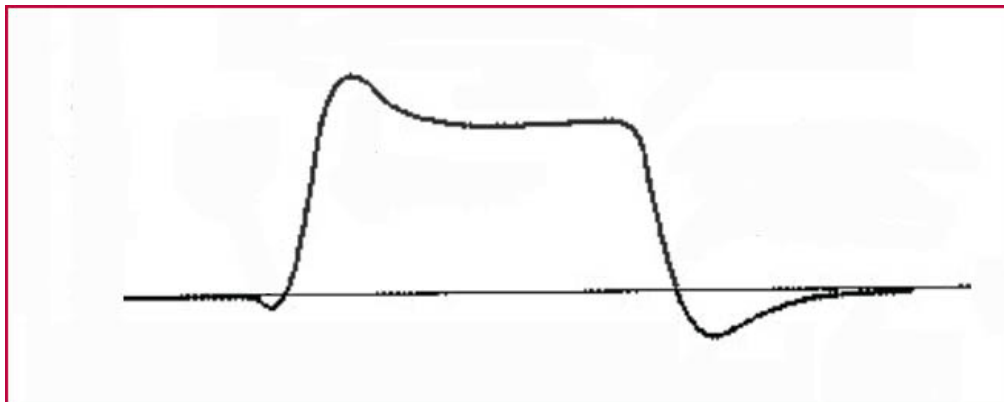
AVM – arterio-venous malformation



MR applications: Function

functional MRI

- Based on BOLD effect
 - Blood oxygenation level dependent
 - Contrast rises with neural activation
 - Dependent on blood flow and oxygenation
 - Differences in diamagnetic effects in deoxyhemoglobin and oxyhemoglobin



Source: <http://www.digitalmediatree.com/sallymckay>

MR applications: Function

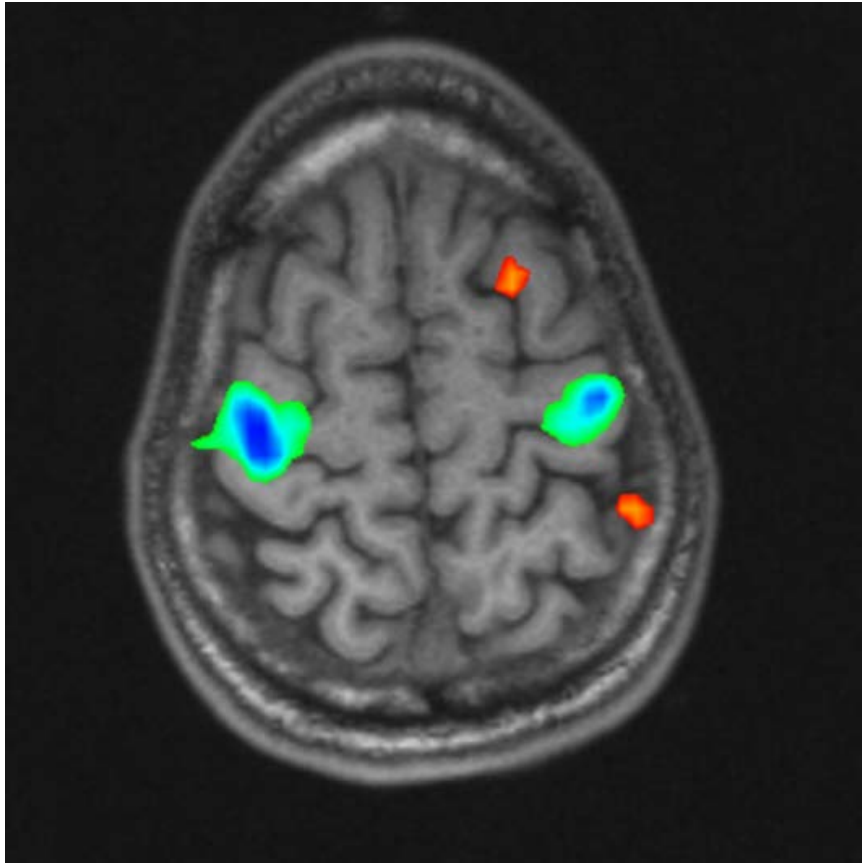
Activation of different parts of the brain

MR paradigms

- Perform different tasks
 - „Wort-Faust“
 - „Bild-Faust“

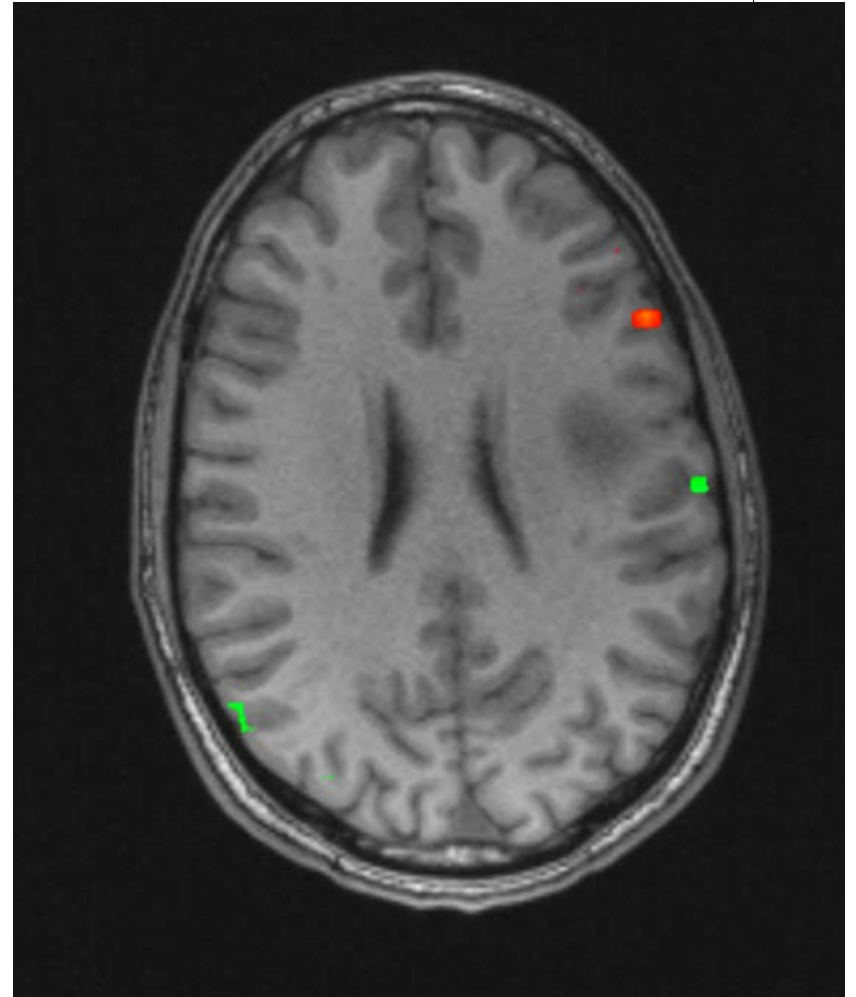
Activation maps are overlaid in colour on anatomical data (T1 MPRage, SPACE, etc.)

MR applications: Function



Motor and speech paradigm

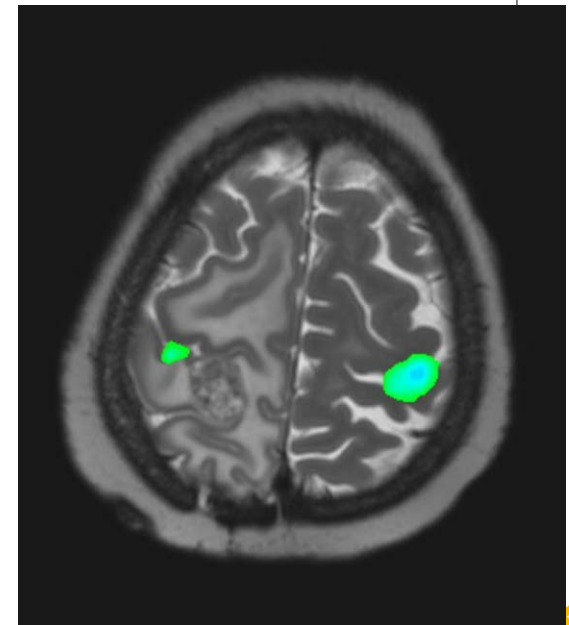
- word association
- clenching fist



MR applications: Function

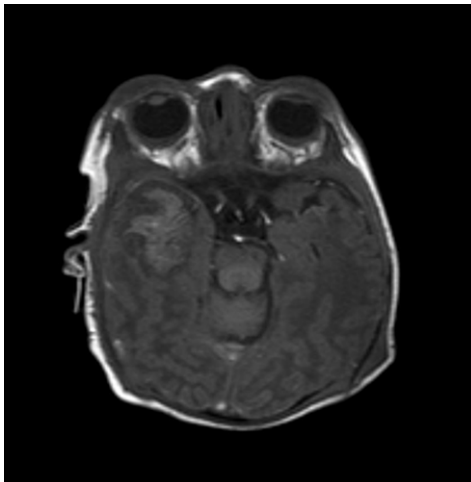
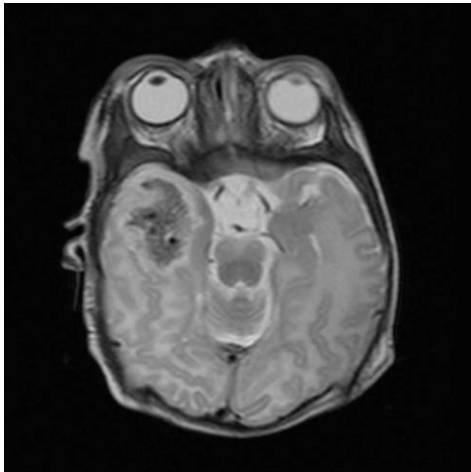
Clinical applications

- Neurosurgical plannings
 - Cases: *schellenberg, m*; **imbrich d44123** tumor zentral
 - Resection margins in relation to functional eloquent areas
- Functional plasticity after stroke or surgery
- Neuro-degenerative disease



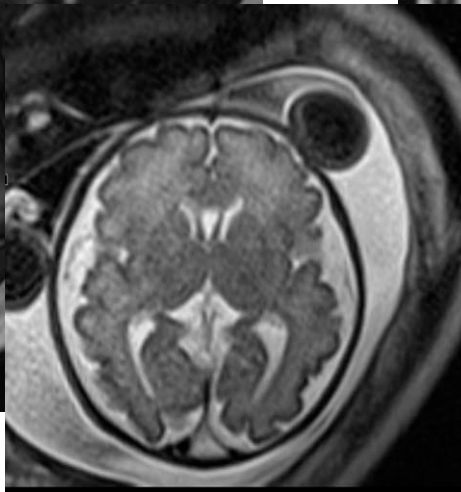
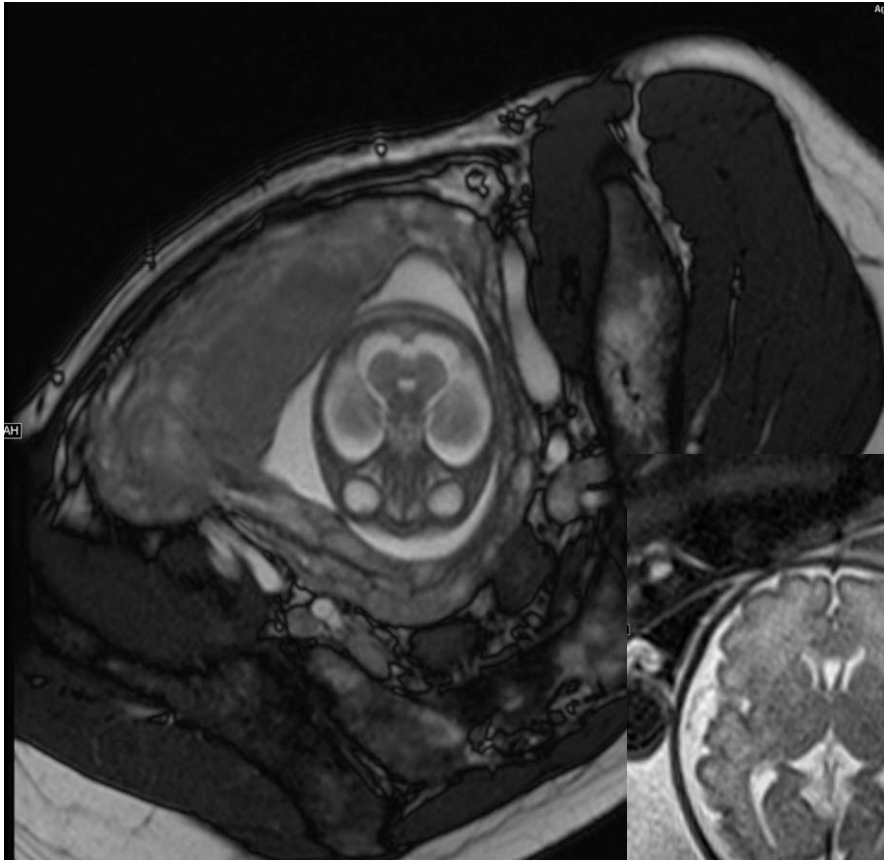
MRI in small infants

Baby: D55814; D56612



Prenatal MRI

Prenatal D49736



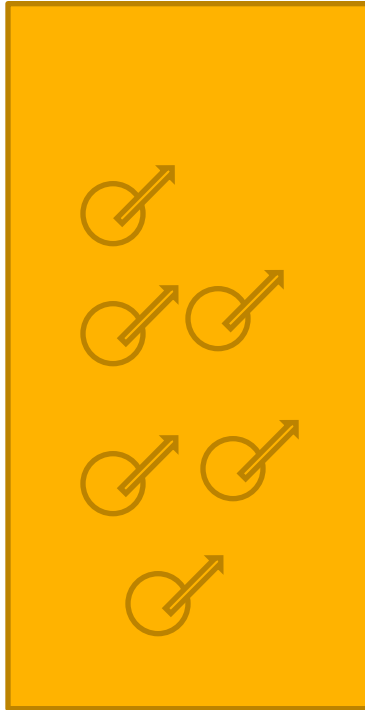
MR applications: Diffusion

Diffusion-Weighted Imaging

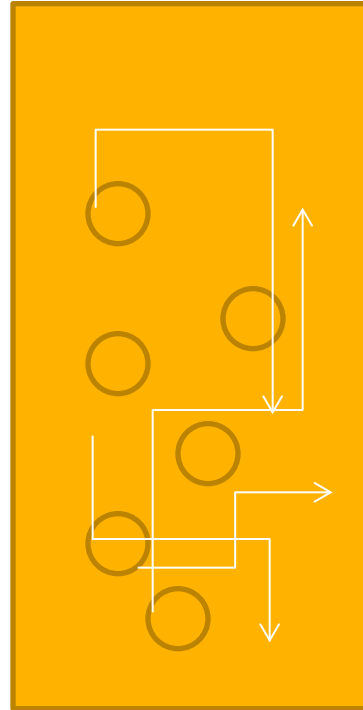
- EPI sequence (echo planar imaging)
 - DWI signal corresponds to T2w image decreased by a signal amount related to the rate of diffusion
 - Reduced diffusion leads to a high signal in DWI

Microscopic molecular motion of water within tissue

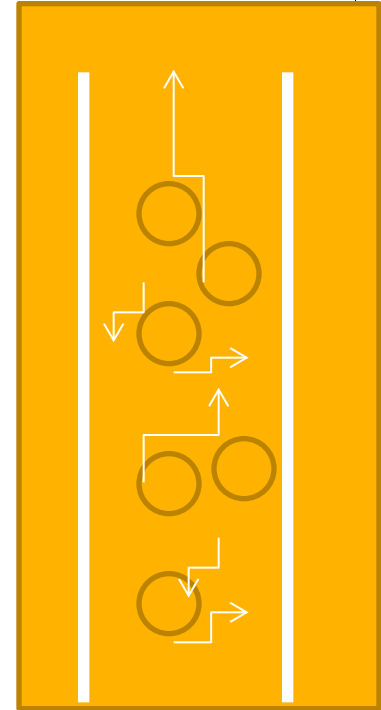
Brownian motion



convection



isotropic
diffusion



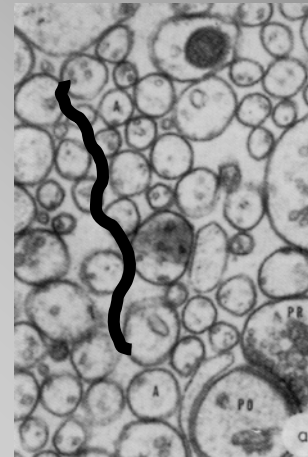
restricted
diffusion

DWI in Neuroradiology

In brain tissue the movement of H_2O -molecules is restricted by anatomic barriers, such as cell membranes

Each change in interstitial volume leads to signal alterations in DWI imaging

Perfusion loss



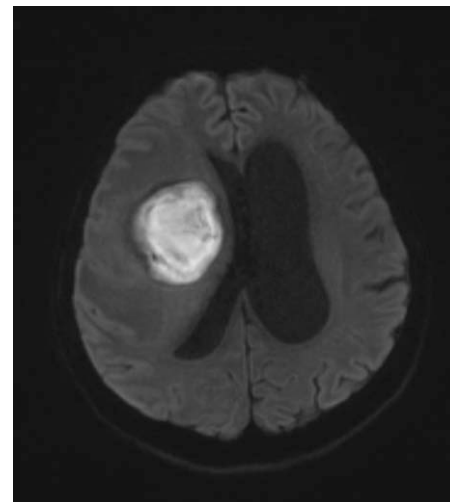
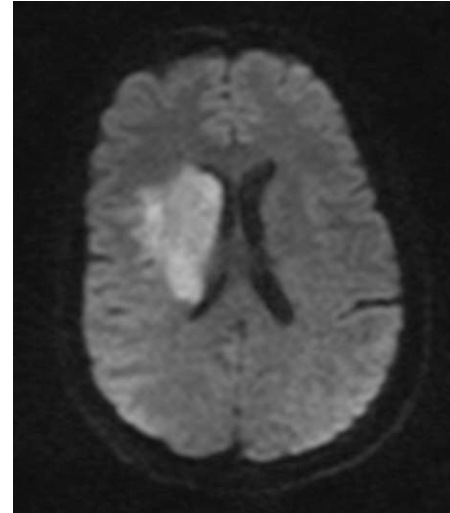
Δ

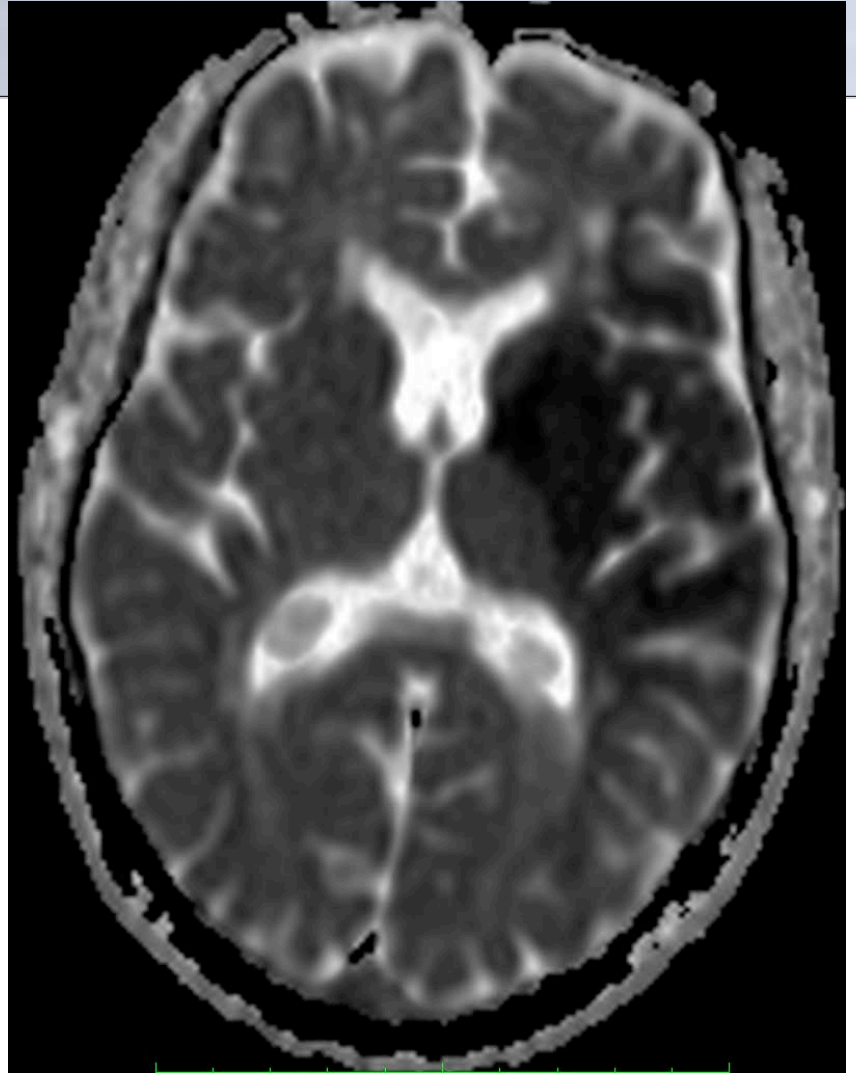
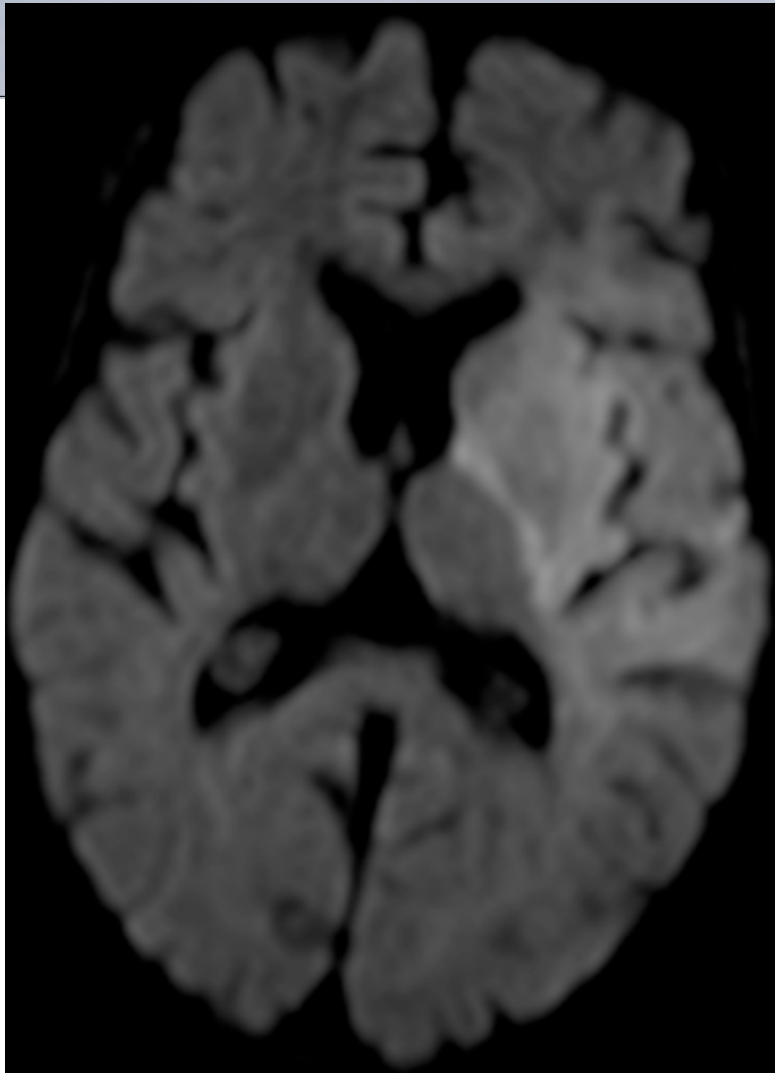
Time after artery occlusion

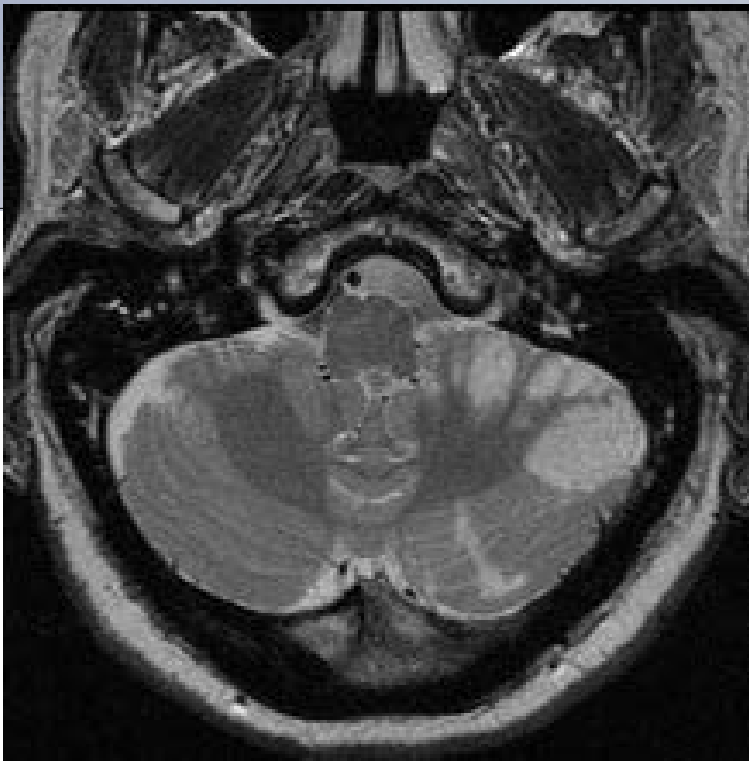
MR applications: Diffusion

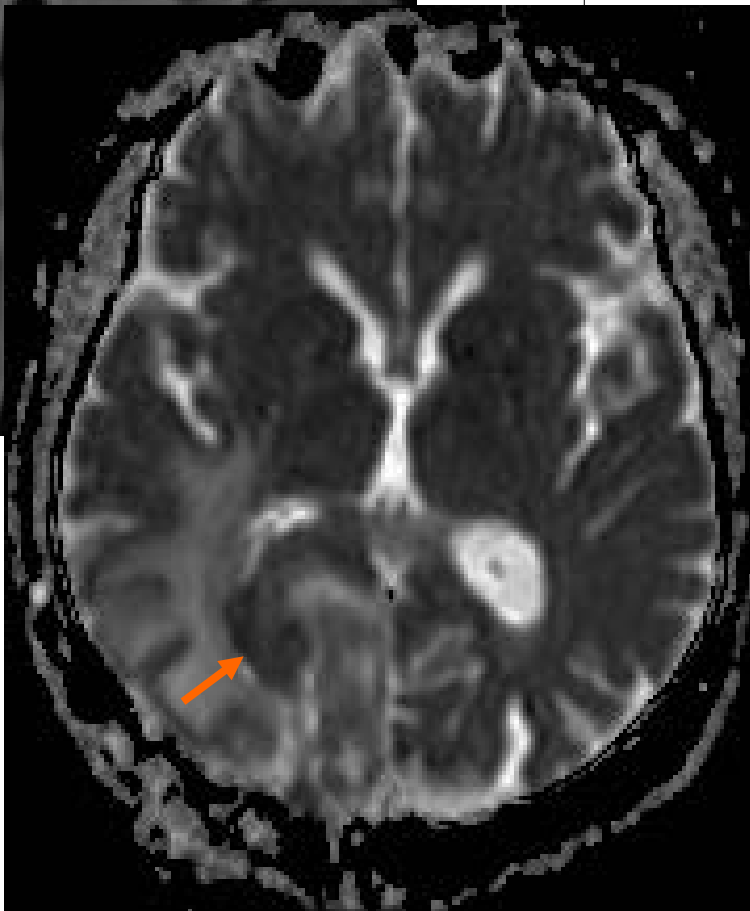
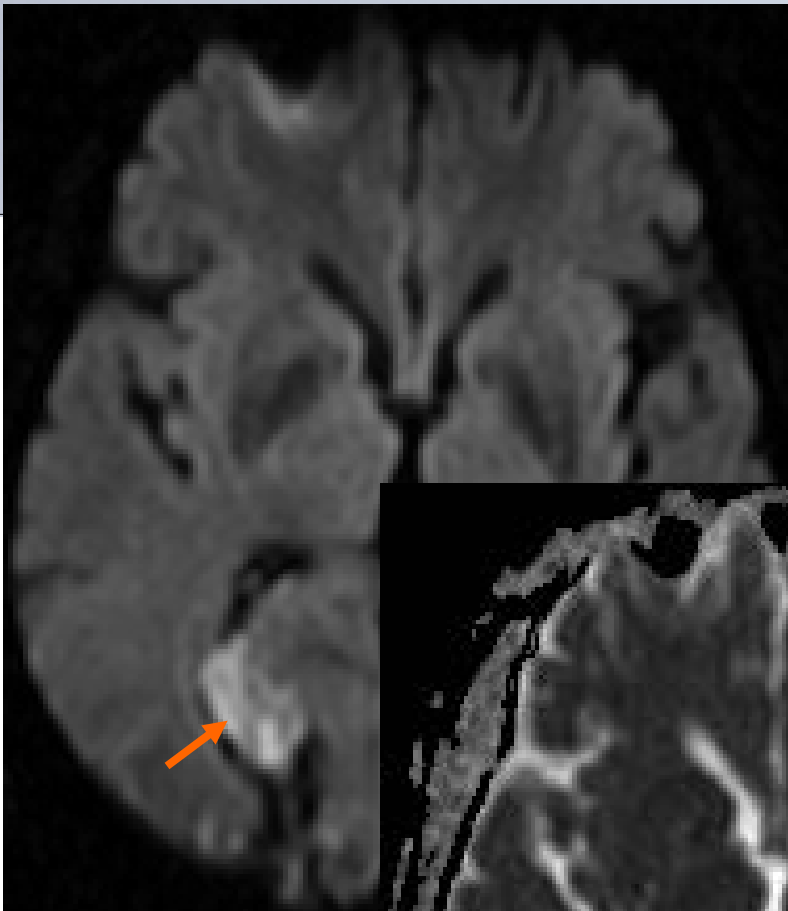
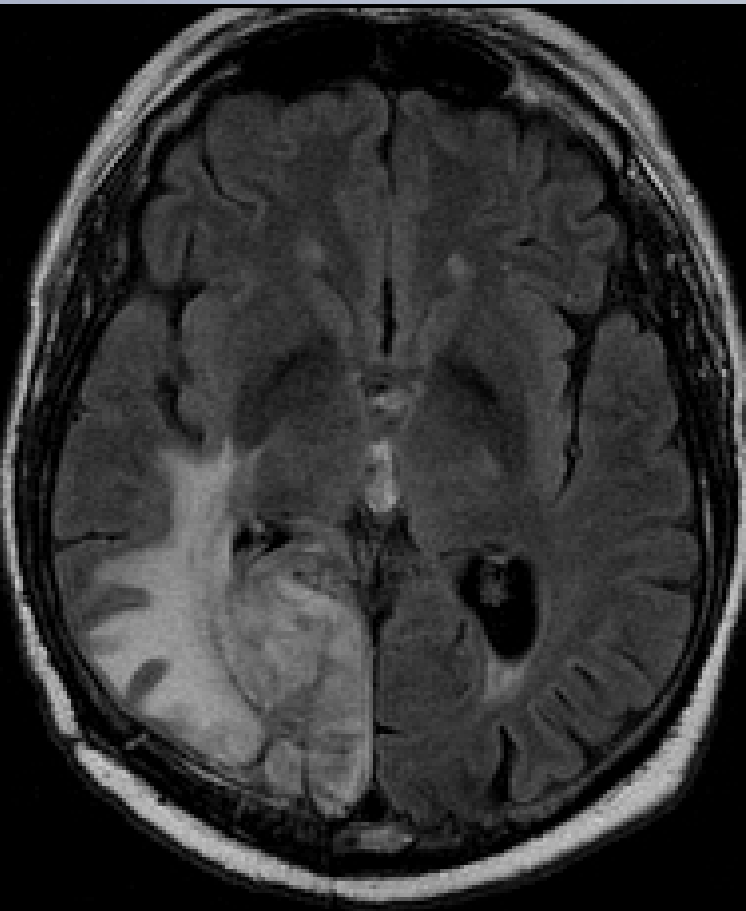
Clinical applications

- Restricted water diffusion is non-specific
 - Ischemia
 - Infection, Inflammation
 - Neoplasm
 - E.g. Lymphoma
 - Hemorrhage
 - E.g. subdural hematoma

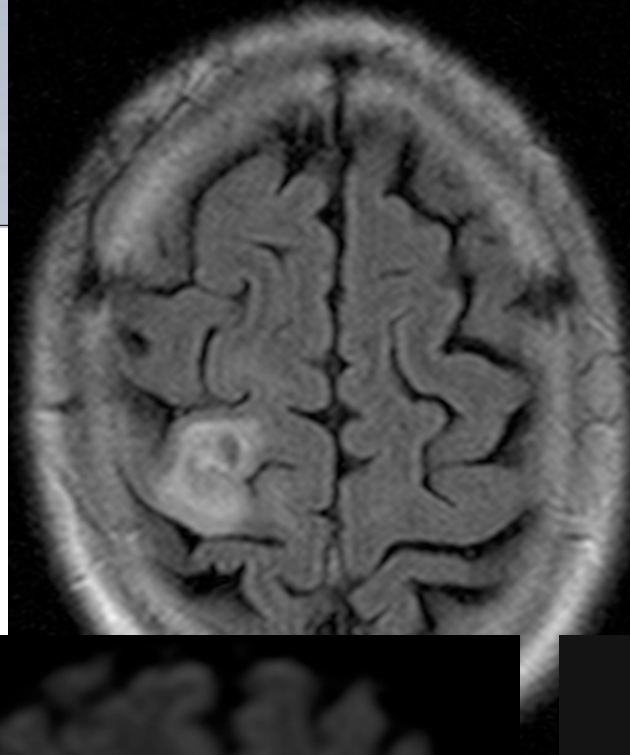
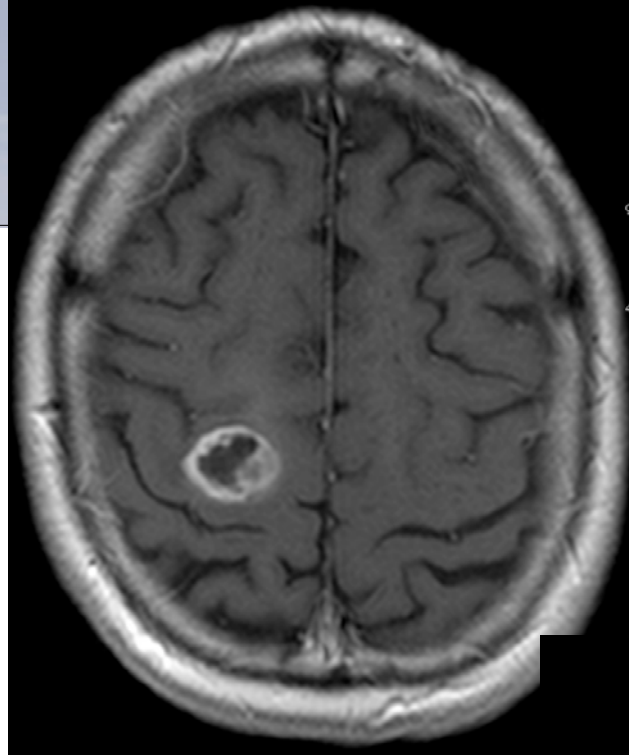




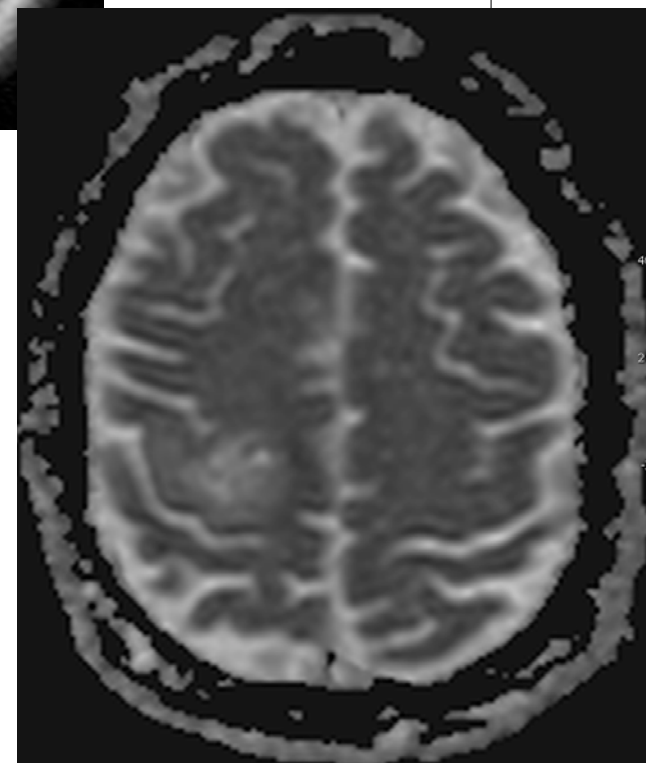
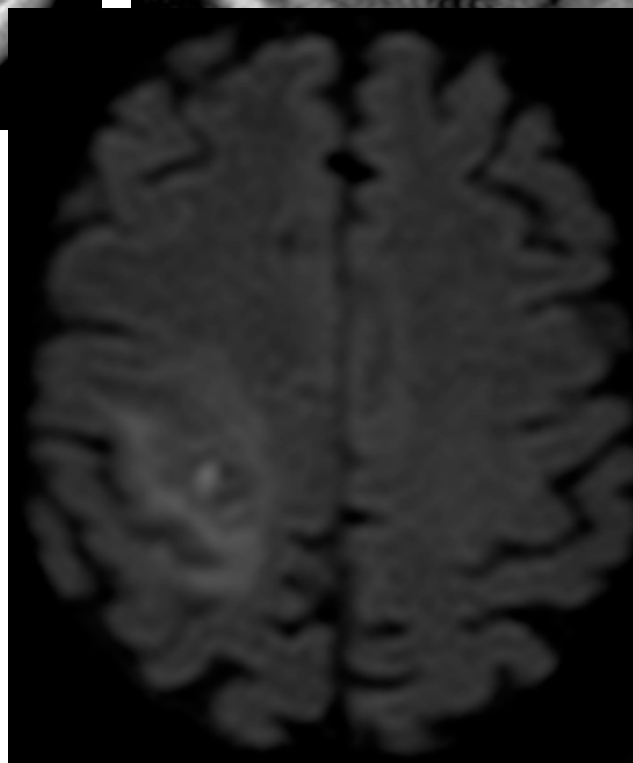


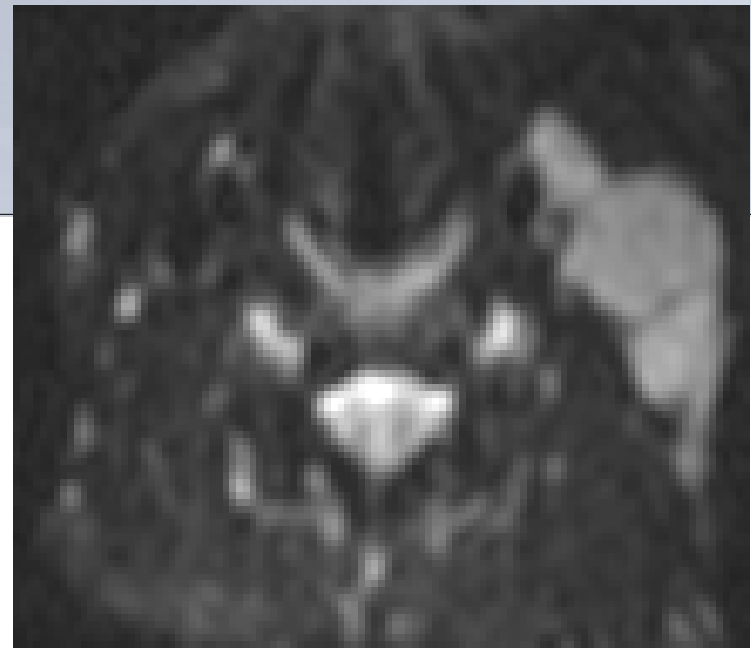


Abscess

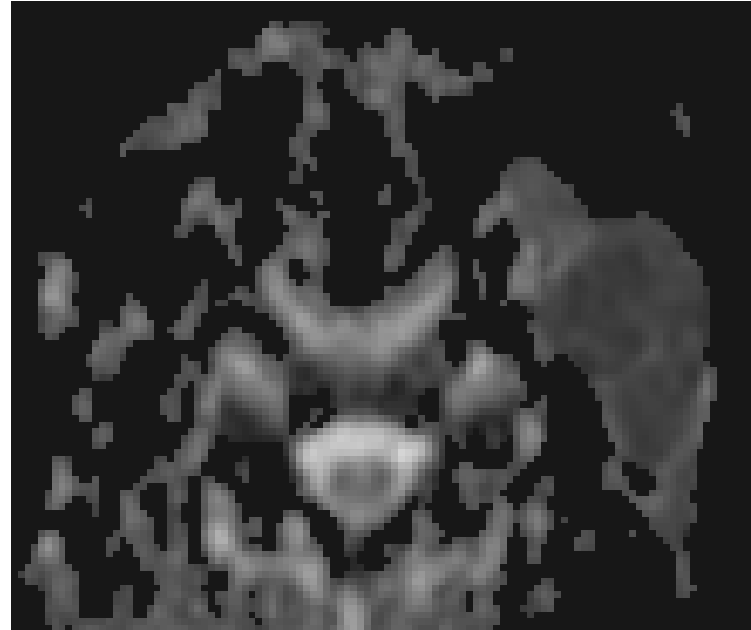


Tumor



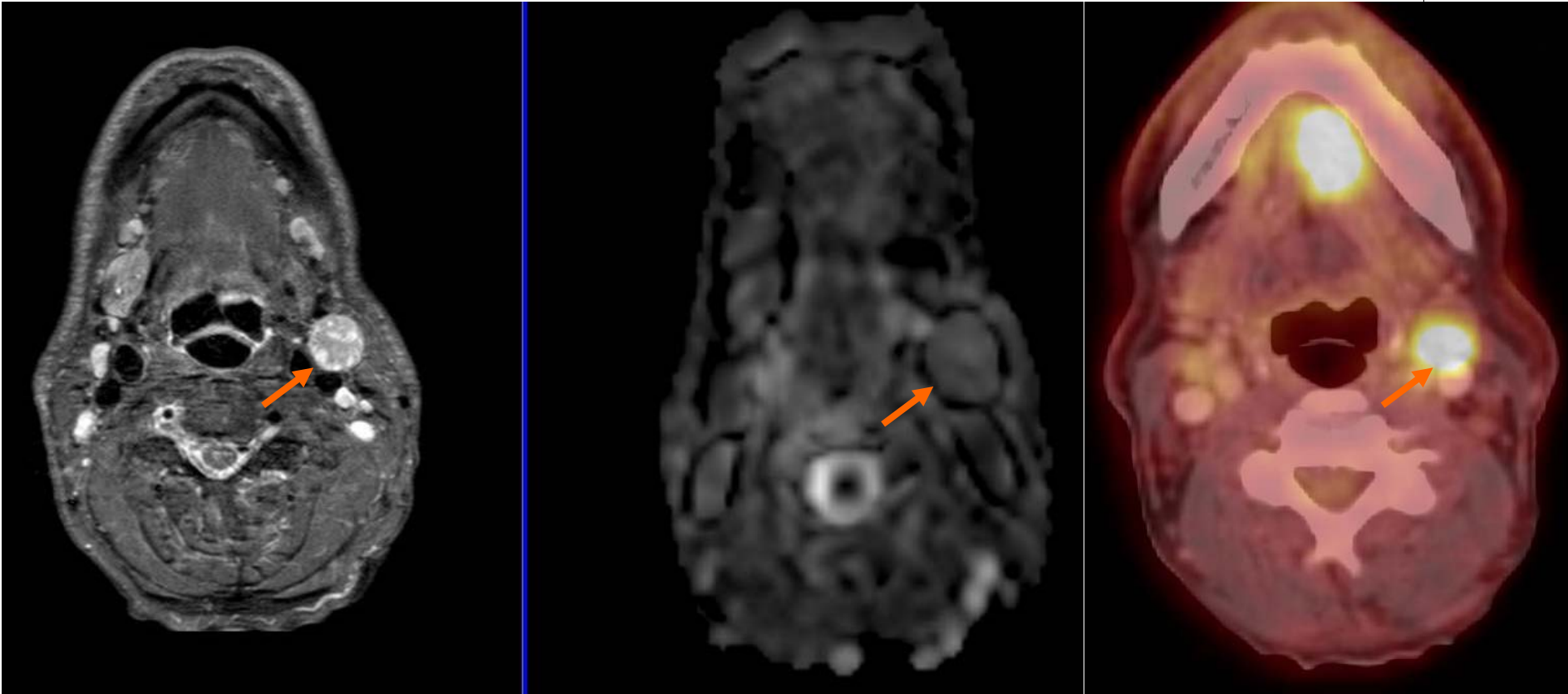


Lymphoma

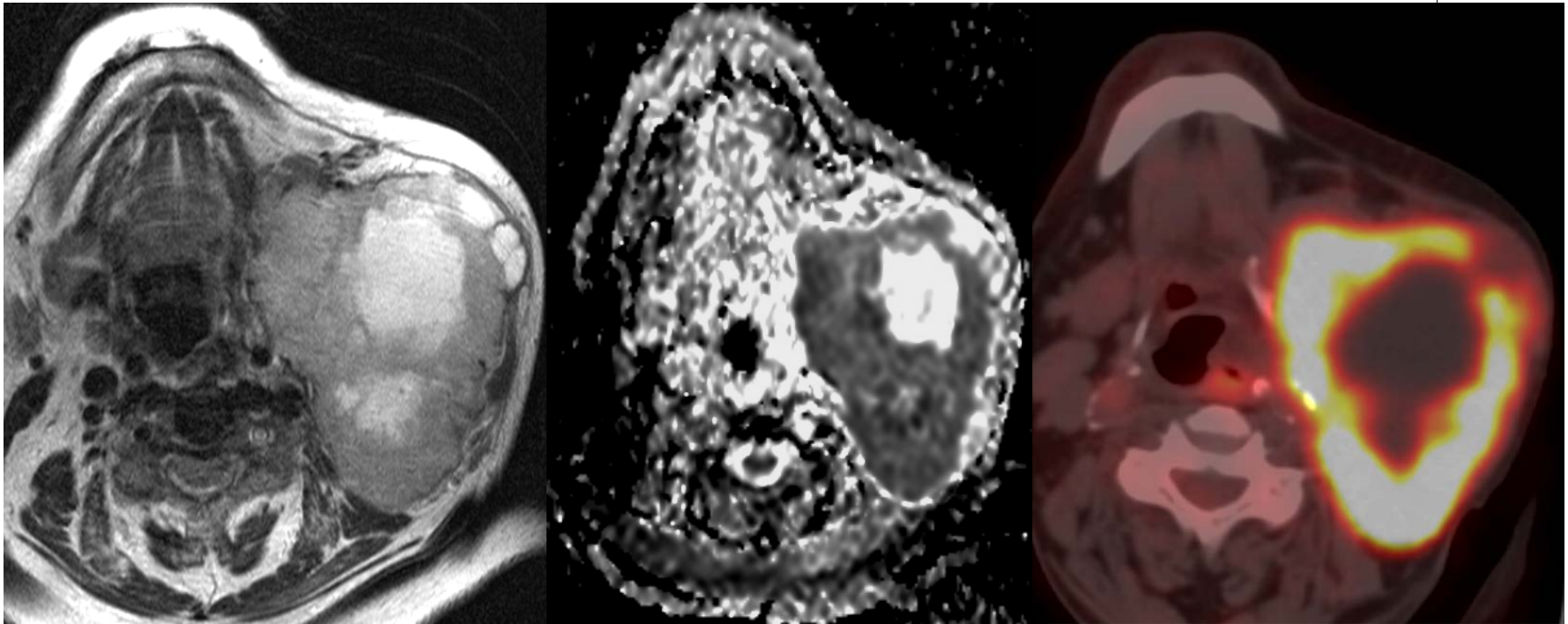


$ADC=0,6 \times 10^{-3} \text{ mm}^2/\text{s}$

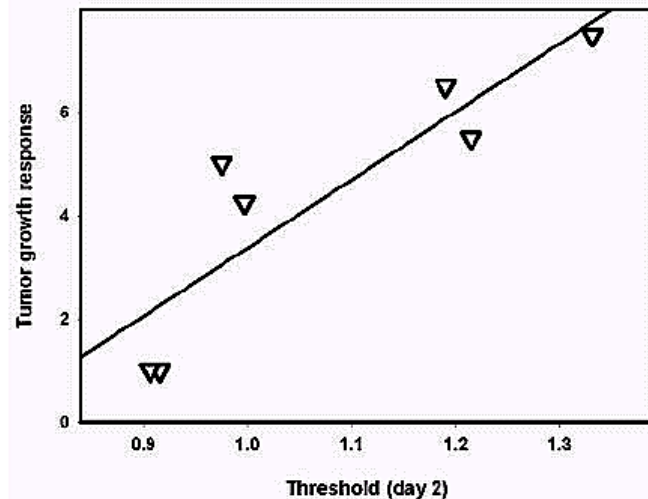
DWI and PET-CT



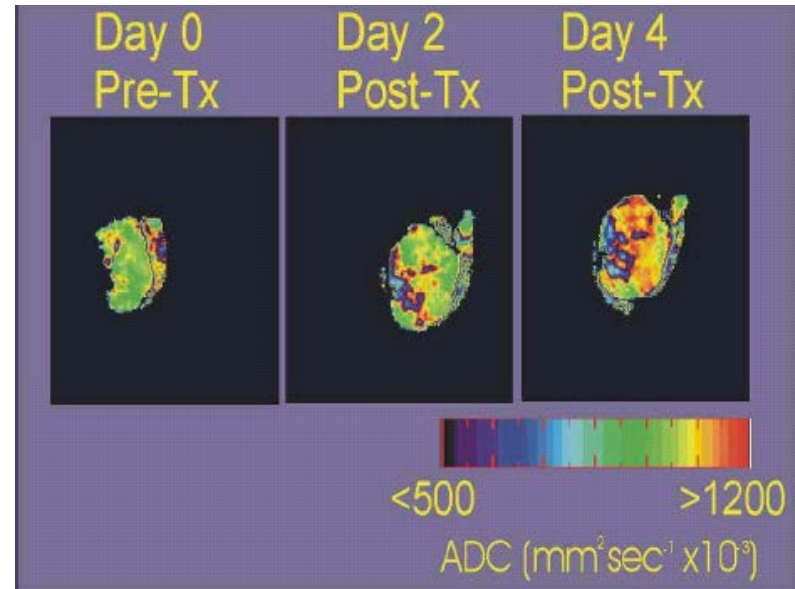
DWI and PET/CT



Therapy Monitoring



Relationship between eventual tumor response and ADC changes 2 days after start of Taxotere chemotherapy.



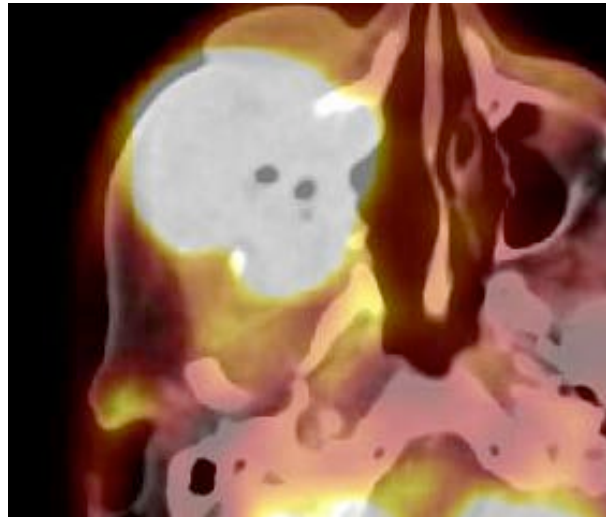
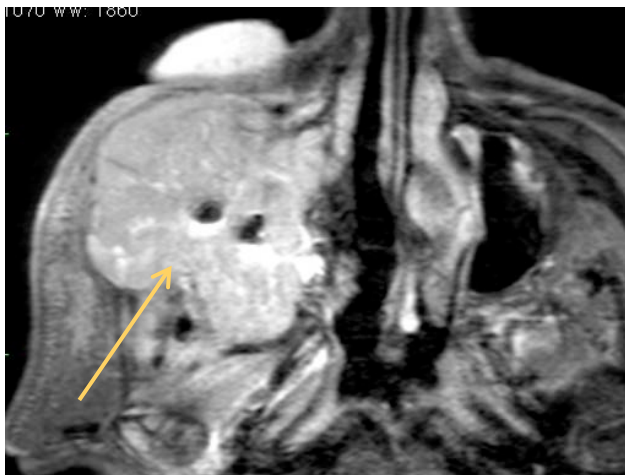
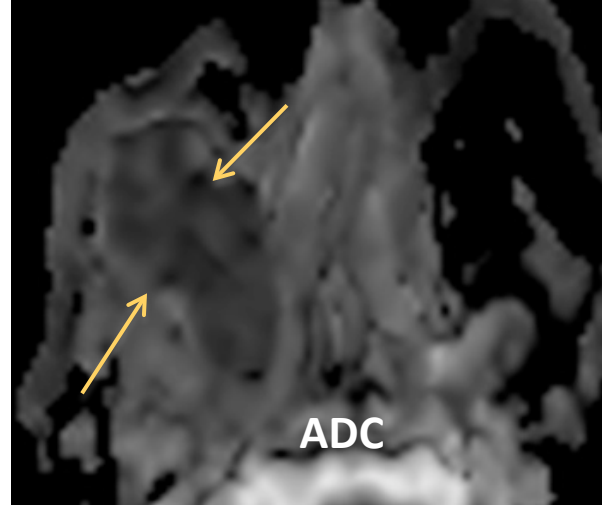
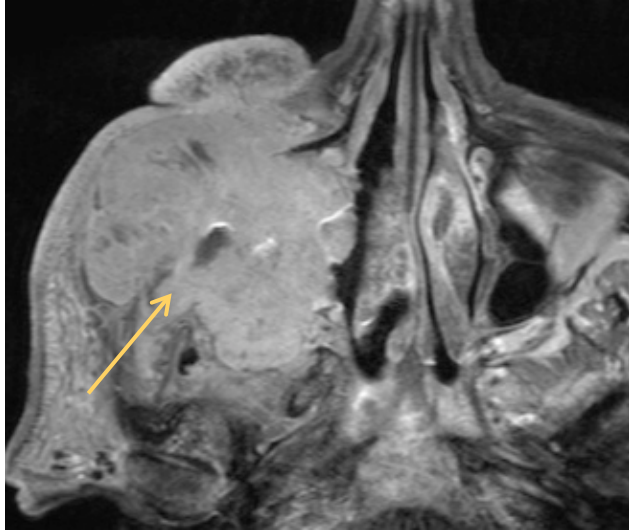
“...ADC increased in most mice following therapy...

... in those cases where a change was not observed, the mice were non-responsive to drug.

... magnitude of the change in diffusion coefficient was directly related to the magnitude of the eventual tumor response.”

Jennings, D et al., Proc. Intl. Soc. Mag. Reson. Med 9 (2001) 143

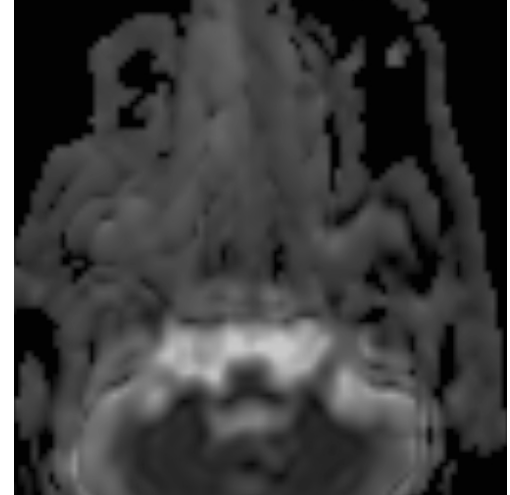
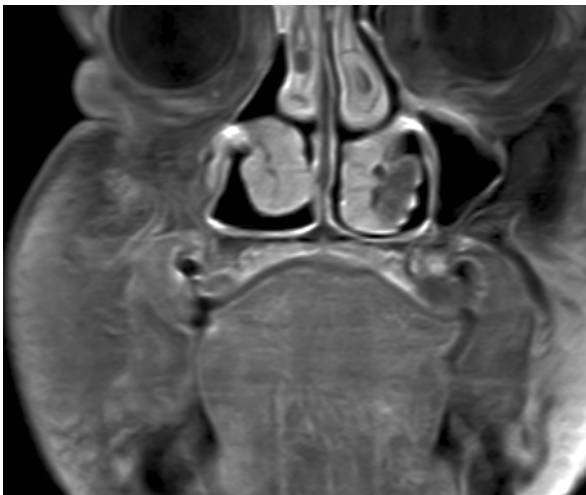
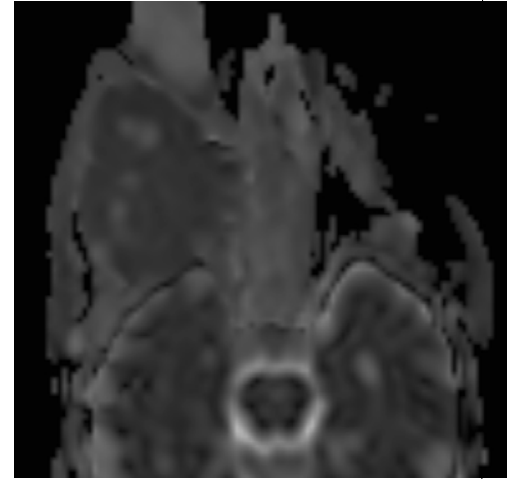
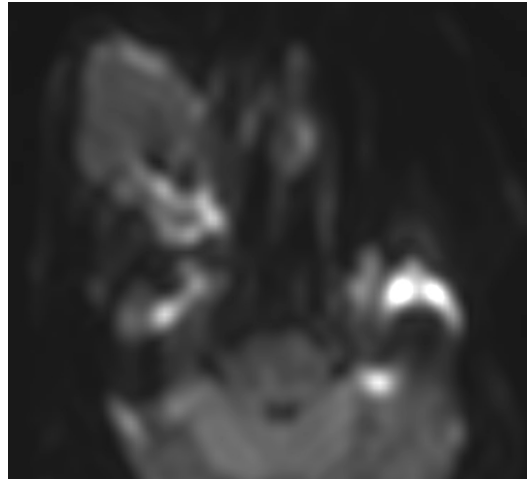
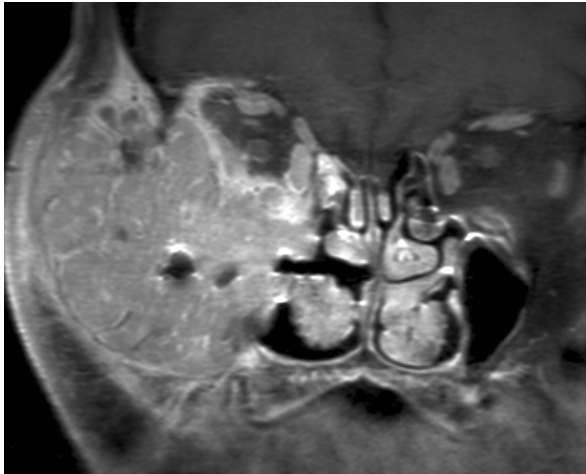
68 year-old patient mit T4b N2 maxillar sinus carcinoma



RTx, CHx



Follow-up



DWI in oncology

- ✓ Based on restricted water diffusion („water as contrast media“).
- ✓ No need of ionising radiation and no external cm application.
- ✓ Detection of recurrent disease
- ✓ Differentiation of tumor tissue (negative correlation grade-ADC).
- ✓ May serve as predictive value for prediction of outcome or treatment monitoring
- ✓ Is independent of tissue relaxation time

MR applications: Diffusion

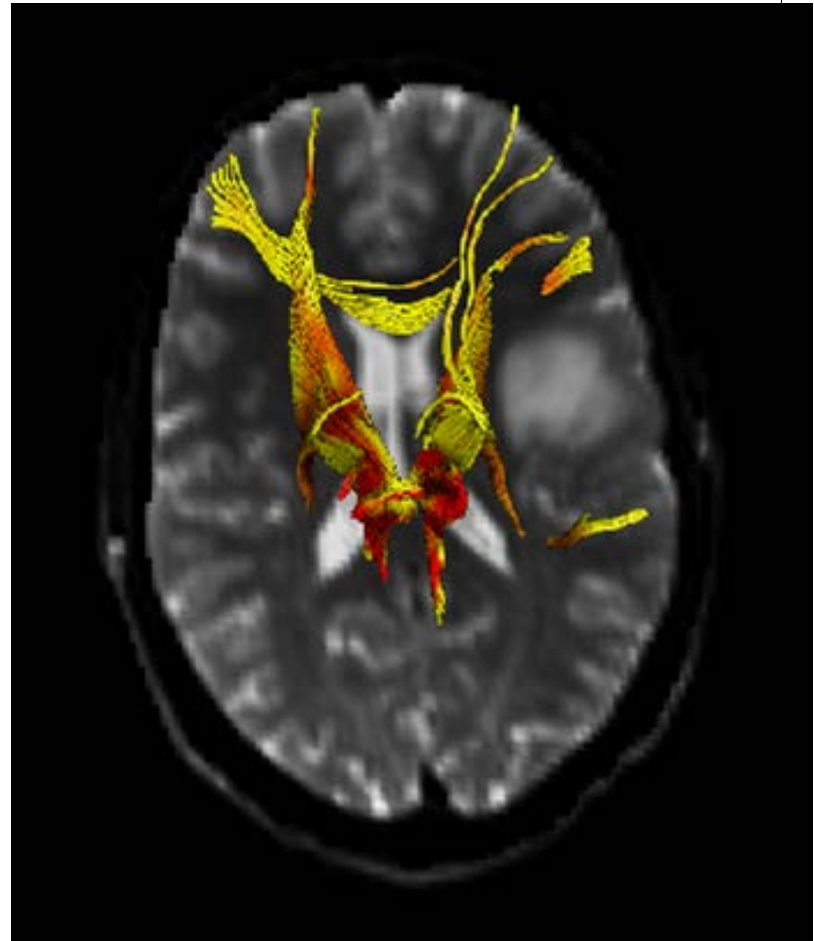
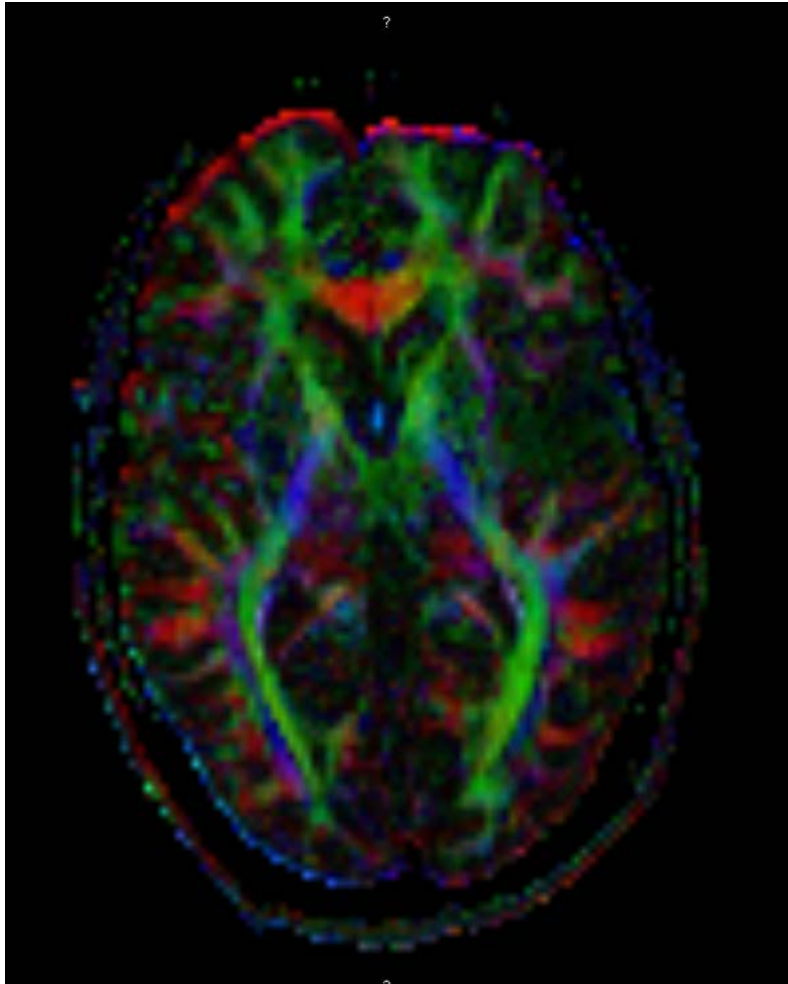
Diffusion Tensor Imaging / Tractography

- Water diffusion is organized in tissues with
- Localisation / orientation of fiber tracts

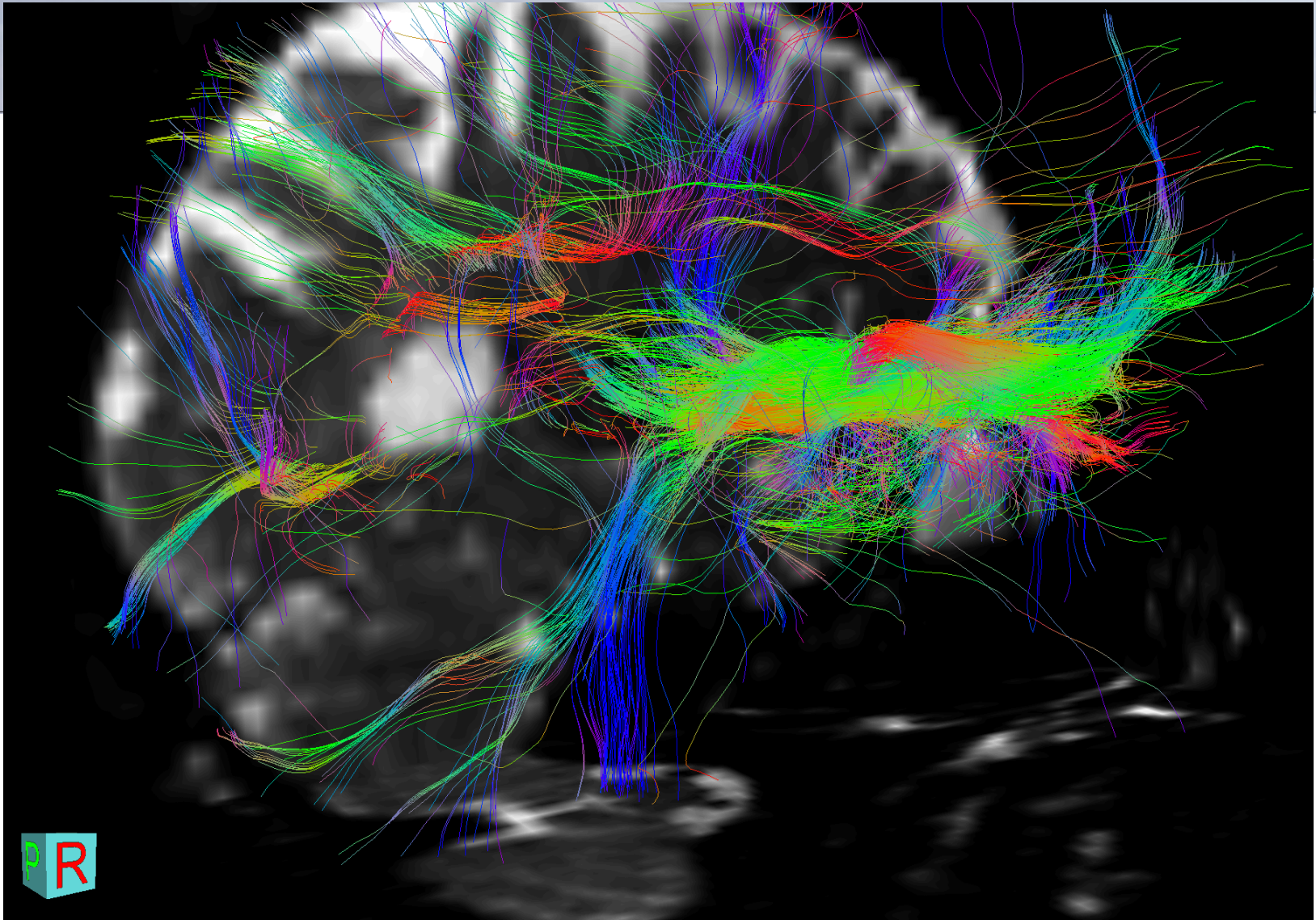
Clinical applications

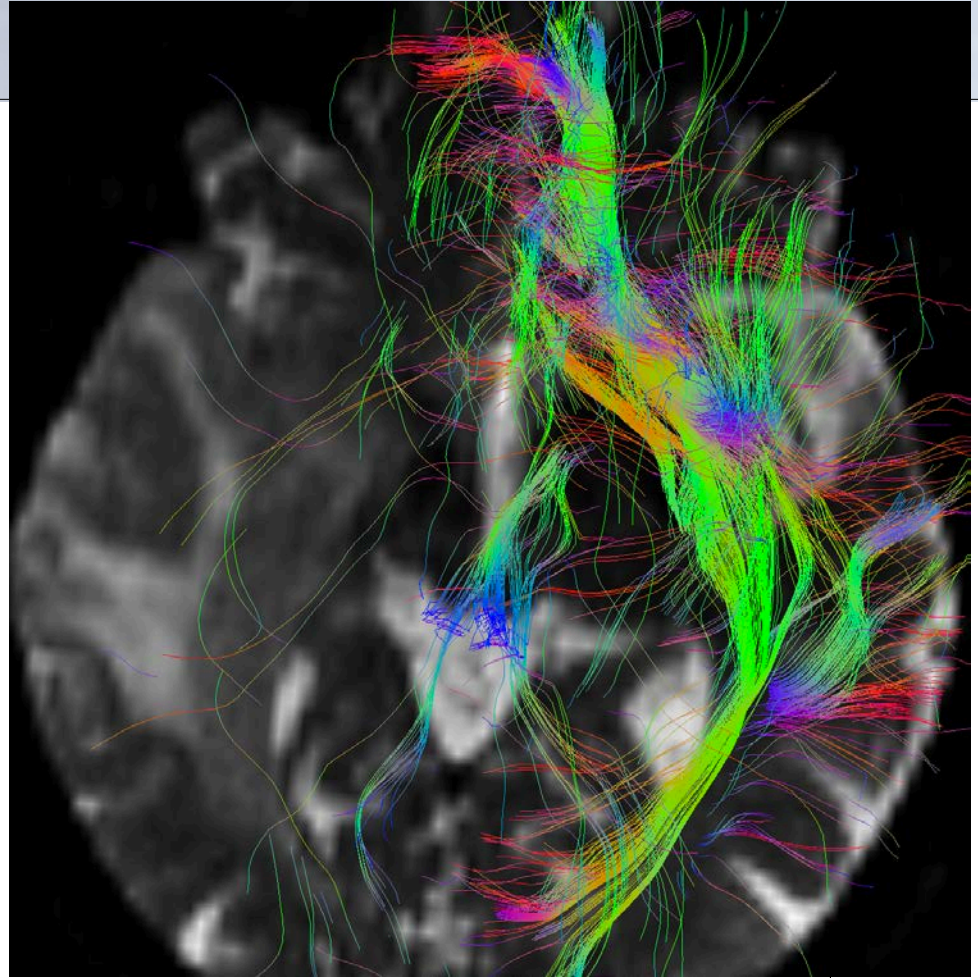
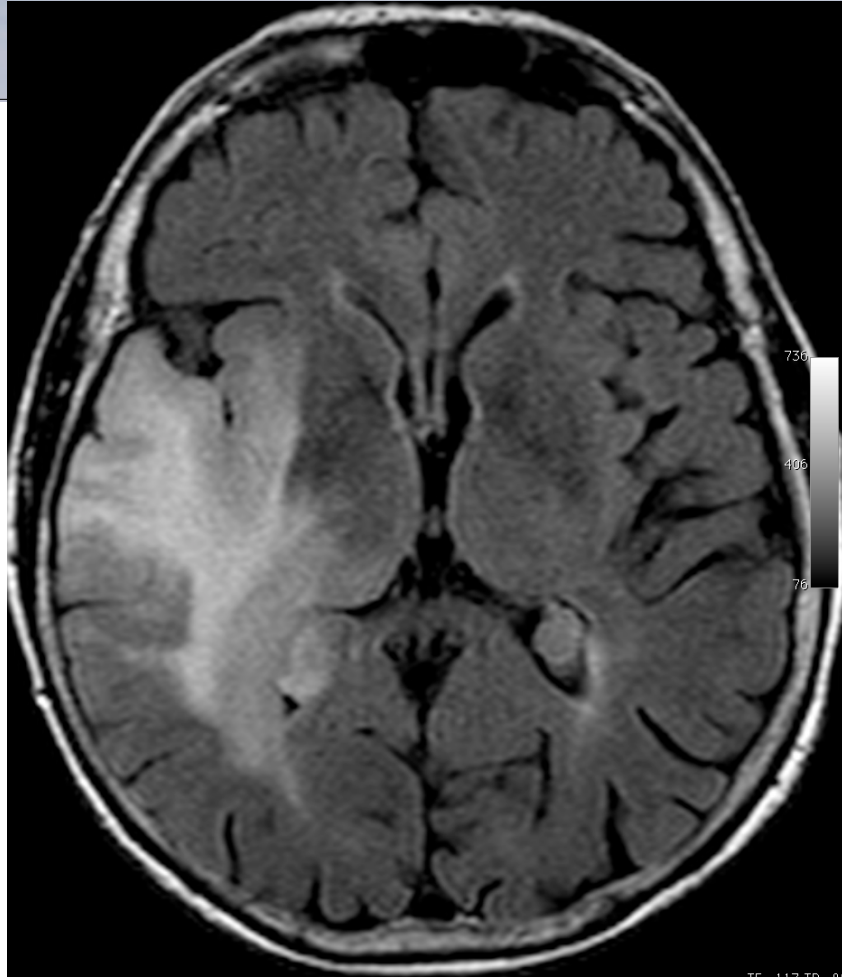
- Surgical planning
- White matter involvement after stroke and trauma

MR applications: Diffusion



Diffusion Tensor Imaging





MR applications: Perfusion

Perfusion Weighted Imaging

- ASL: no contrast agent (electromagnetically labelled arterial blood)
- Only gives cerebral blood volume

DCE: dynamic contrast enhanced T1w

- Depict cerebral microcirculation

DSC: dynamic susceptibility weighted T2*

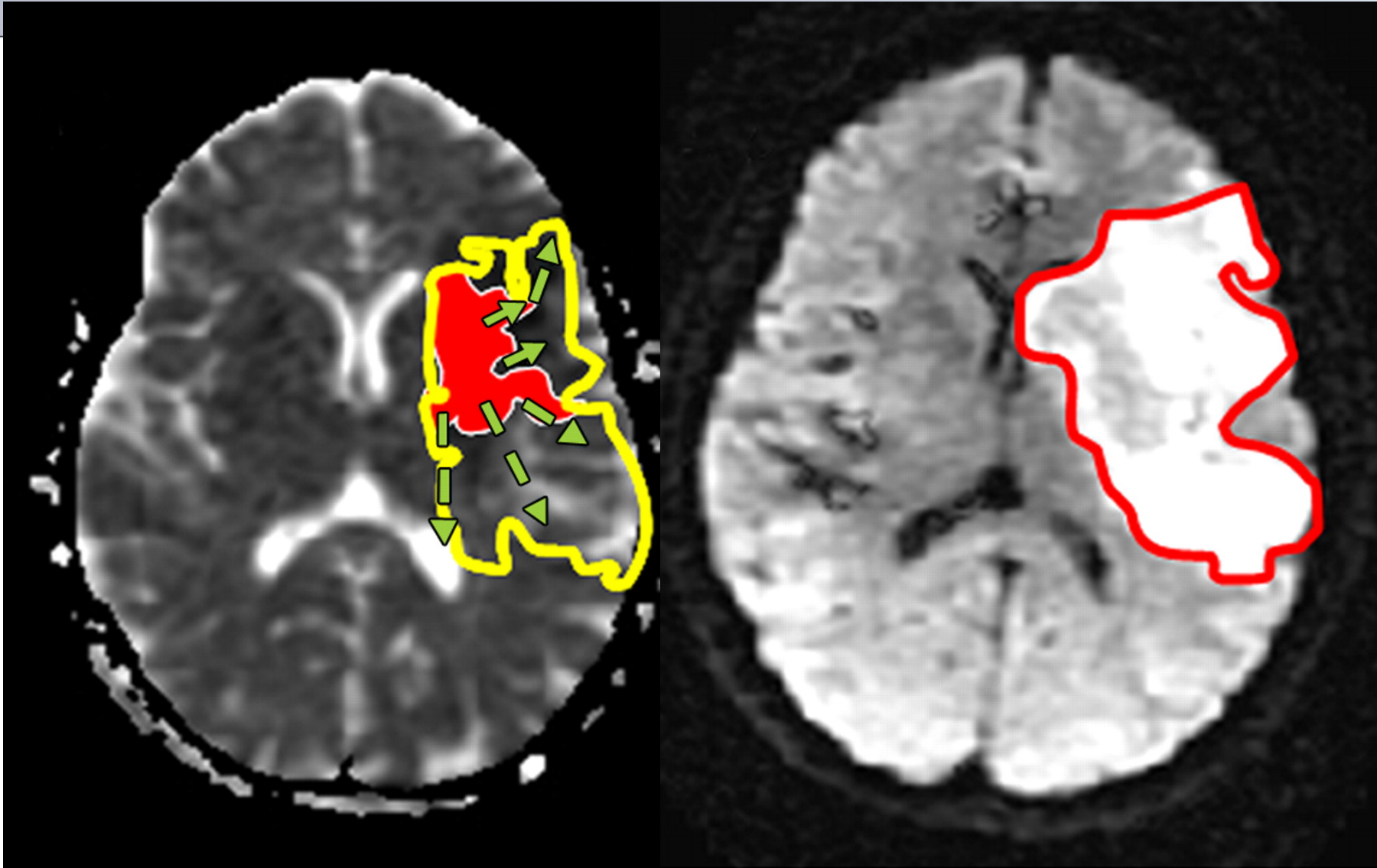
- Provides vascularity, cerebral blood volume, time-to-peak

MR applications: Perfusion - DSC

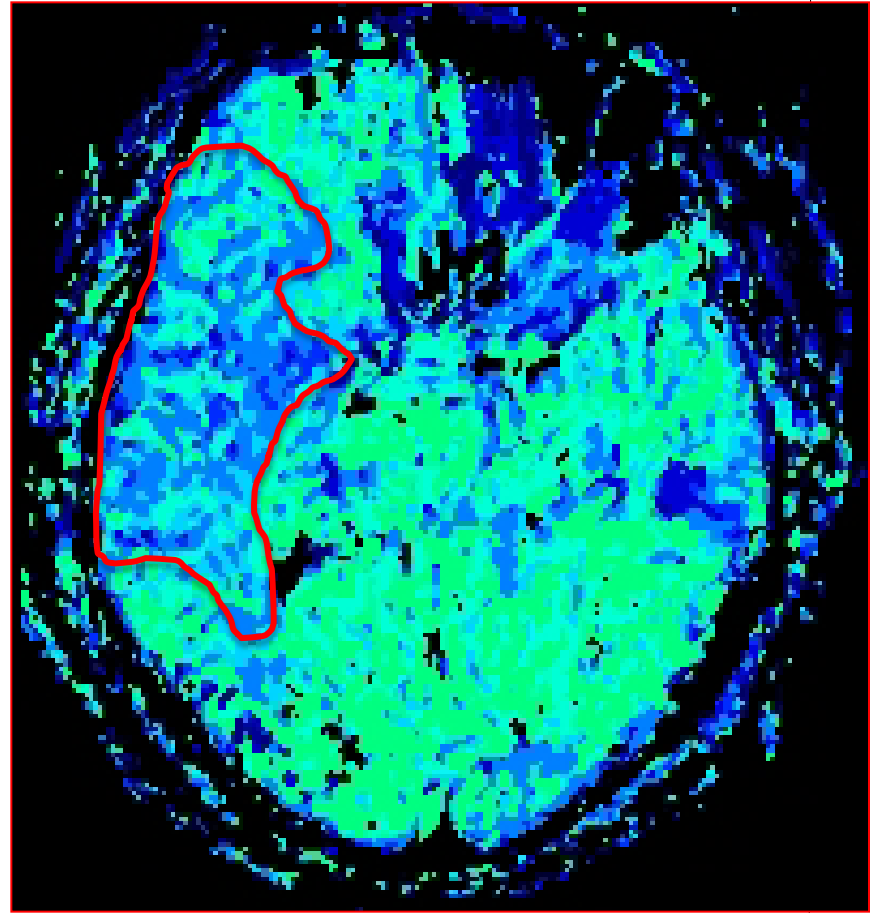
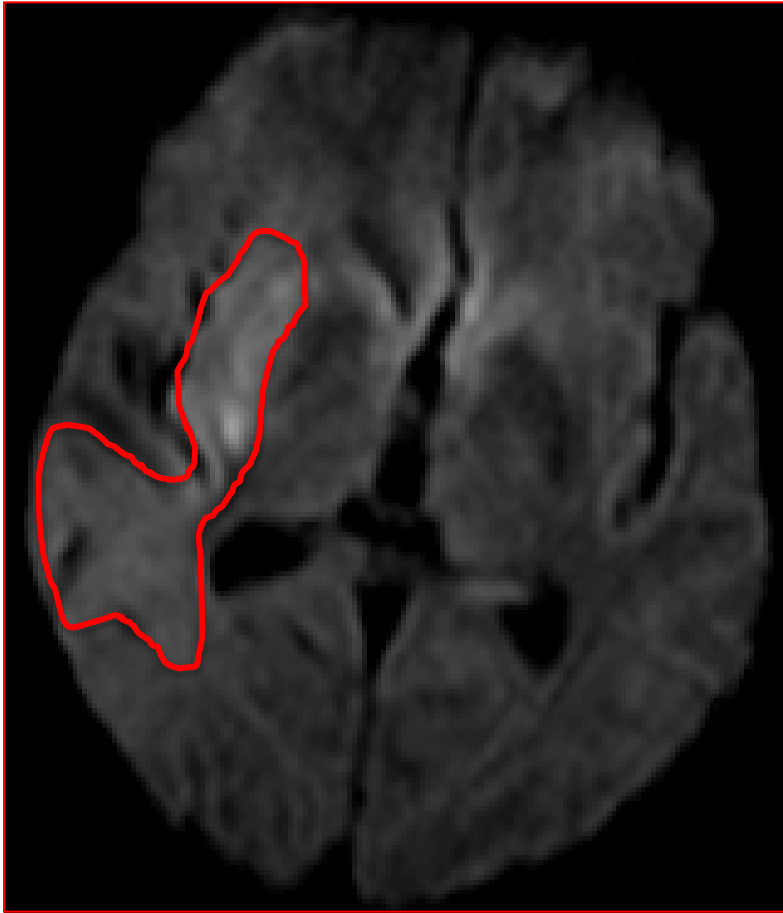
Clinical applications

- Akute Stroke
 - Perfusion Diffusion Mismatch: ischemic penumbra
 - Tissue at risk
- Brain neoplasms
 - proliferation and neoangiogenesis
 - Degree of tumor angiogenesis / vessel permeability

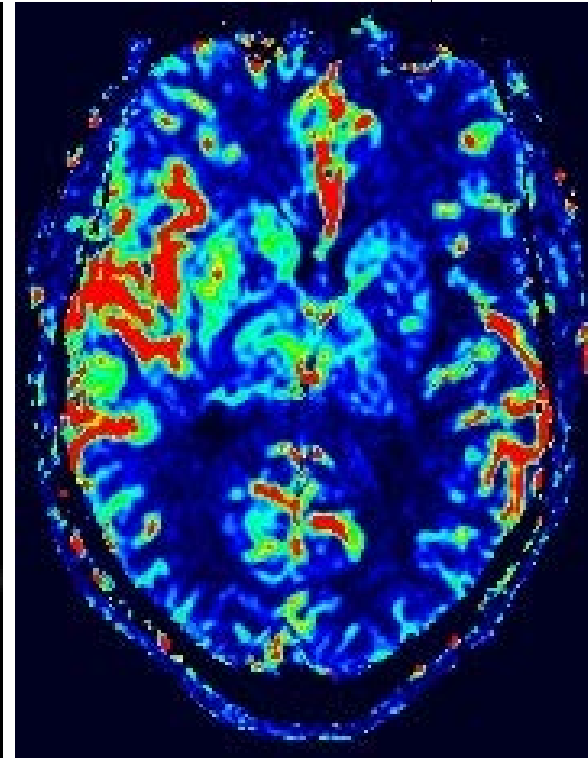
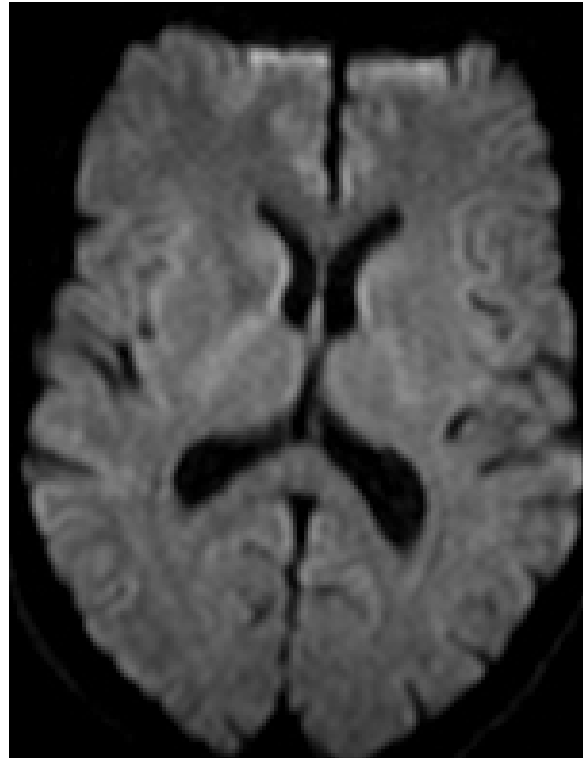
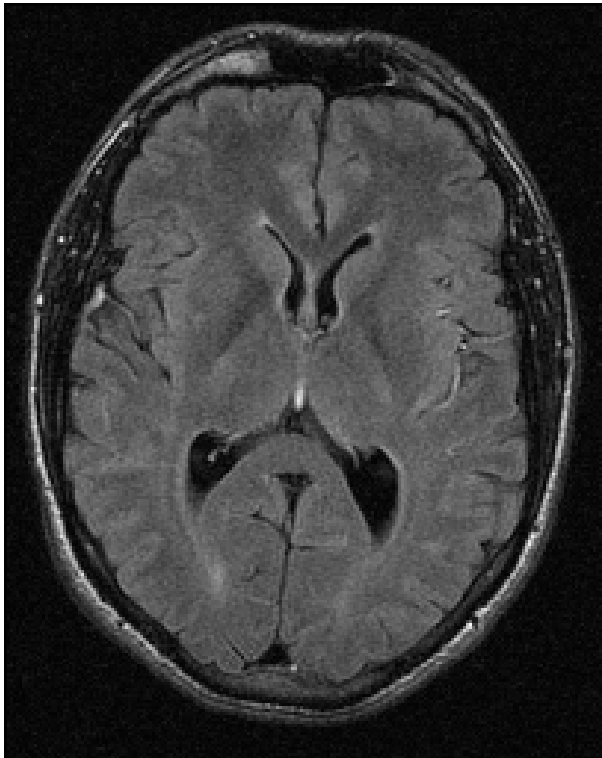
Natural course of an infarct (“worst case scenario”)



Diffusion-Perfusion Mismatch



Diffusion-Perfusion Mismatch

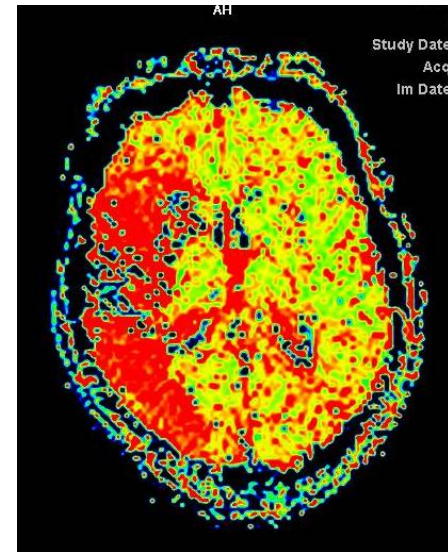
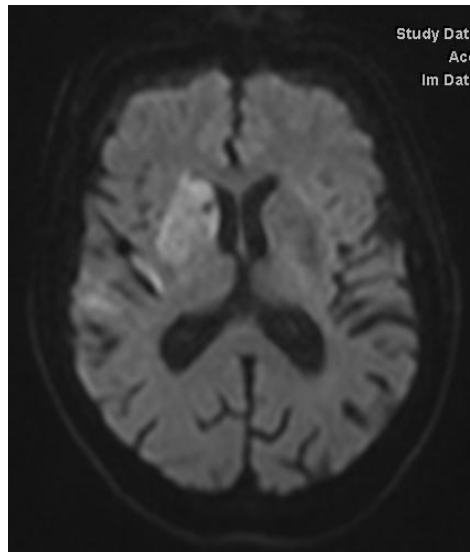


MR applications: Perfusion, Diffusion and Angio

Therapy with Marcumar – no systemic lysis possible

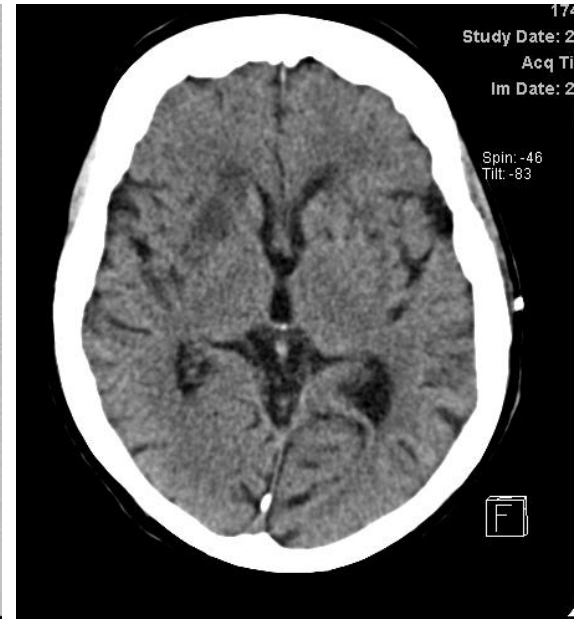
CE-Angio: Missing contrast in the right MCA

Mismatch DWI/FLAIR



MR applications: Perfusion, Diffusion and Angio

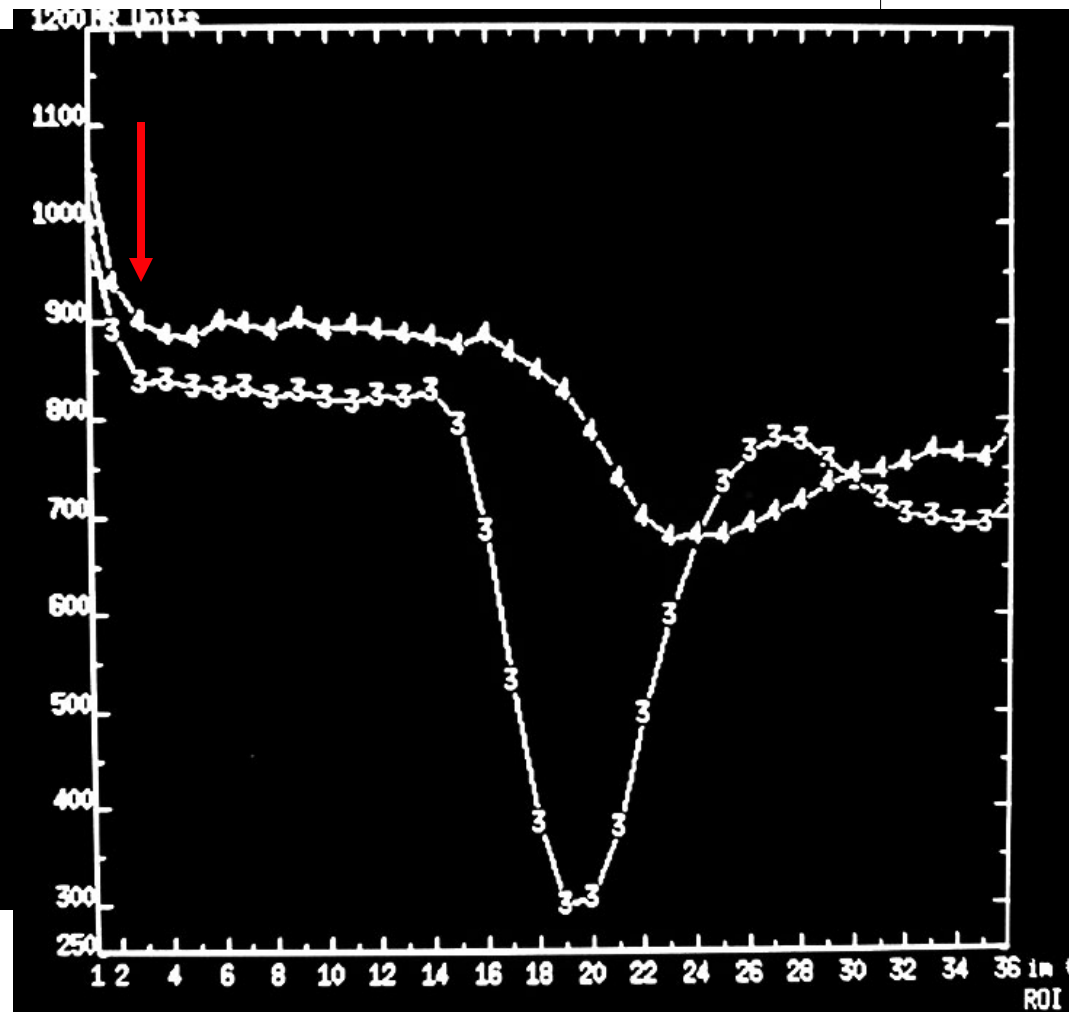
- Thrombectomy with stent retriever
- Only small area of infarction in the control CT



Gadolinium Bolus Tracking

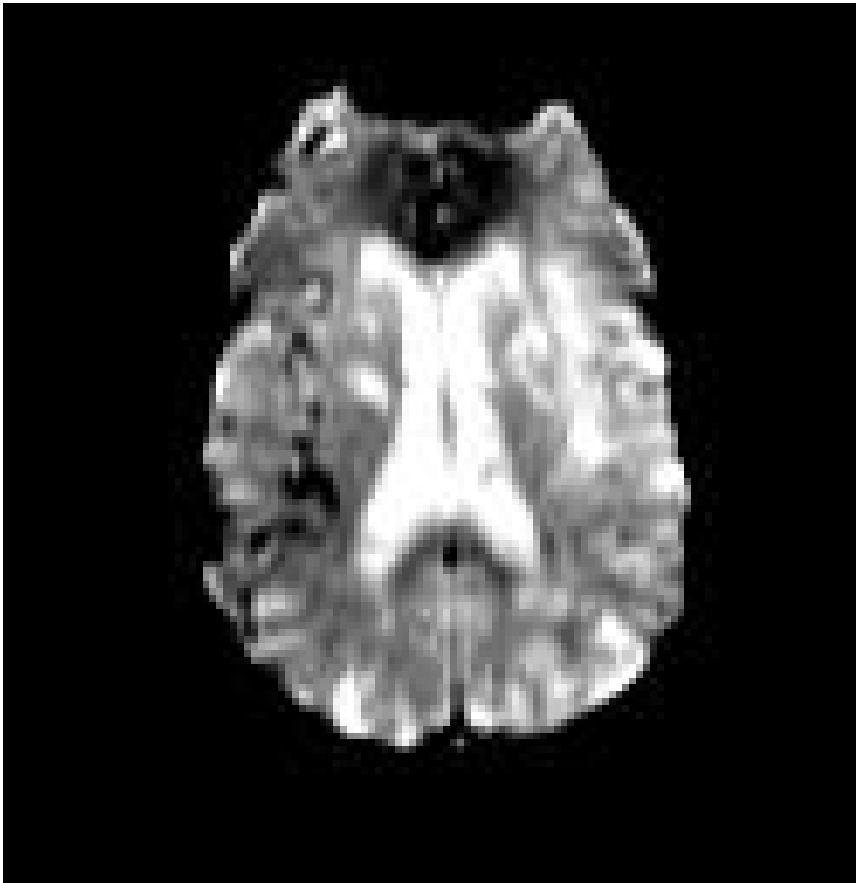


T2* Image

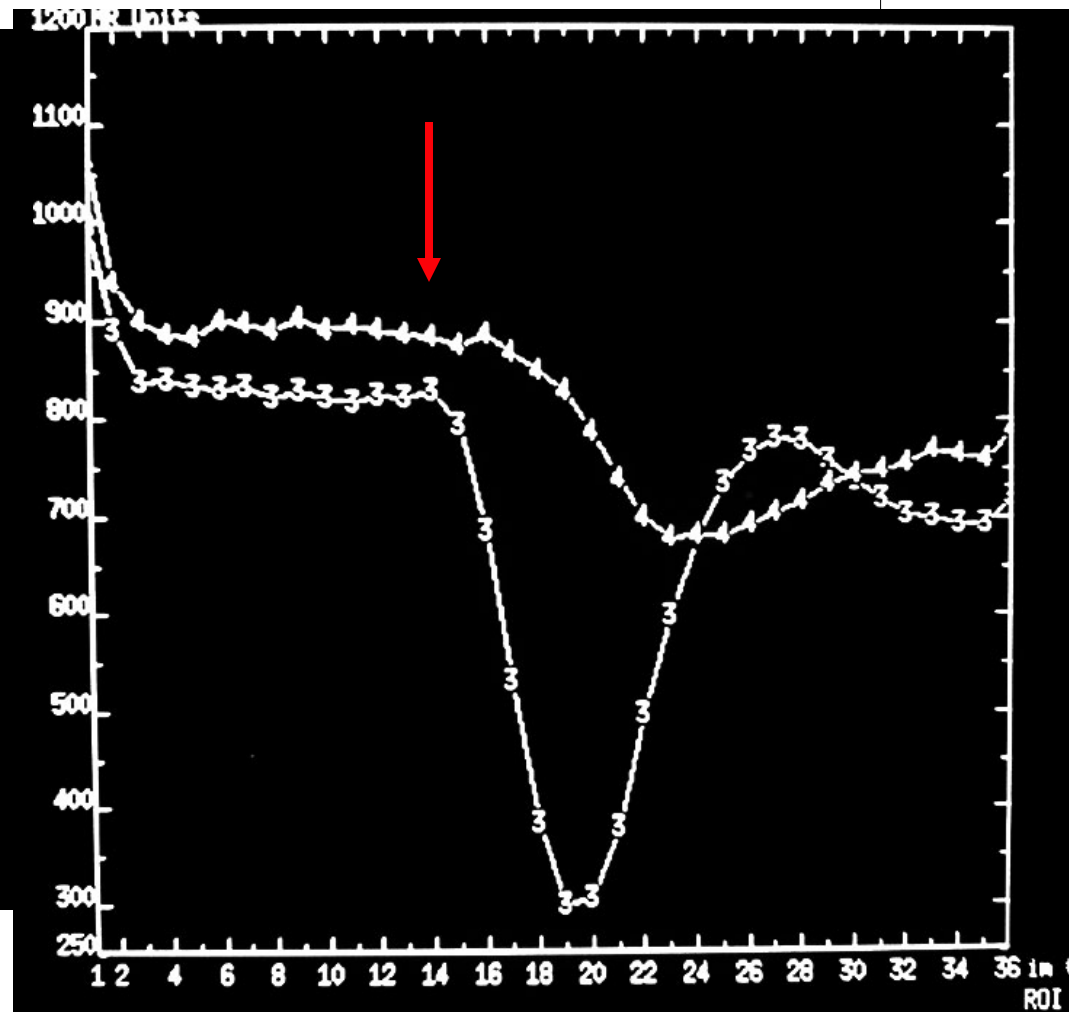


SI vs Time Curve

Gadolinium Bolus Tracking

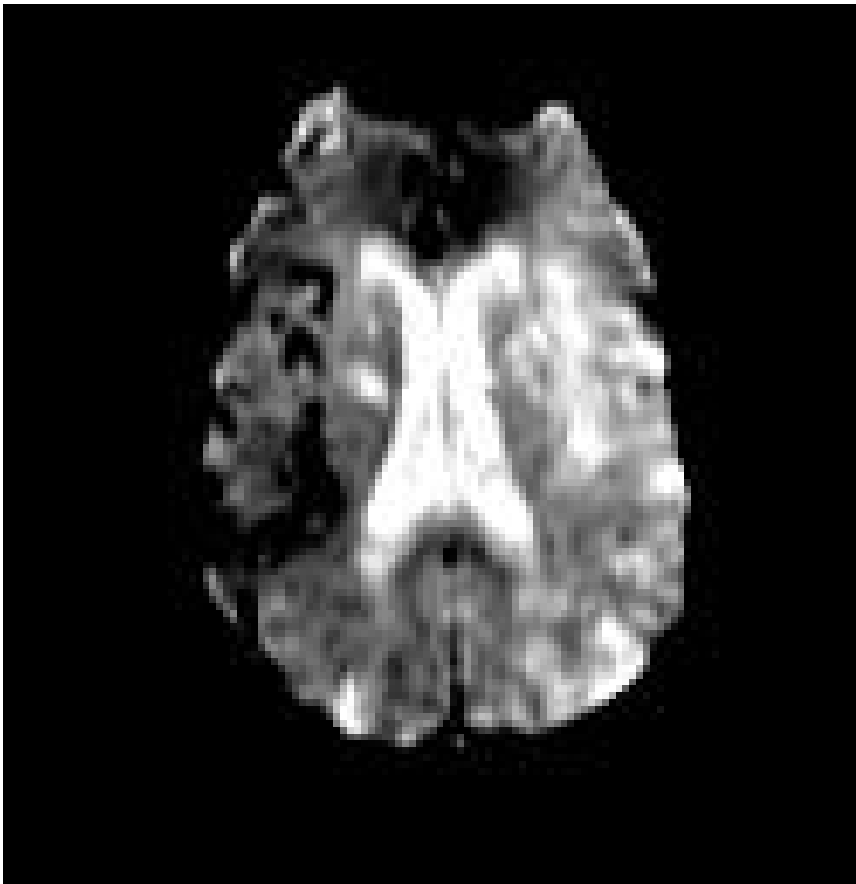


T2* Image

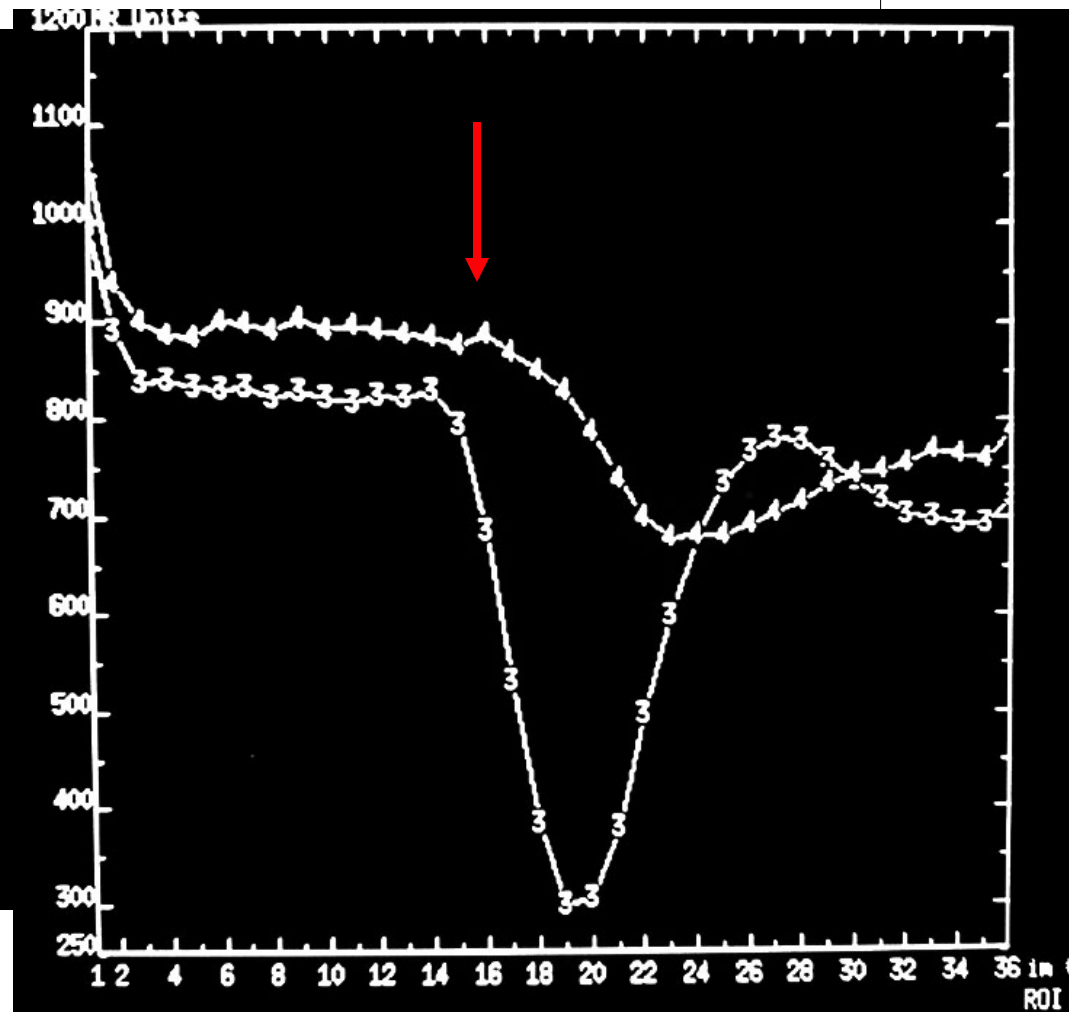


SI vs Time Curve

Gadolinium Bolus Tracking

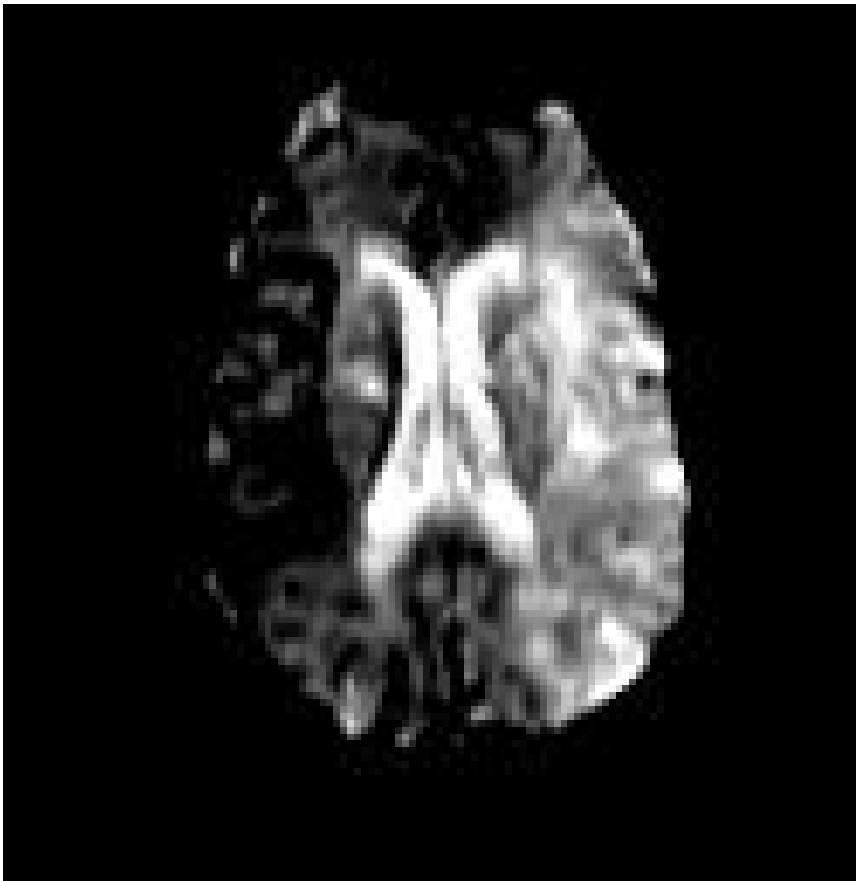


T2* Image

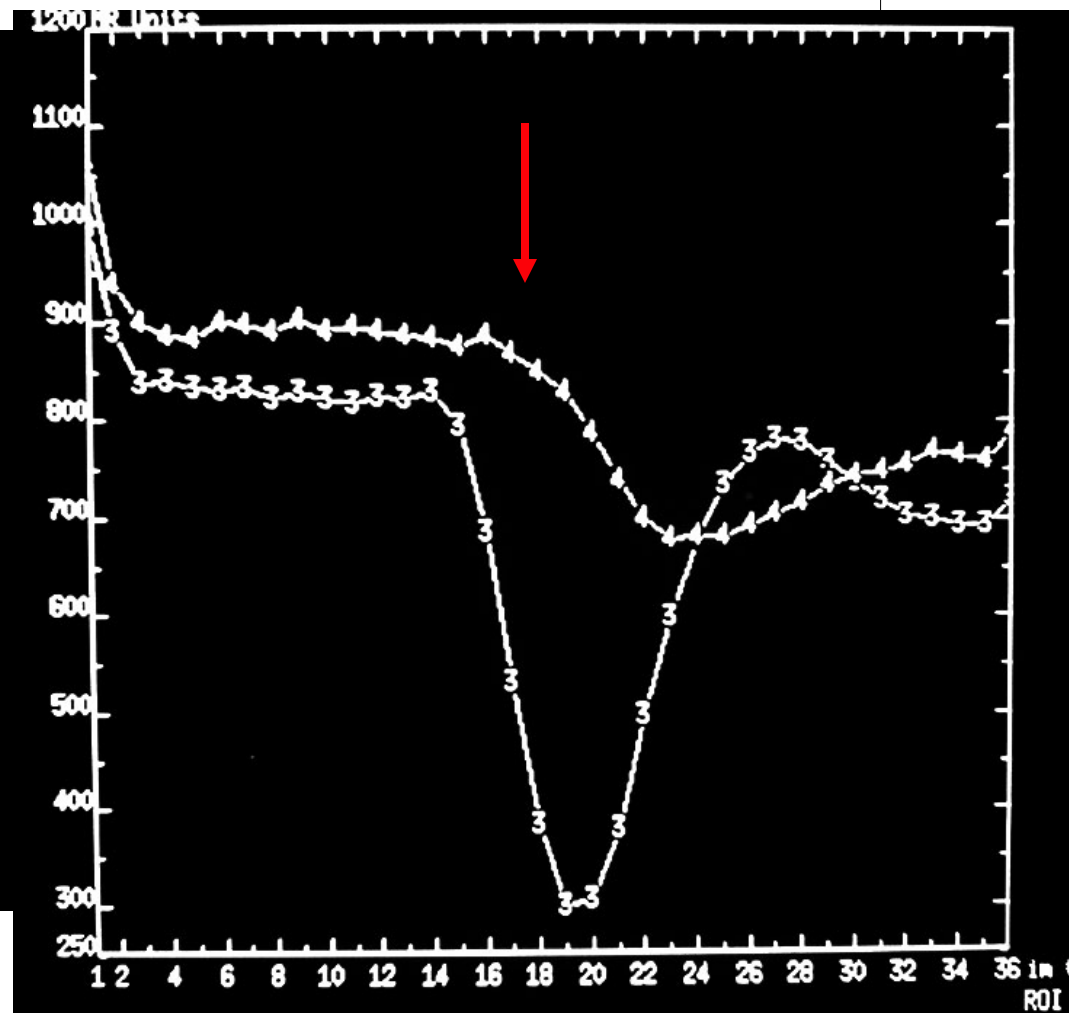


SI vs Time Curve

Gadolinium Bolus Tracking

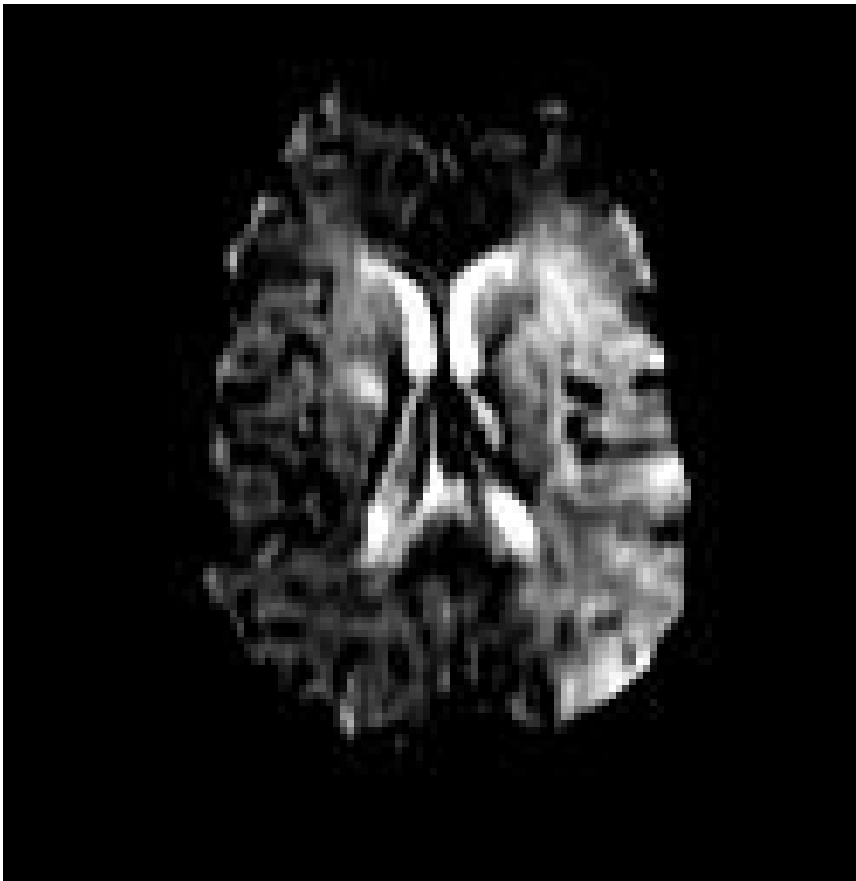


T2* Image

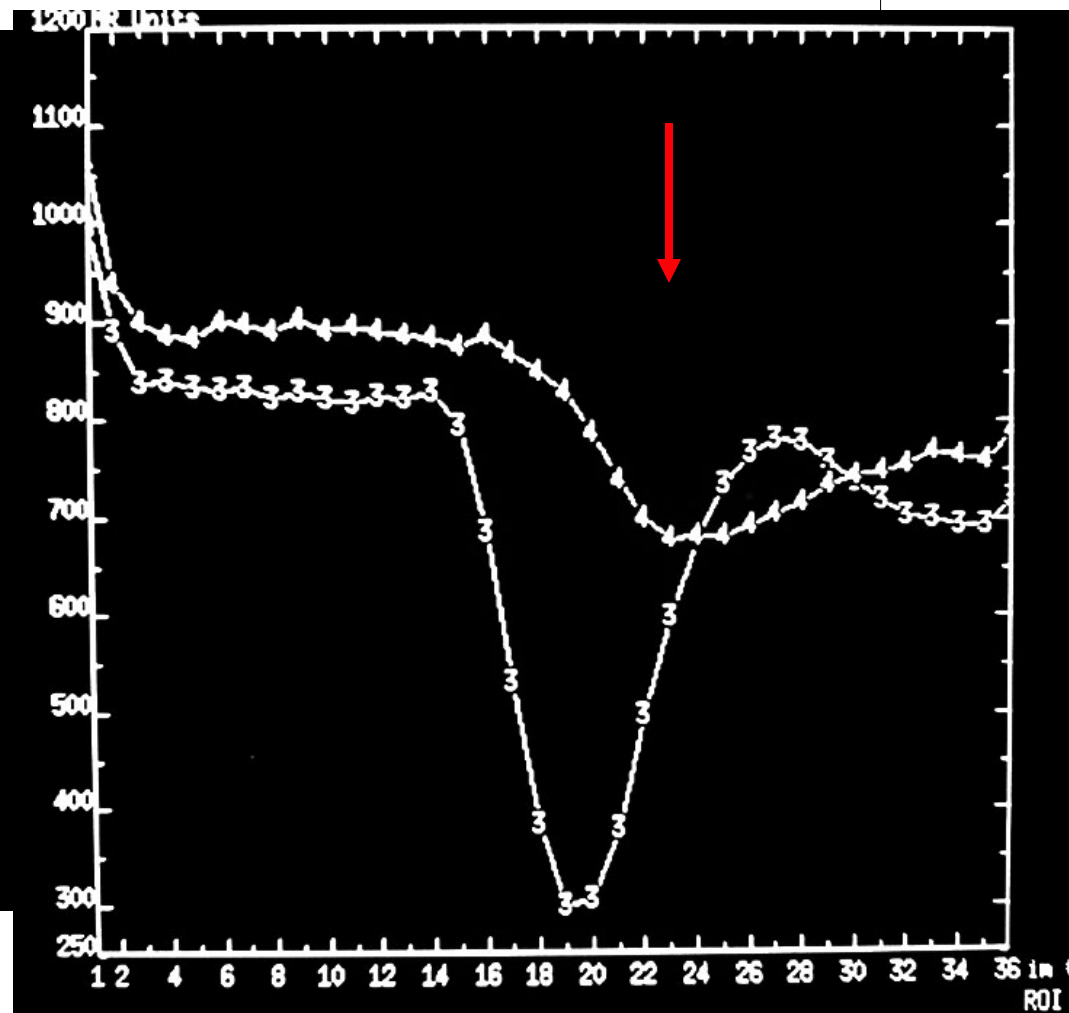


SI vs Time Curve

Gadolinium Bolus Tracking

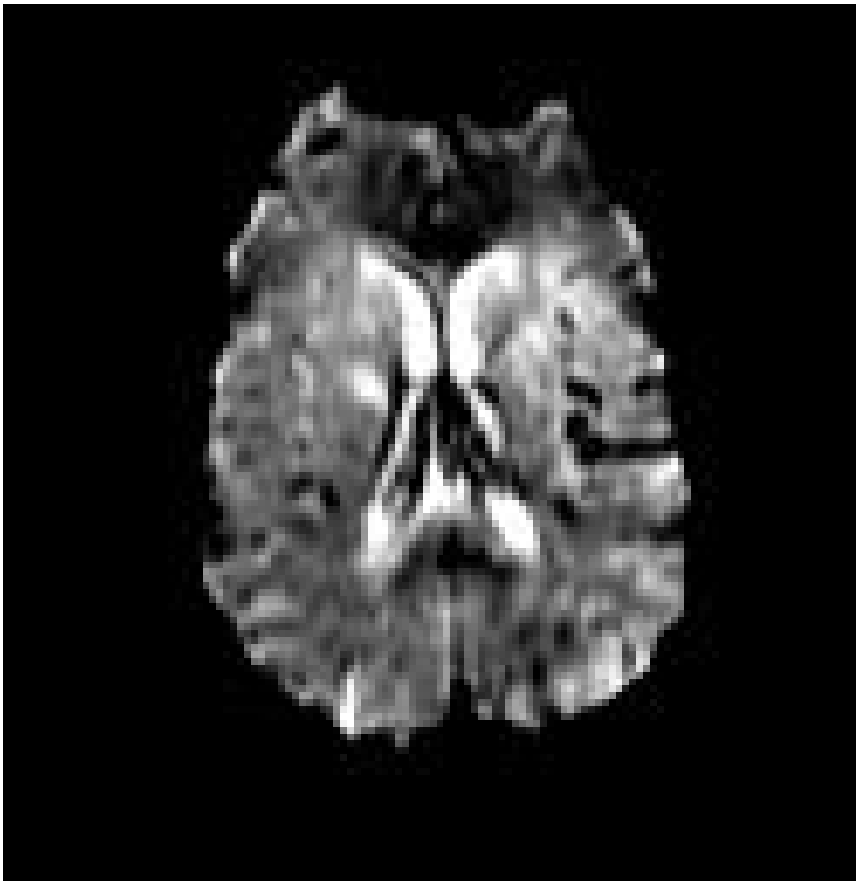


T2* Image

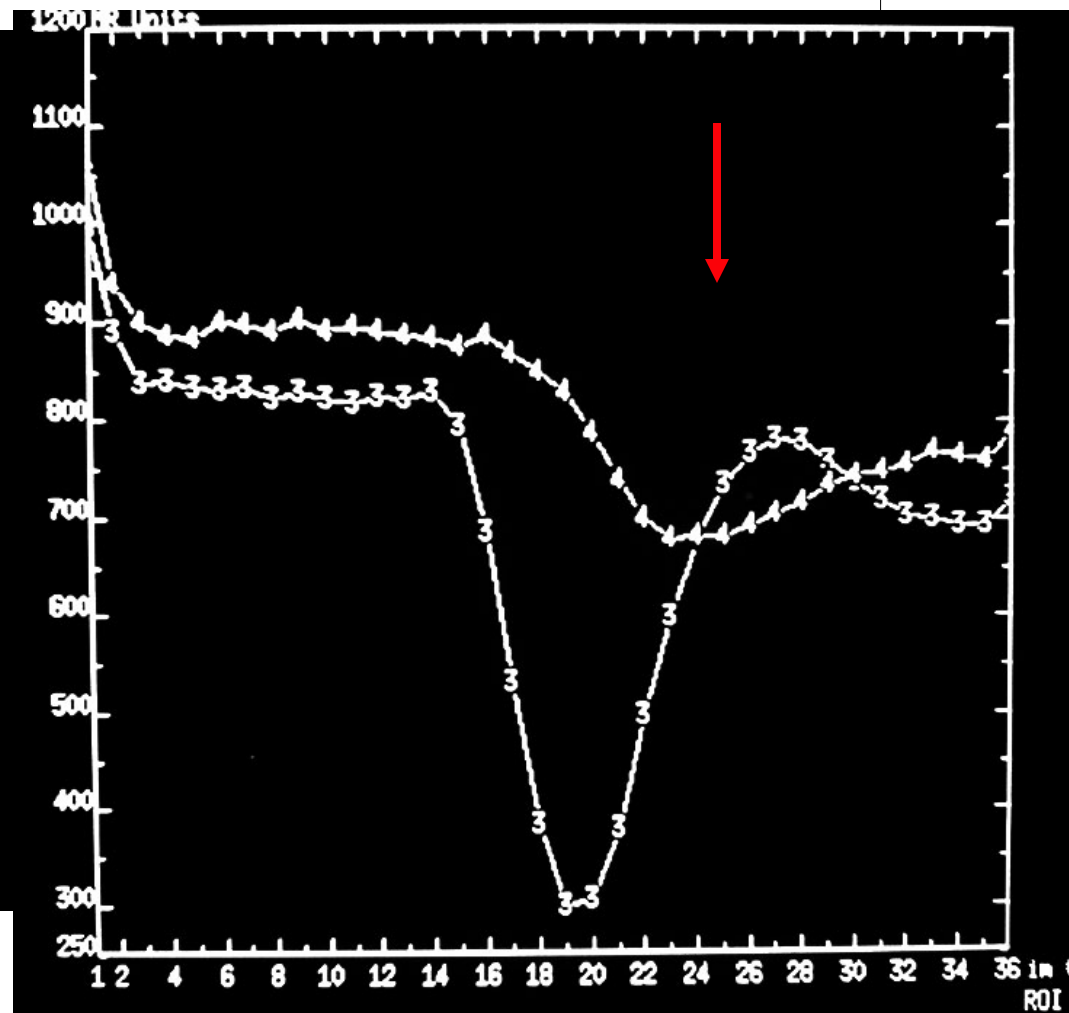


SI vs Time Curve

Gadolinium Bolus Tracking

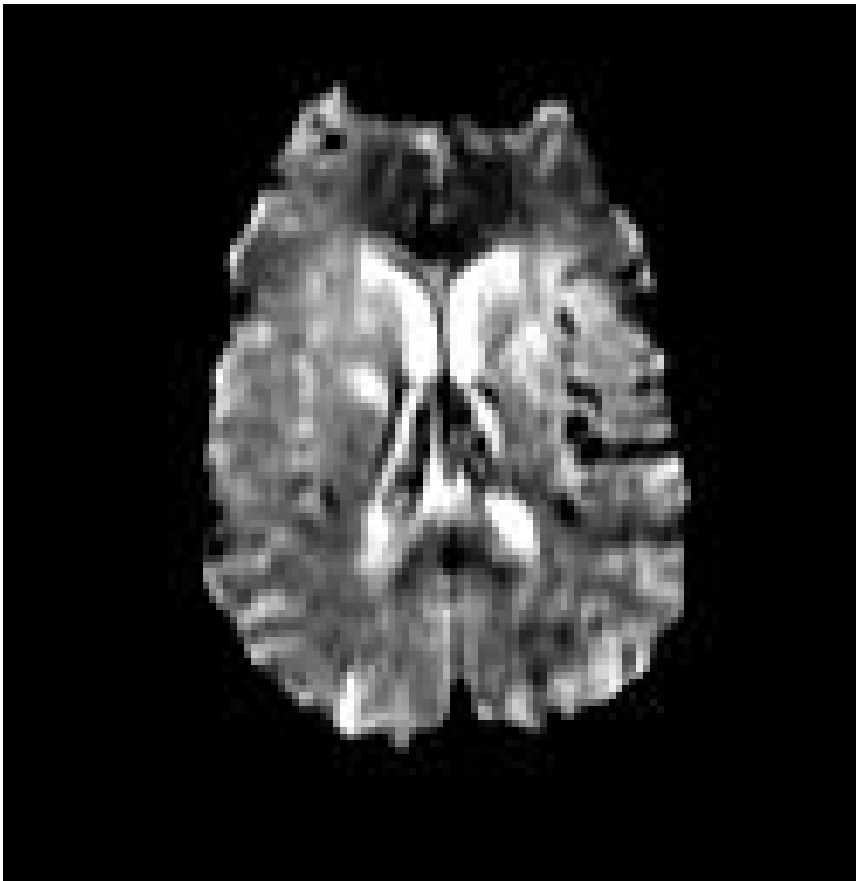


T2* Image

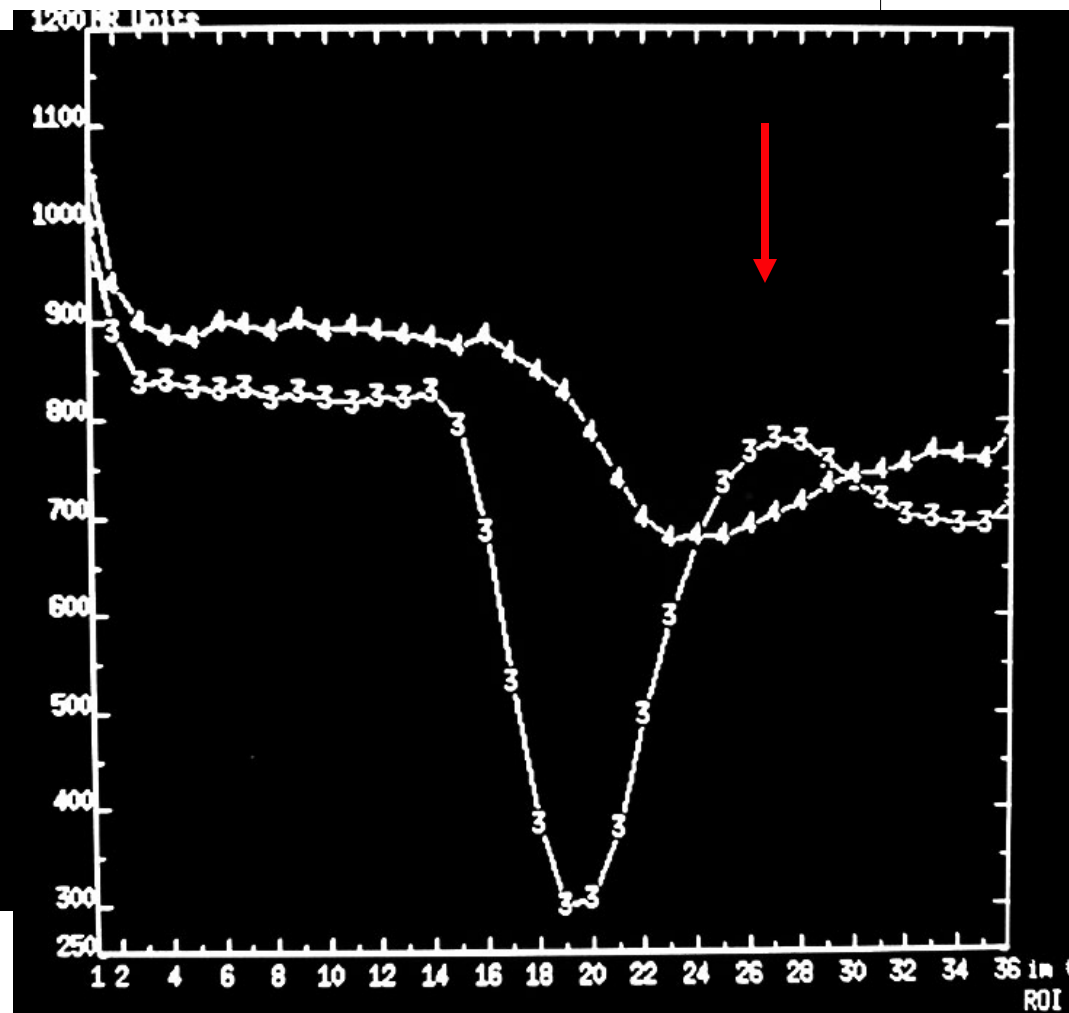


SI vs Time Curve

Gadolinium Bolus Tracking

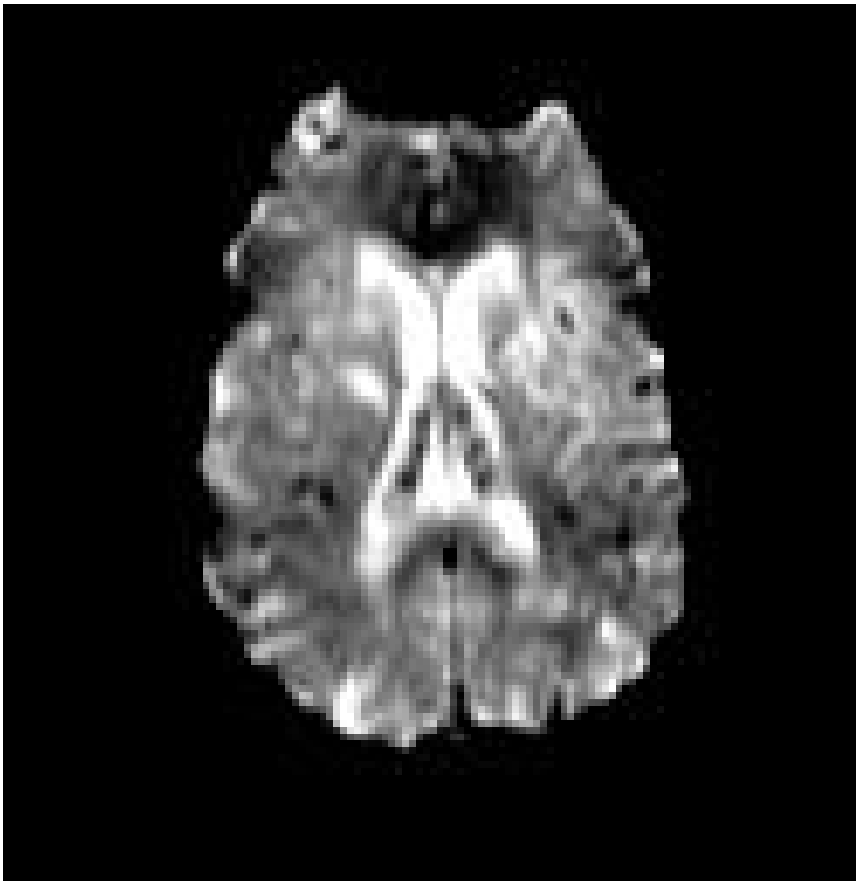


T2* Image

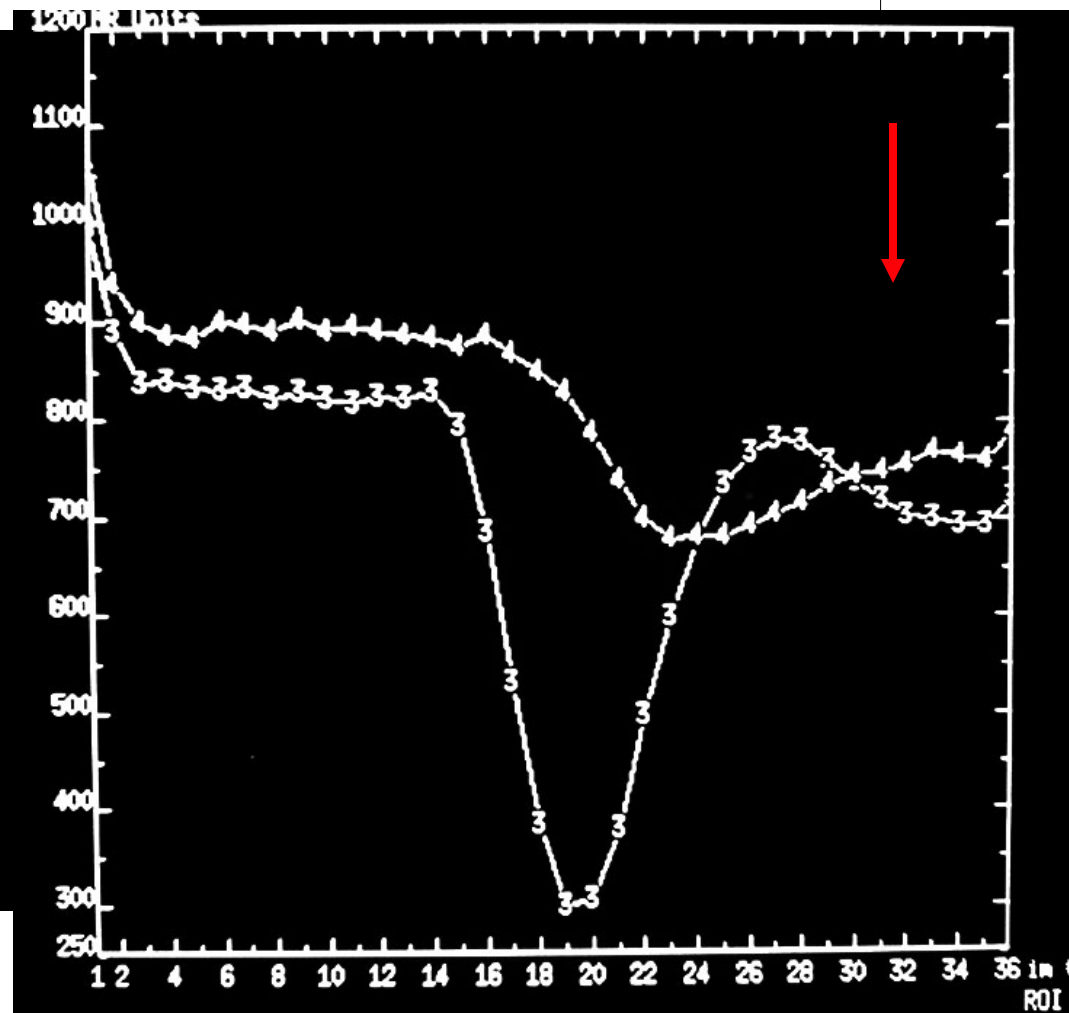


SI vs Time Curve

Gadolinium Bolus Tracking

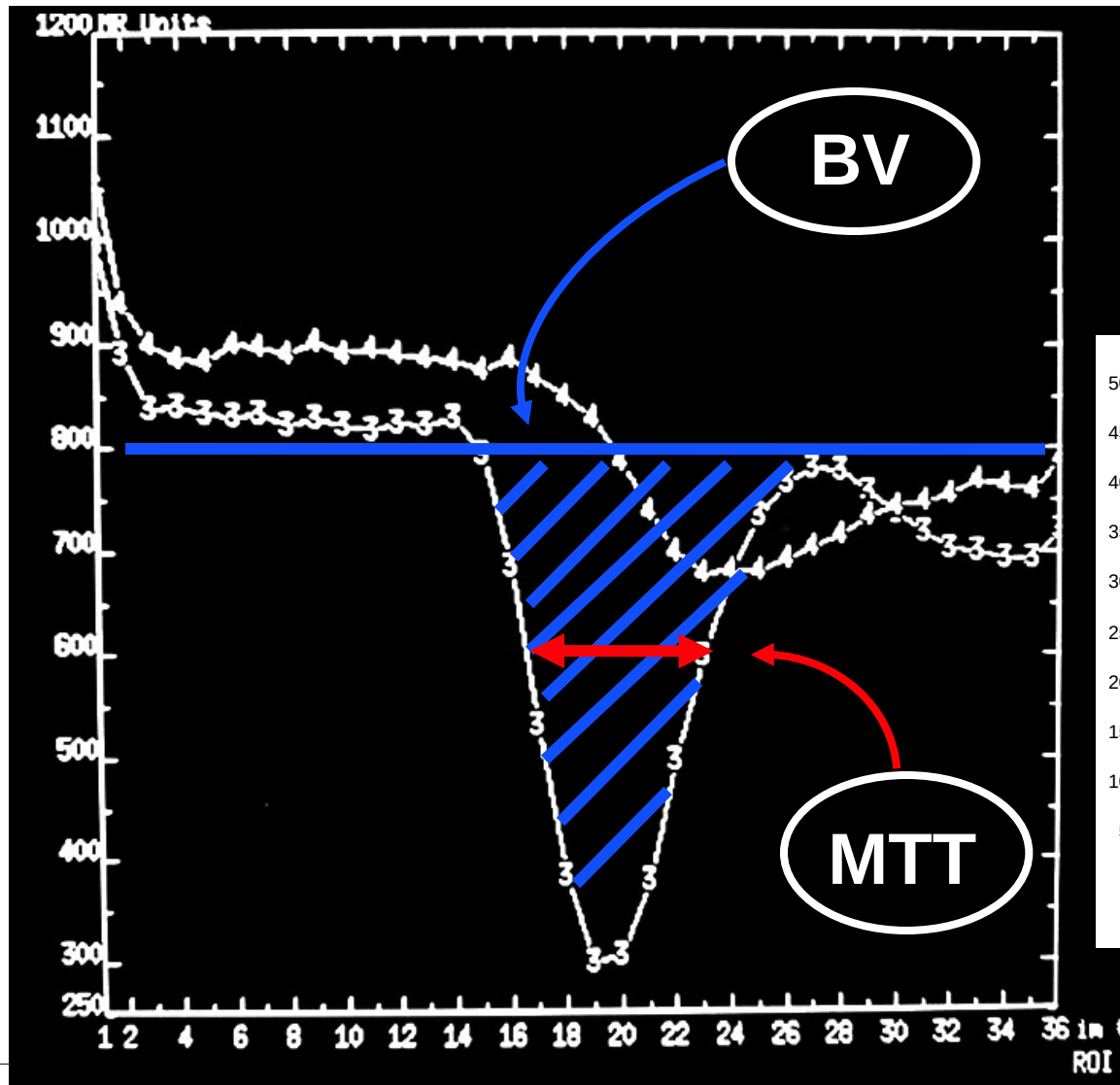


T2* Image

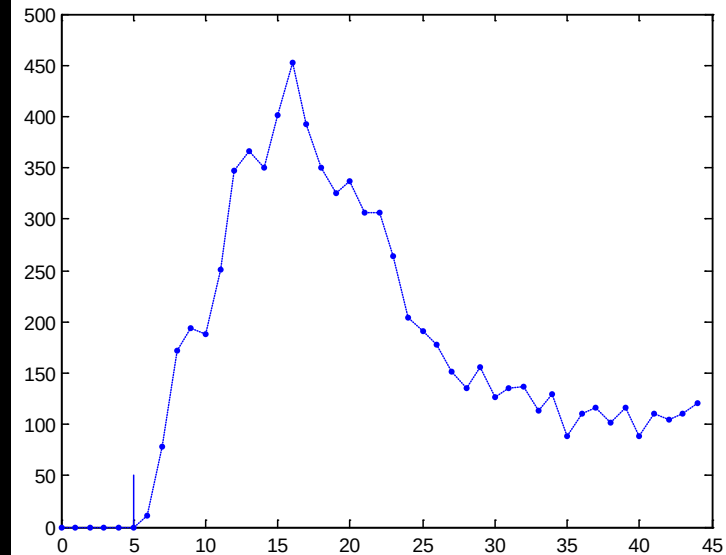


SI vs Time Curve

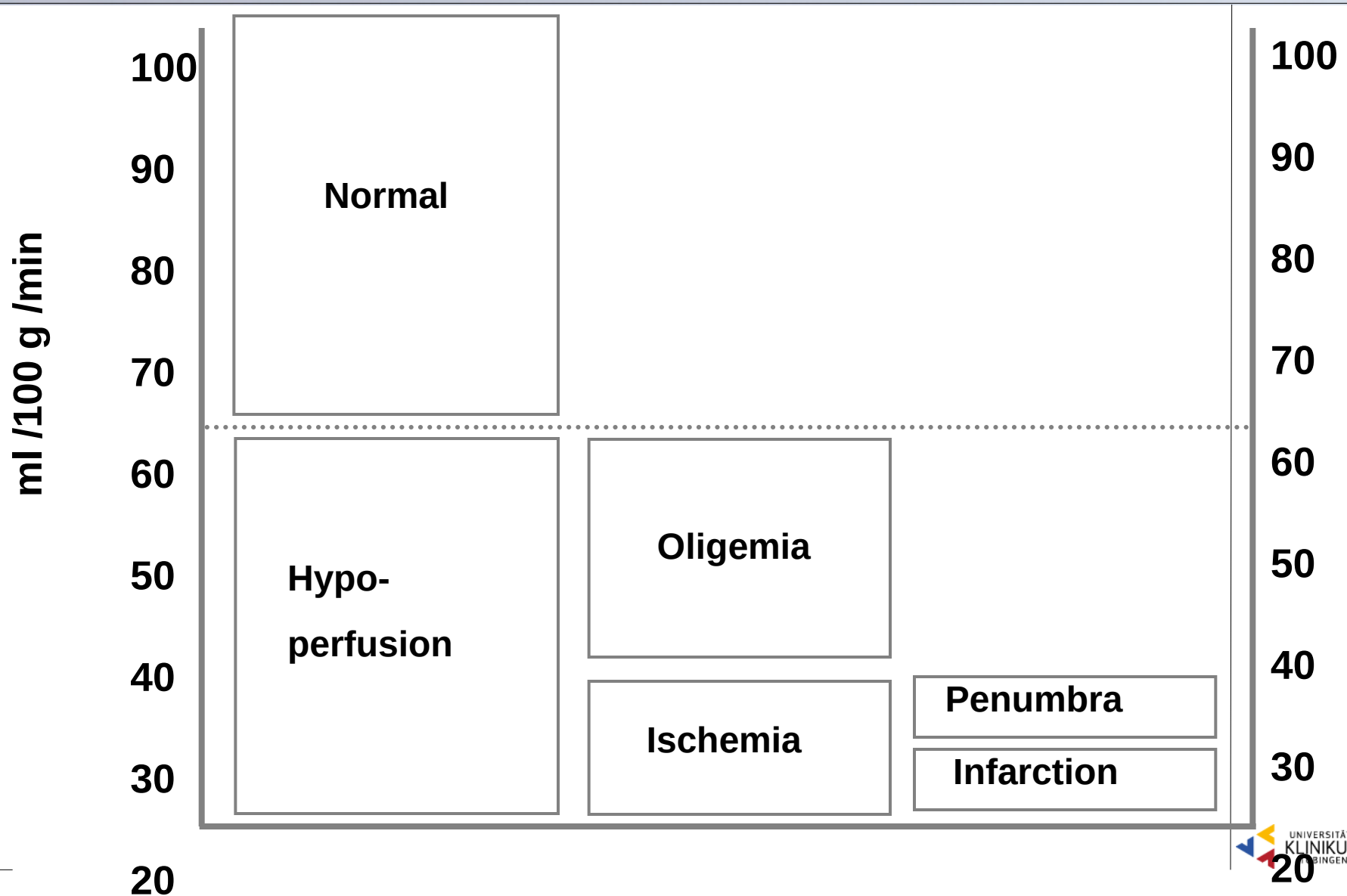
Perfusion quantification



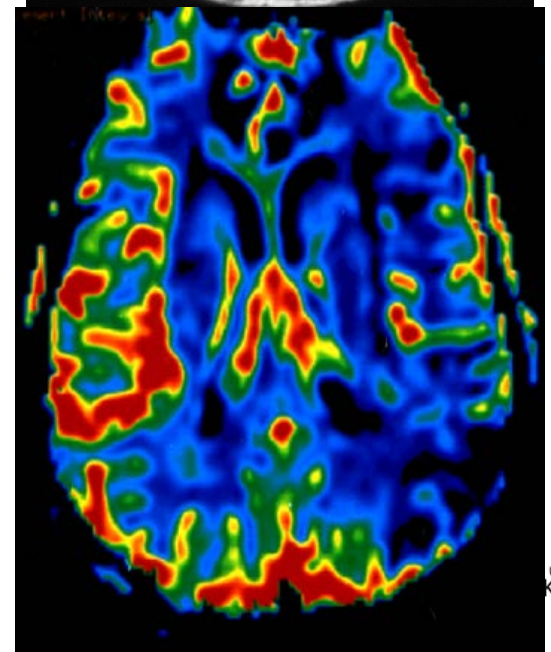
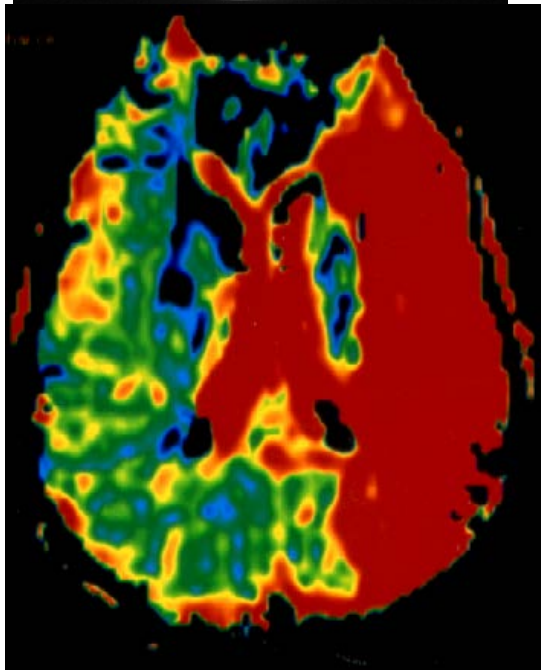
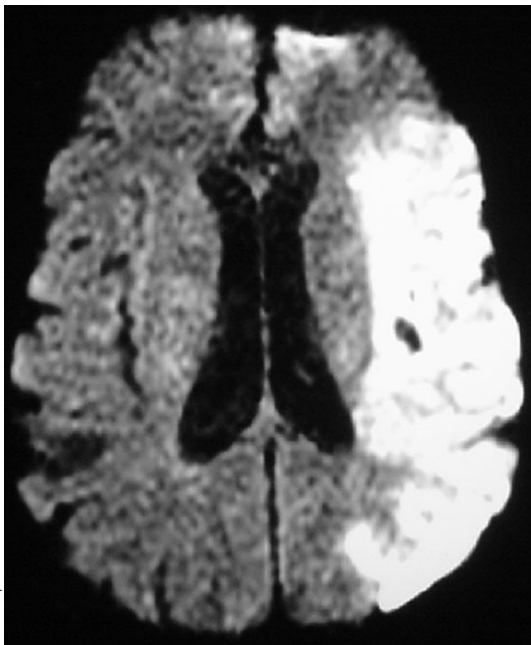
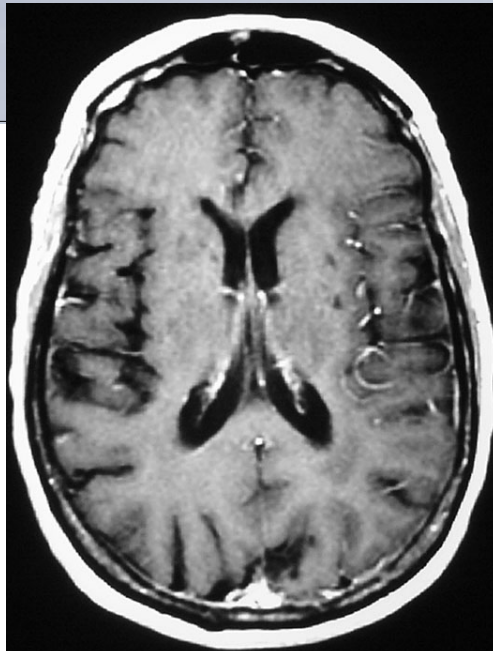
$$BF = \frac{BV}{MTT}$$



Cerebral blood flow



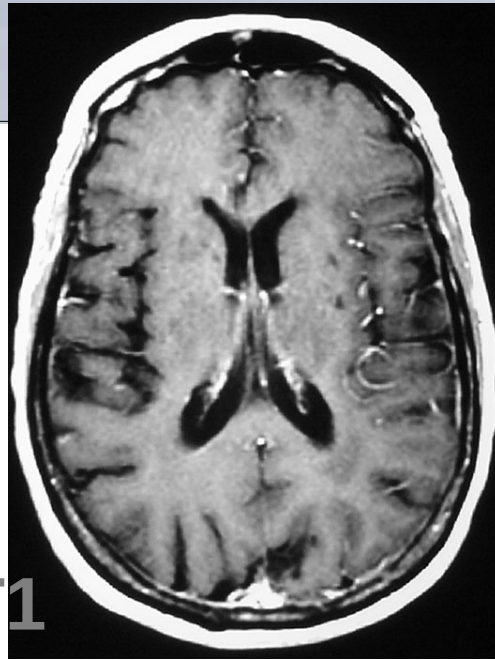
Acute ischemia in MCA territory



CT



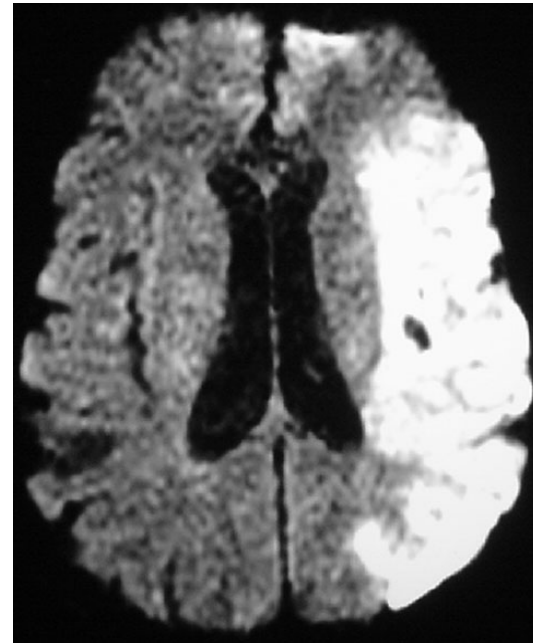
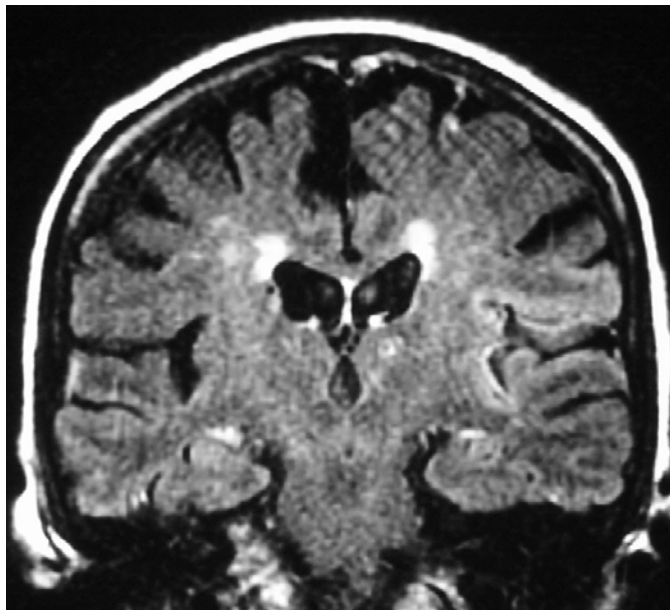
T1



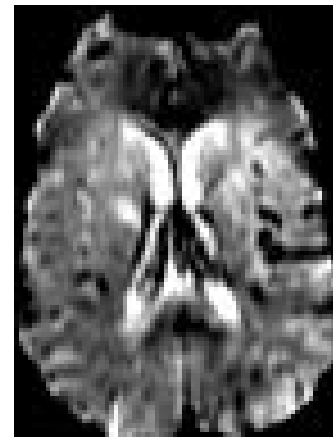
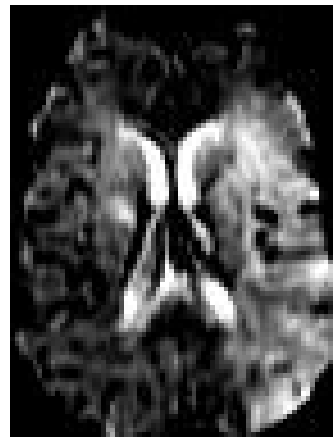
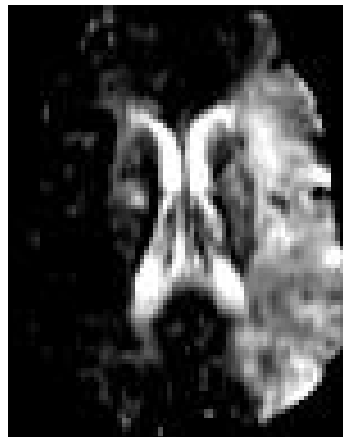
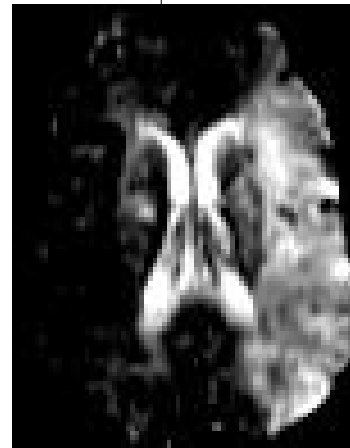
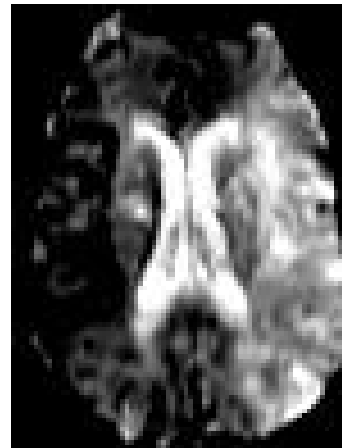
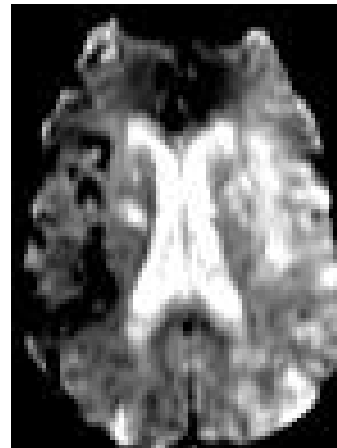
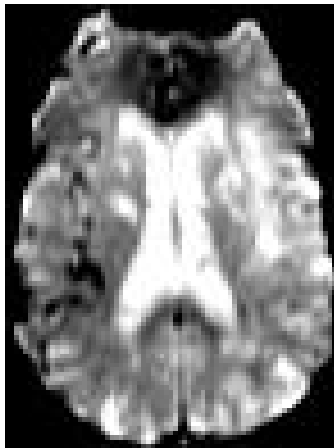
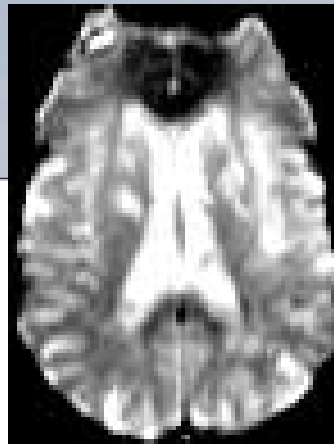
T2



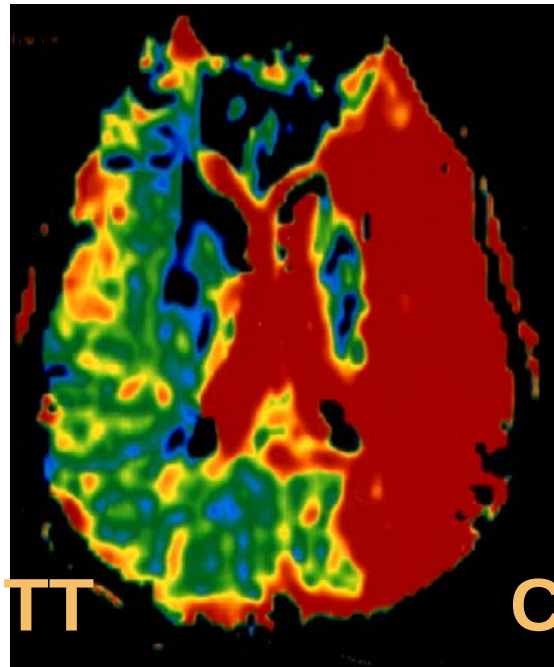
FLAIR



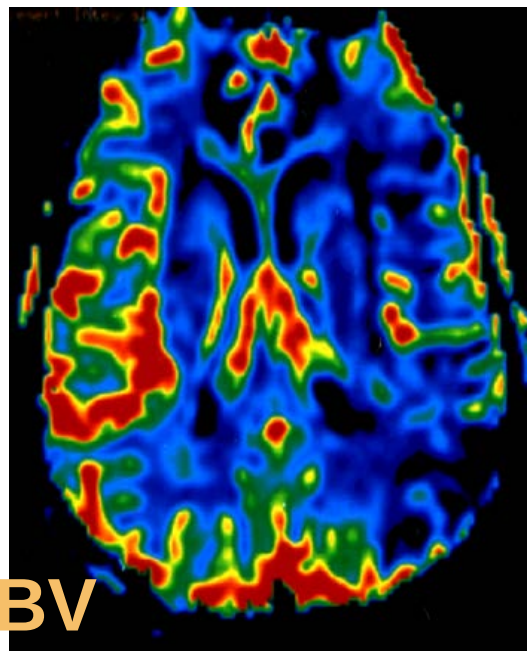
DWI



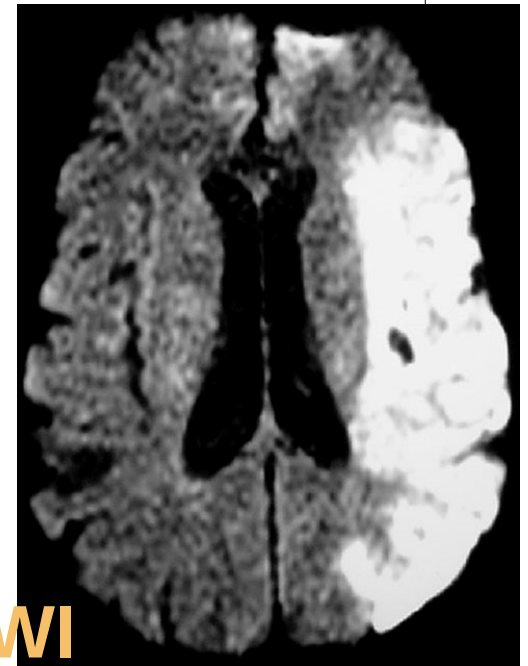
PWI-DWI Match



MTT



CBV



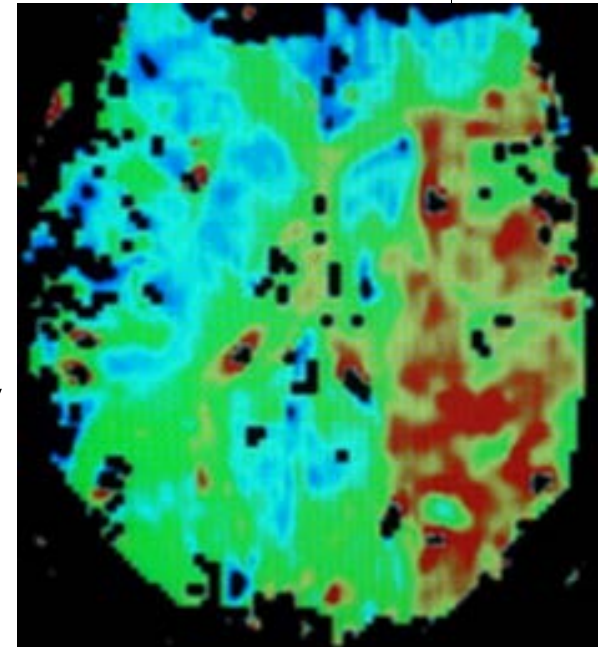
DWI

Diffusion - Perfusion Mismatch

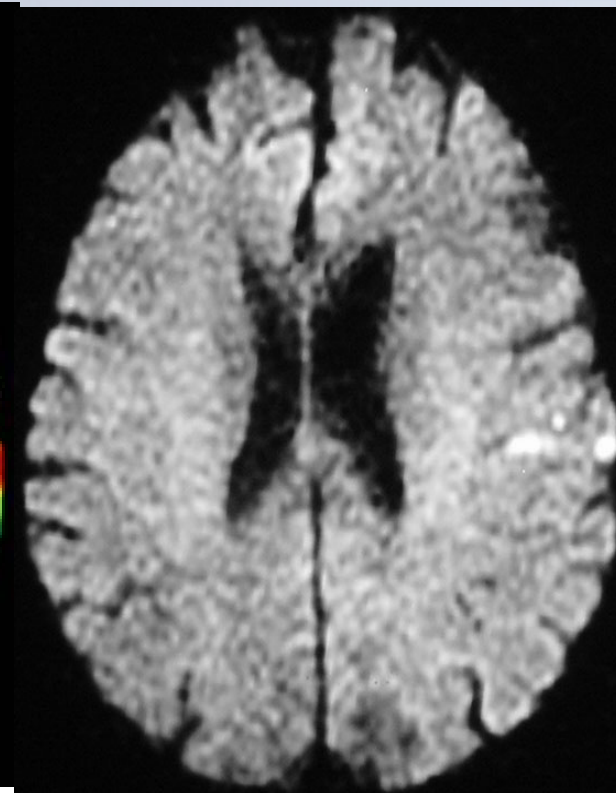
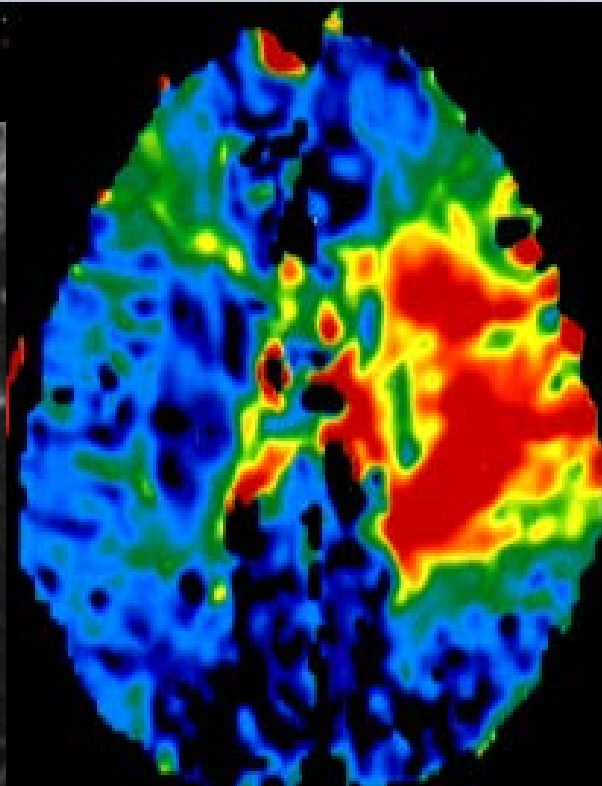


DWI

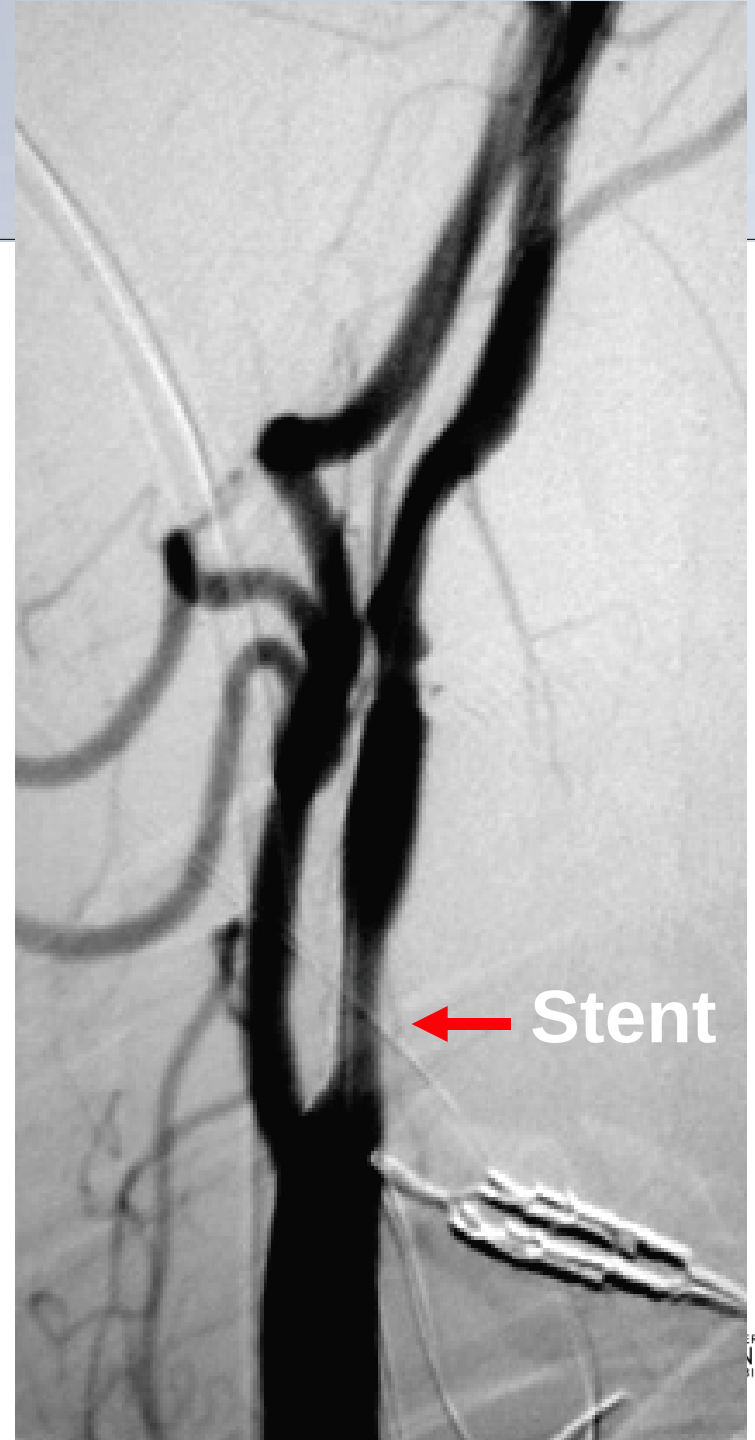
**Mismatch =
Target of any
therapeutic
intervention**



PWI

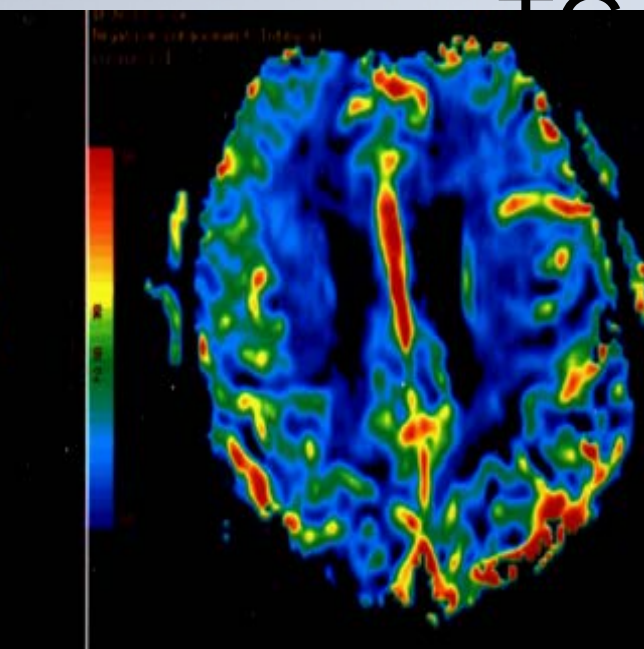
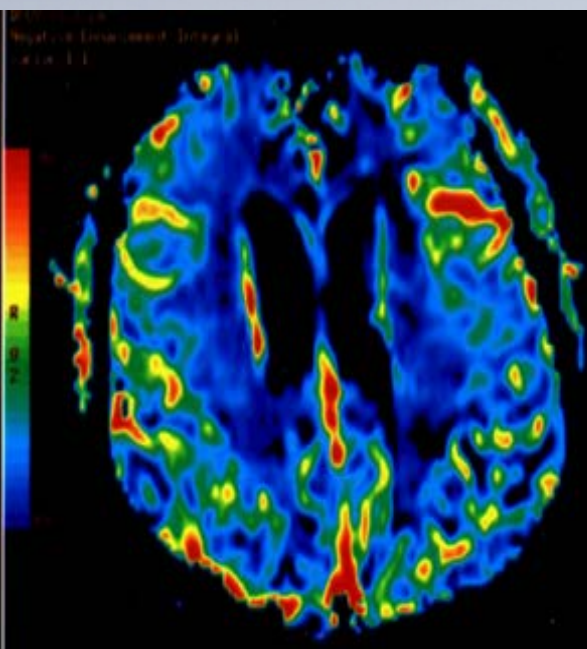
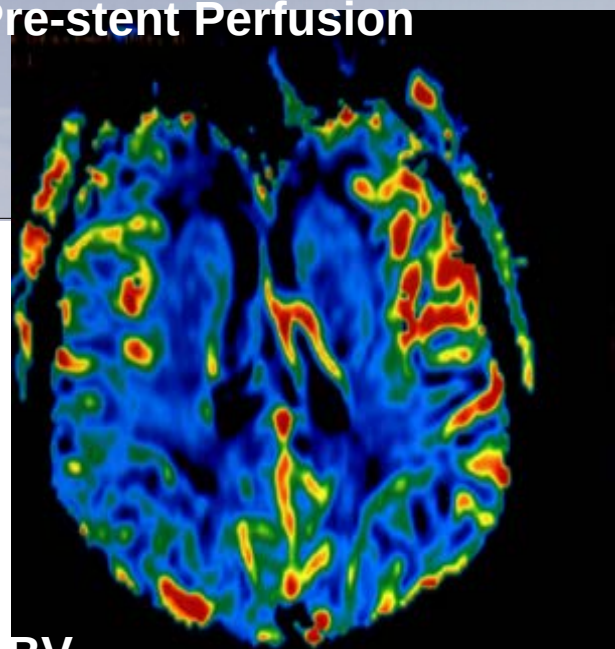


TC

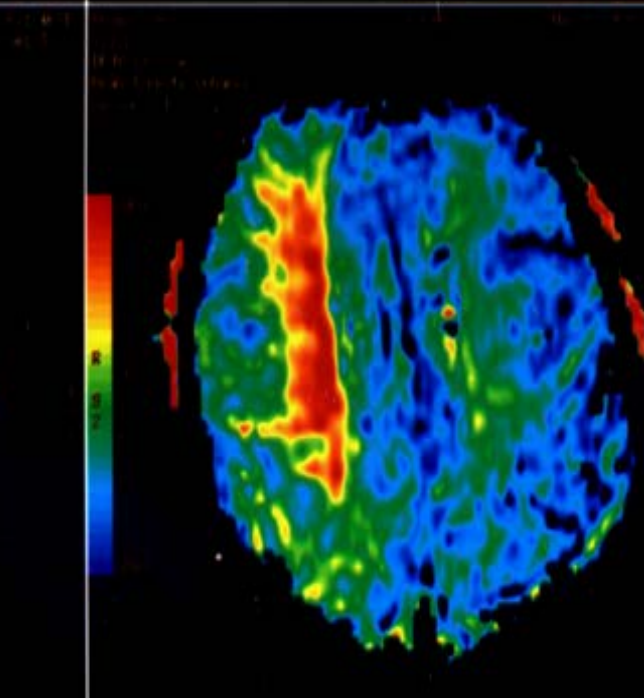
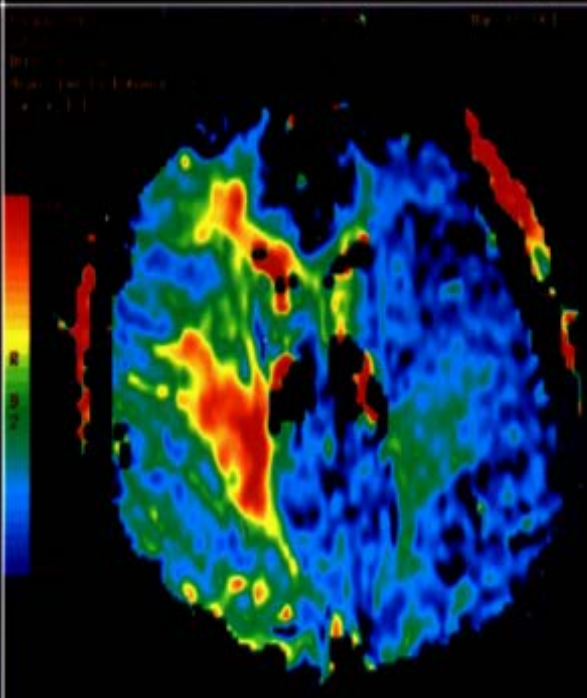
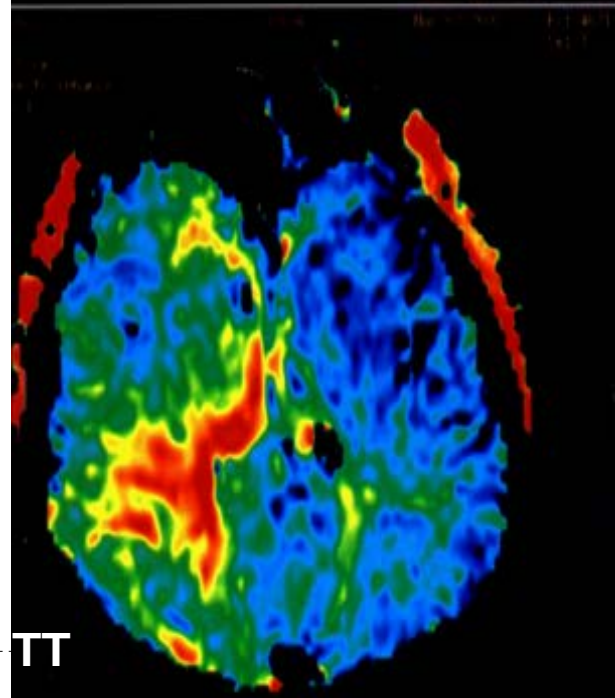


Pre-stent Perfusion

10

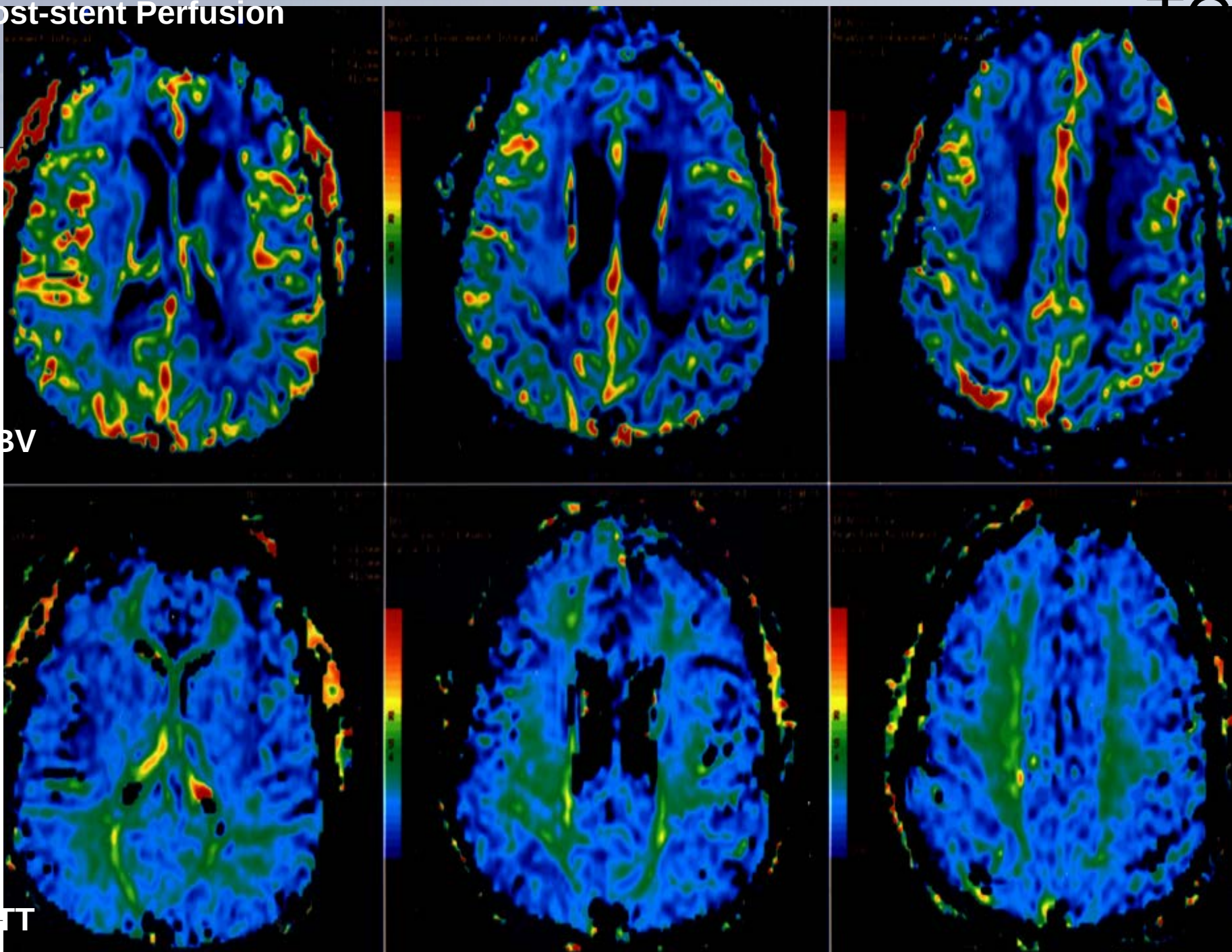


BV



TT

Post-stent Perfusion



Take-home messages

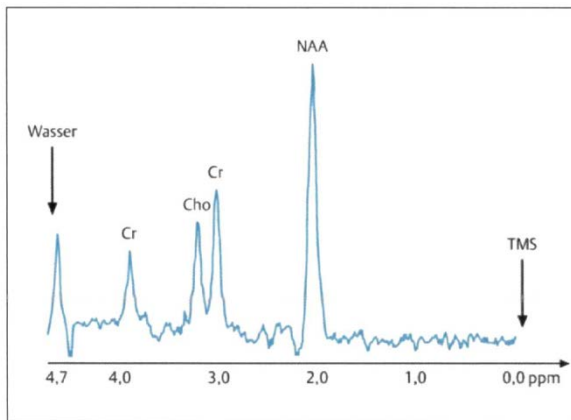
Perfusion-MRI -> Hemodynamics

Diffusions-MRI -> Brownian movement

Perfusion-MRI correlates with clinical findings and helps for planning of therapy

Spectroscopy

- Larmor frequency
- Small deviations in resonance frequency due to local magnet field inhomogeneities in different molecular composition



Spectroscopy

MR Spectroscopy

- Measurement of brain metabolite composition
- Neuronal markers: NAA (N-Acetyl-Aspartat)
- Energy stores: Cr (creatine)
- Cellular turnover: Cho (choline)
- Oxygen deficiency: lactate
- Tissue necrosis: lipids

Spectroscopy: Brain metabolites I

N-acetylaspartate (NAA)

- Intracellular, exclusively in neurons

Creatine/Creatine phosphate (Cr/PCr)

- Metabolites of energy metabolism, intracellular, dissolved in cytosol, membrane bounded

Choline (Cho)

- Intracellular, part of myelin → in cell membrane

Myo-Inositol (Ins or ml)

- Exclusively in astroglia → gliosis marker

Spectroscopy: Brain metabolites II

Glutamine/Glutamate (Glx)

- Excitatory neurotransmitter and its amid

Lactate (Lac)

- Metabolite of anaerobic glycolysis → hypoxia marker

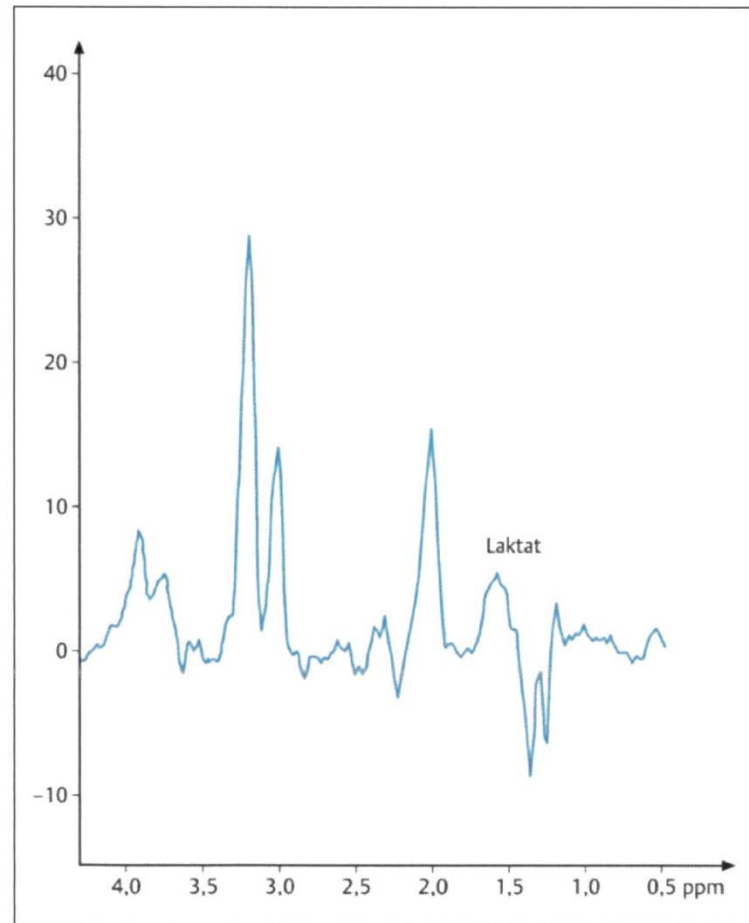
Lipids (Lip)

- Cell membrane

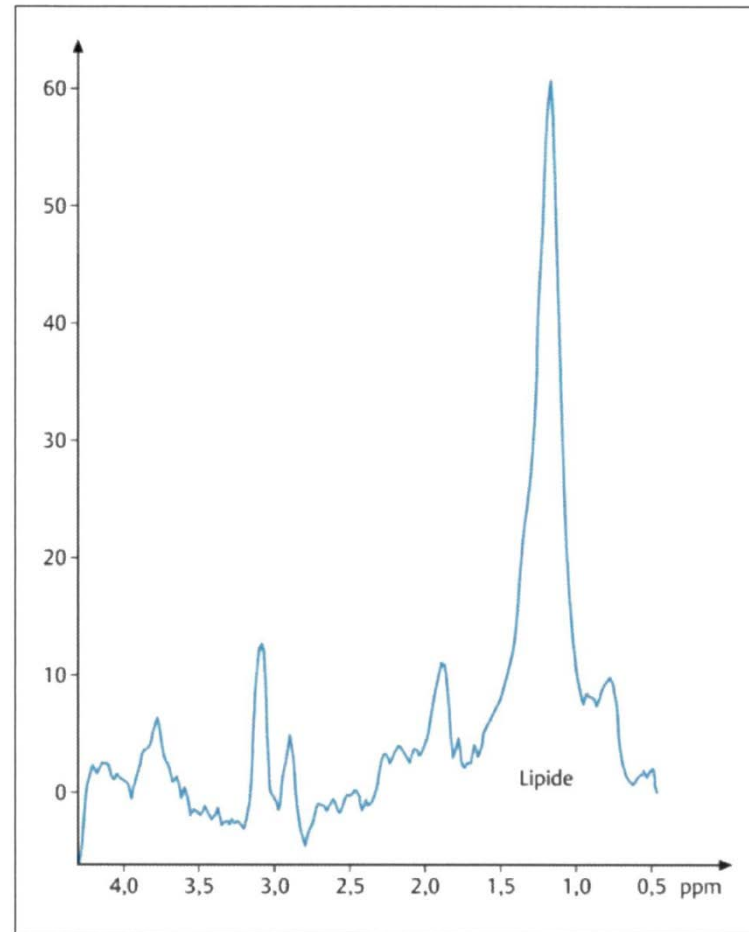
Other metabolites (glycine, phenylalanine, scyllo-Inositol, 2-HG, succinate ...)

- Usually not distinguishable, might be elevated in some diseases, sometimes specific for a certain disease

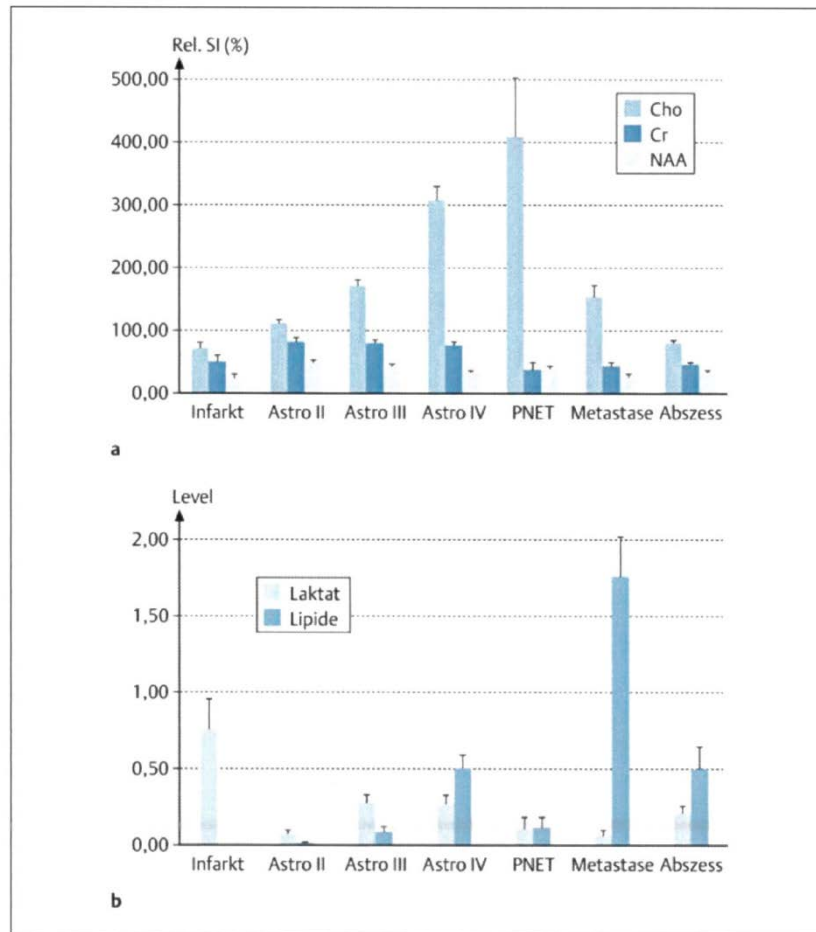
Inflammation, hypoxia



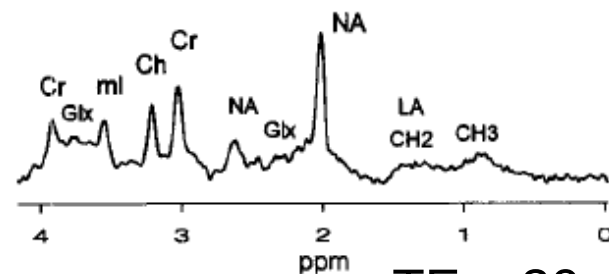
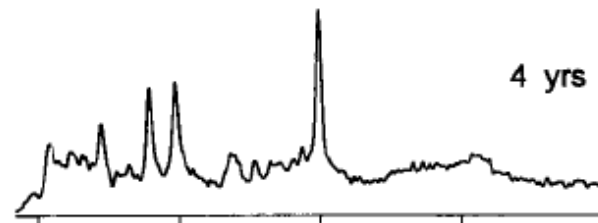
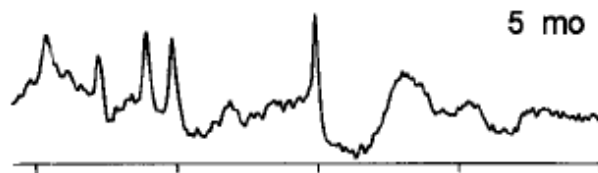
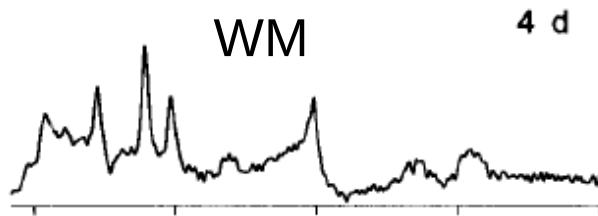
Radiation necrosis



Cholin / NAA ratio in tumor grading



MRS in Pediatric Neuroimaging



Metabolite levels are age dependent

Normal levels reached around:

- Choline – 4-5 years
- NAA – 3-5 years
- mIno – 1.5-2 years
- Creatine – 1-1.5 year

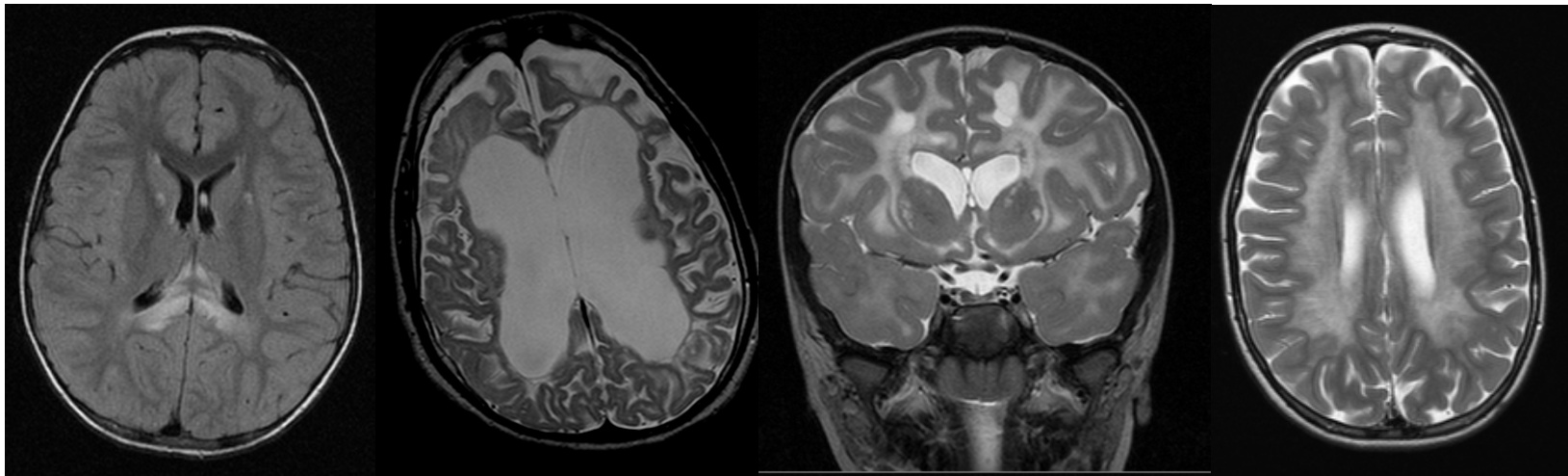
Most notable changes within the first year

Image from: Kreis R et al. Magn Reson Med, 1993, 30: 424-437 © Williams & Wilkins

MRS in Pediatric Neuroimaging

Leukoencephalopathy

- For the age of the child not appropriate myelination
- Imaging: T2 hyperintens white matter
- In some cases disease typical pattern
- Different causes: Hypomyelination, demyelination, tissue rarefaction



MRS in Pediatric Neuroimaging

Hypomyelination

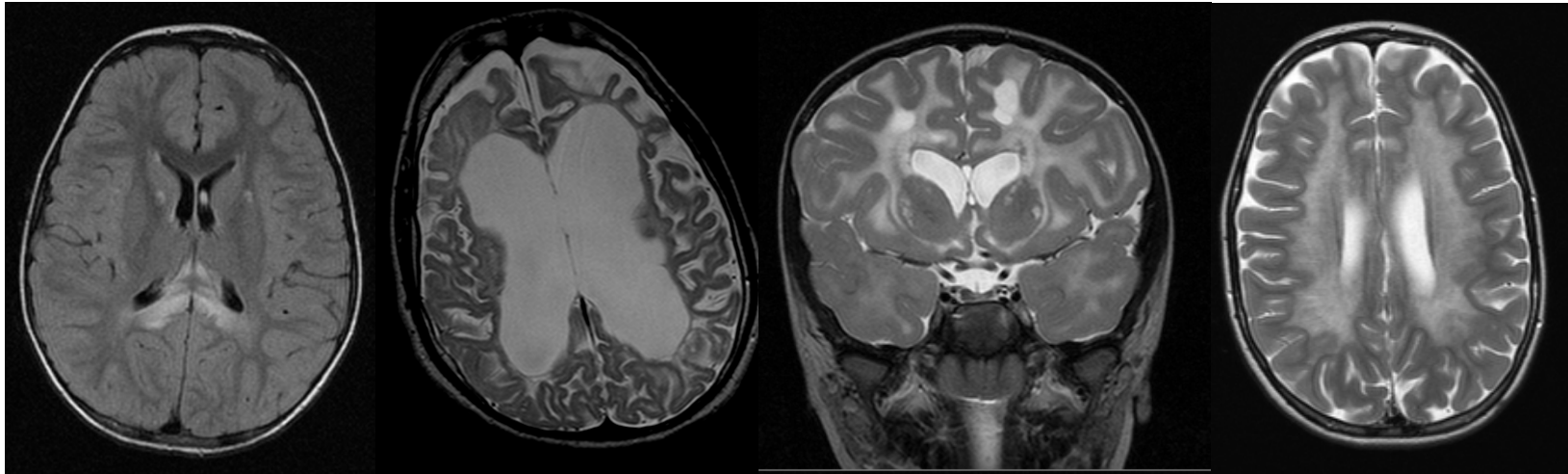
- Relatively normal metabolite levels, usually no Lactate and normal NAA

Demyelination

- Cholin increase, Lactate increase, NAA decrease

Tissue rarefaction

- Decrease of Cho, Cr, NAA, Lactate increase



Tumor grading

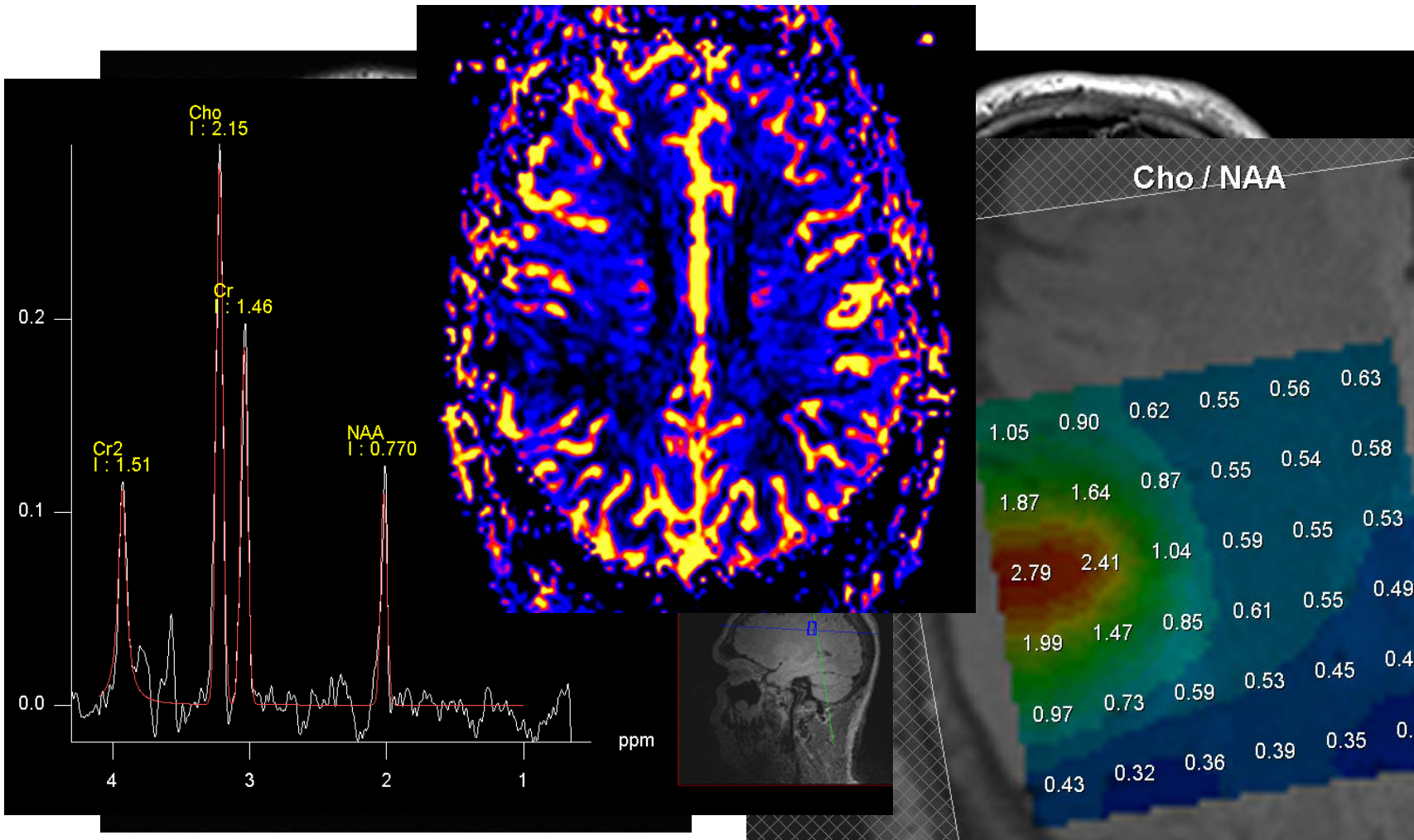
Height of choline peak correlates with rate of proliferation

- Cho/Cr – normal tissues approx. 1 (for low TE!)
- Cho/NAA – normal tissue approx. 0.5 (for low TE!)
- Comparison with normal appearing voxel

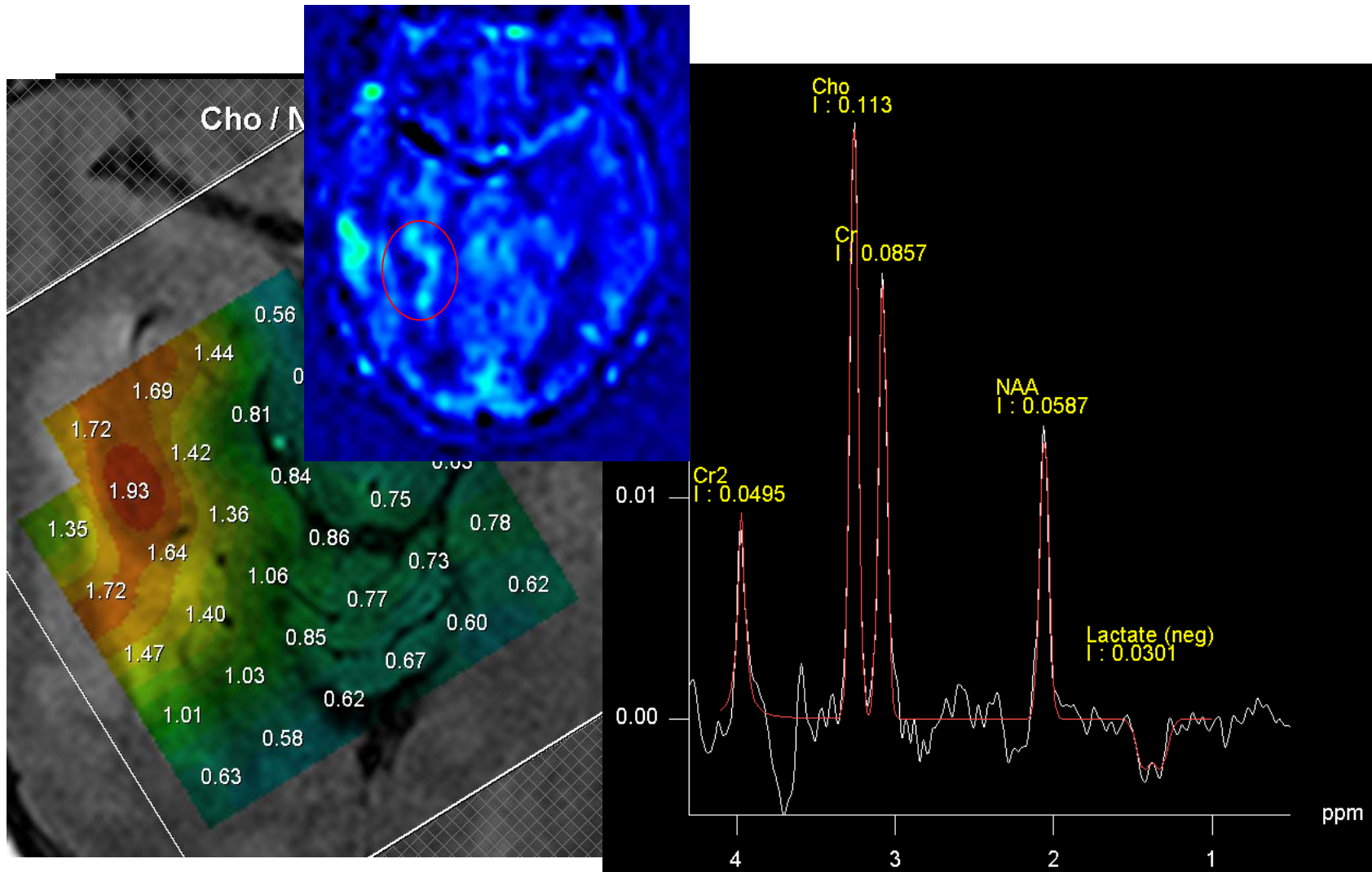
Lactate → marker of rapid growth/necrosis

Lipids → marker of necrosis

Astrocytoma °II

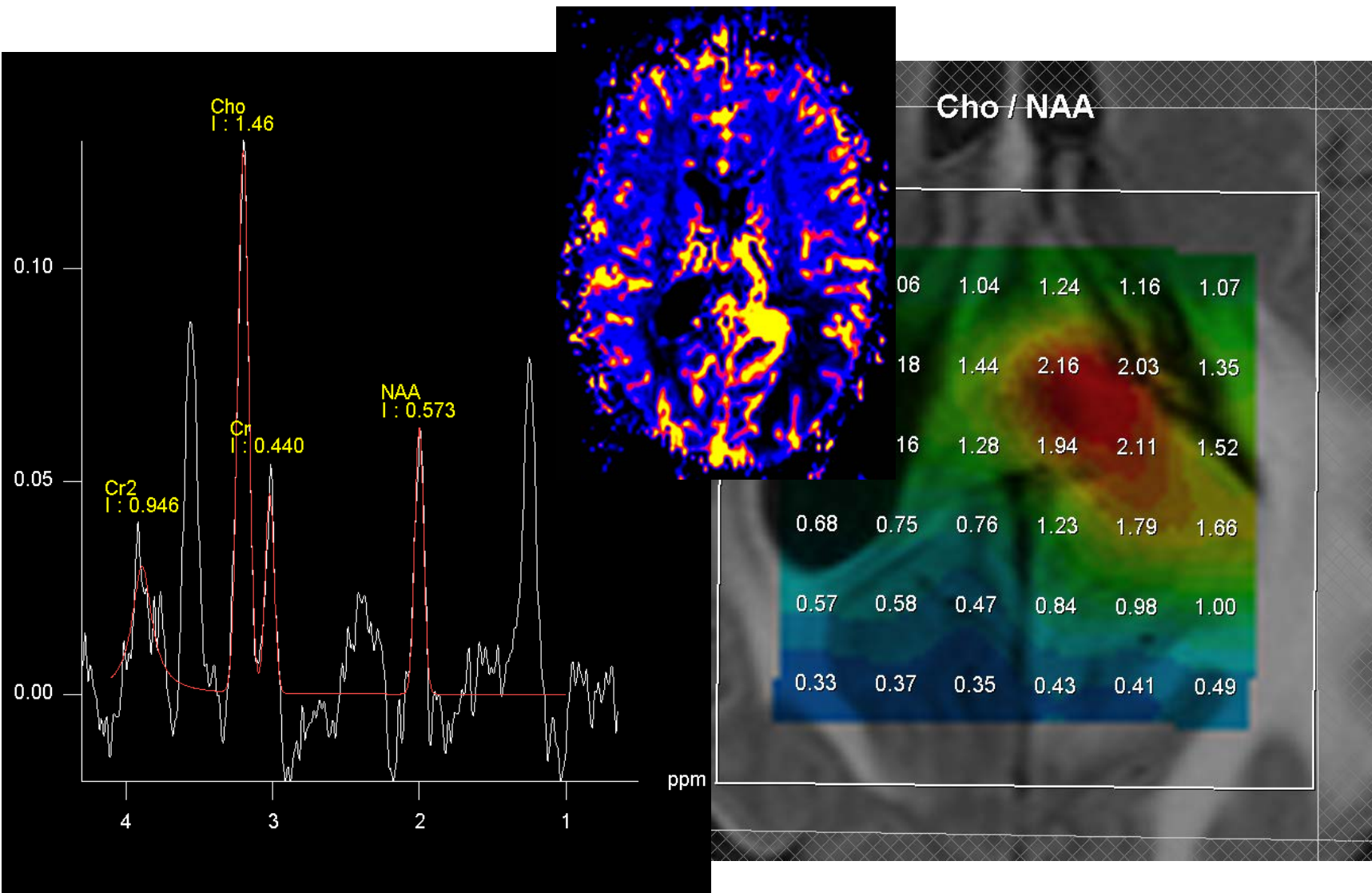


Astrocytoma °III



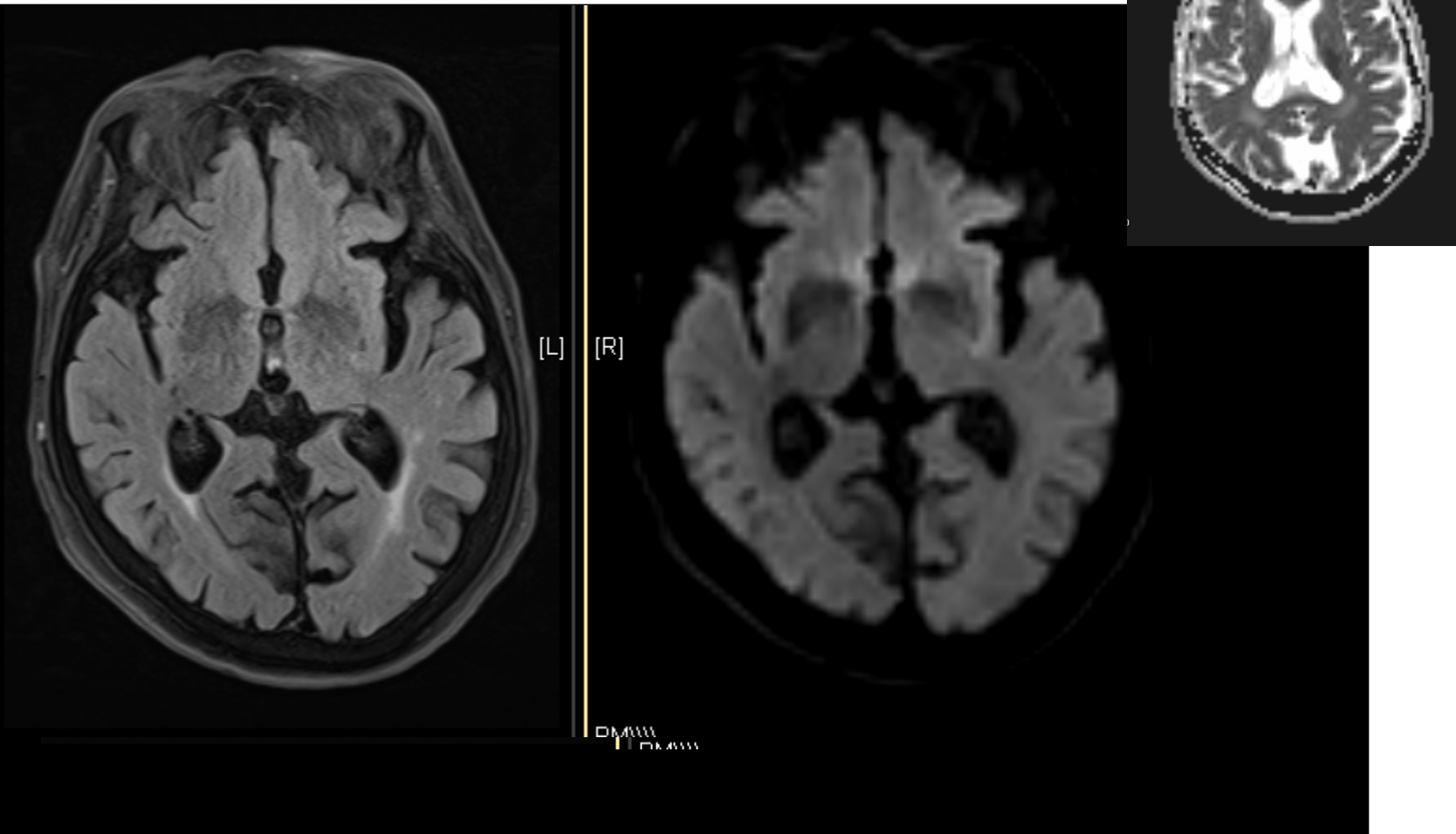
TE = 135 ms

Glioblastoma °IV

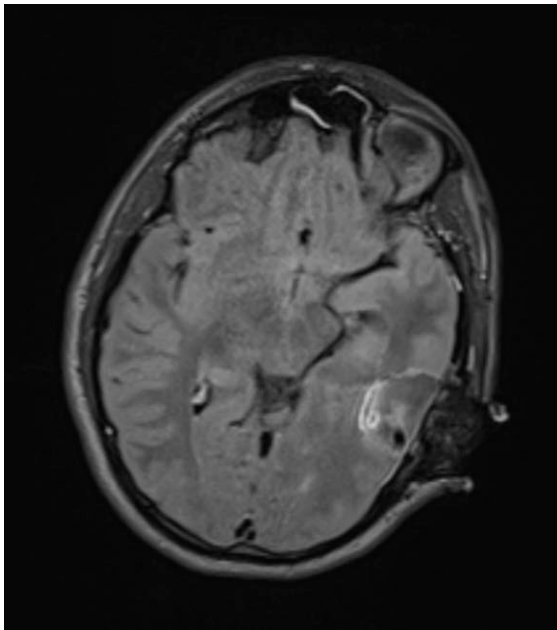


Cases

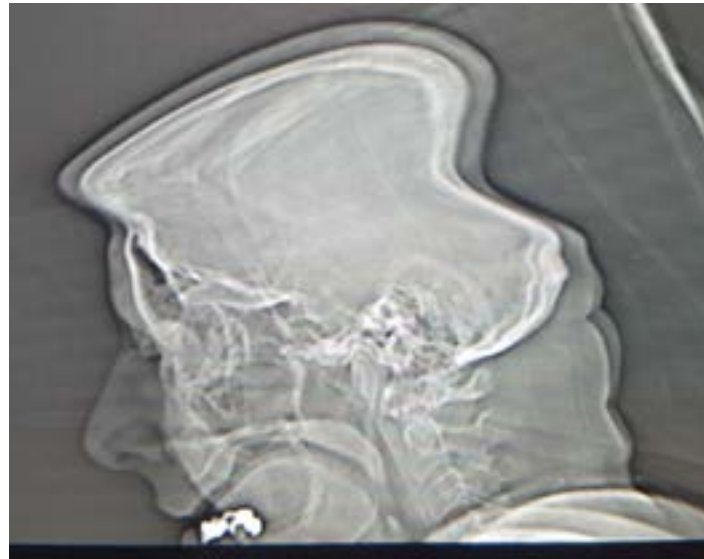
89 y.o. patient, woke up with right side hemiparesis and dysarthria



MR applications: IMRI



You made it!



Dr. med. Georg Bier

Dept. of Diagnostic and Interventional
Neuroradiology

georg.bier@med.uni-tuebingen.de