

Korszerű eljárások az idegsebészeti diagnosztikában és terápiában
Kötelező szinten tartó tanfolyam
2019. 12. 04.

Képalkotó eljárások az idegsebészeti kórképek differenciáldiagnosztikájában

Martos János

Komputertomográfia

A műtőben!



Hyperdens media jel



Stroke

Intracerebralis hematoma

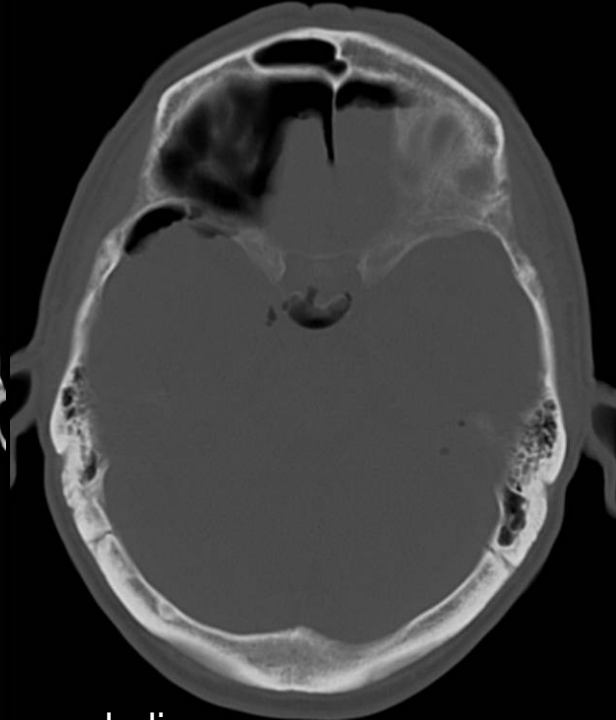
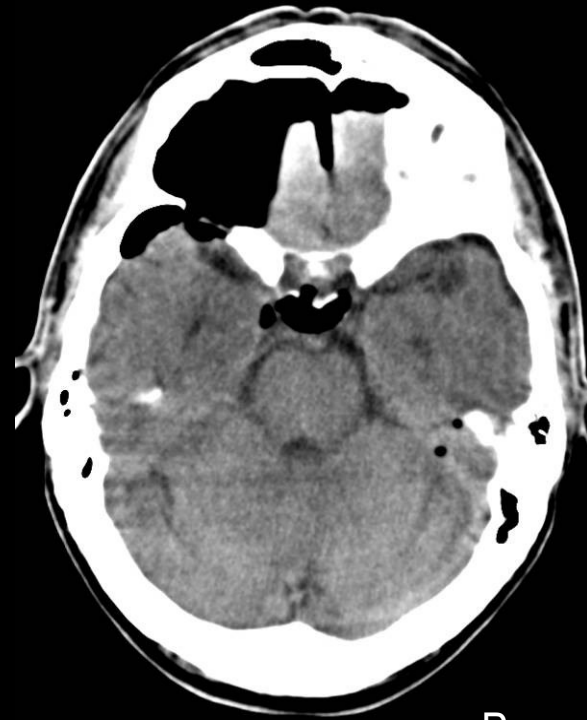


Krónikus infarktus

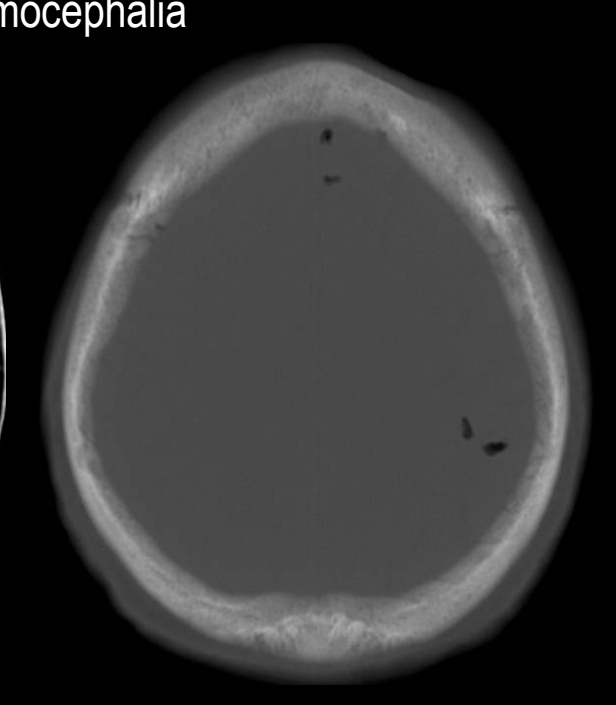
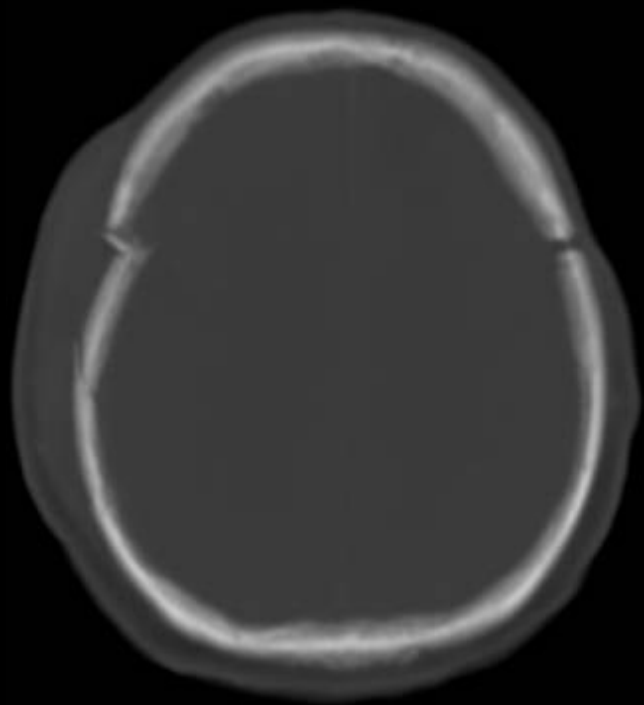
Subarachnoidális vérzés



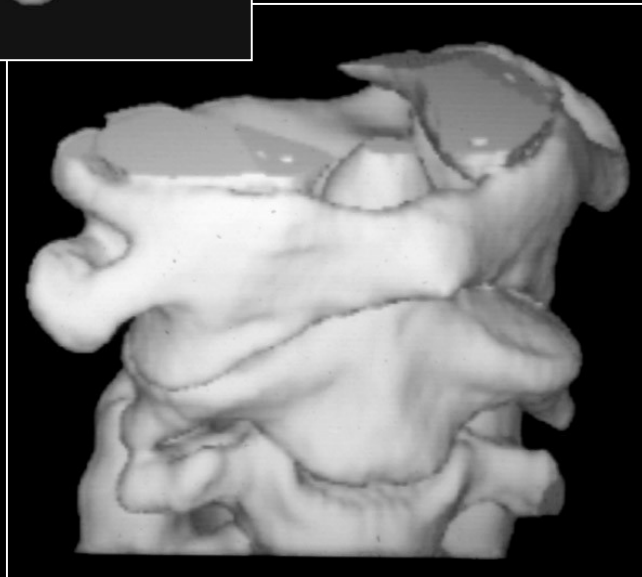
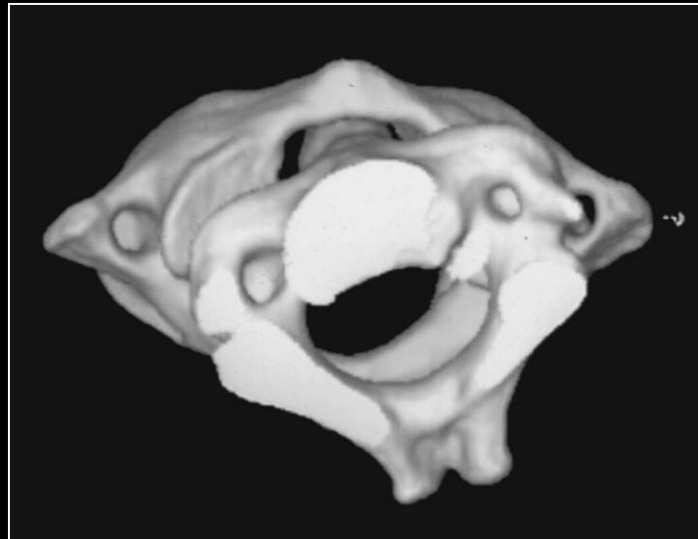
Koponya trauma



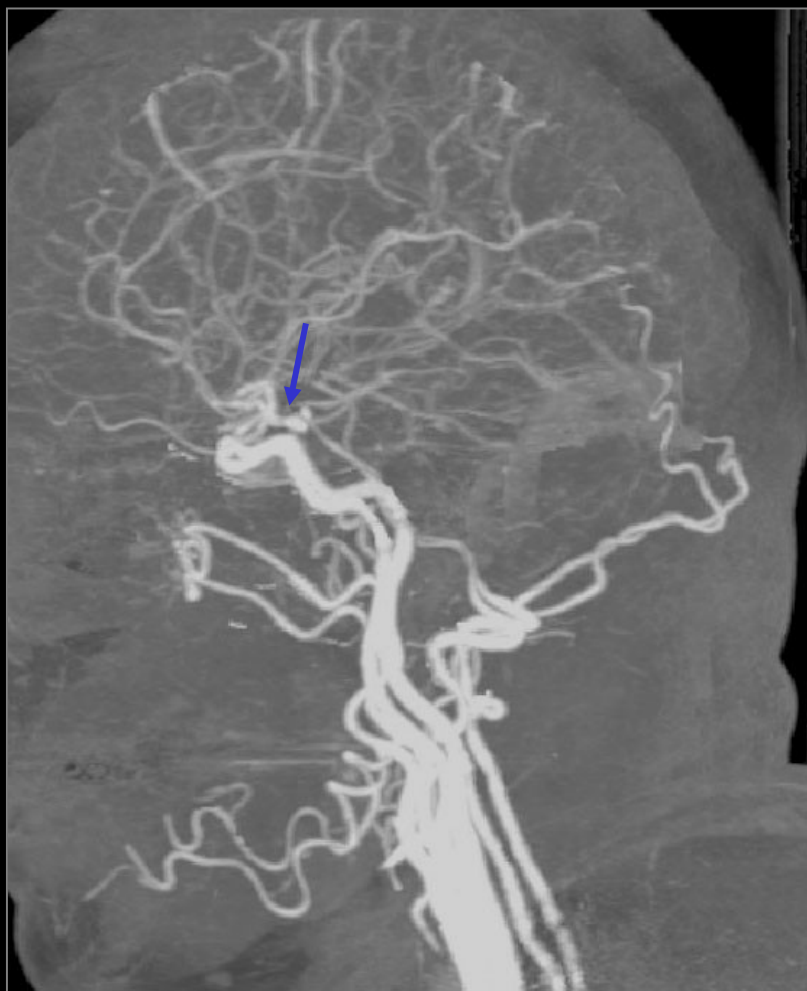
Pneumocephalus



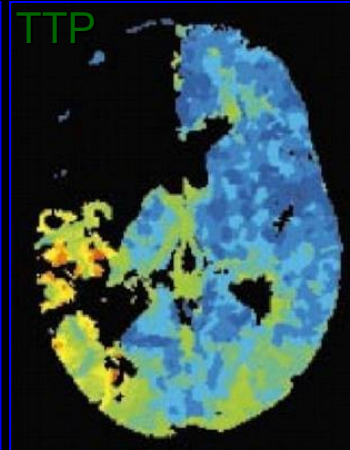
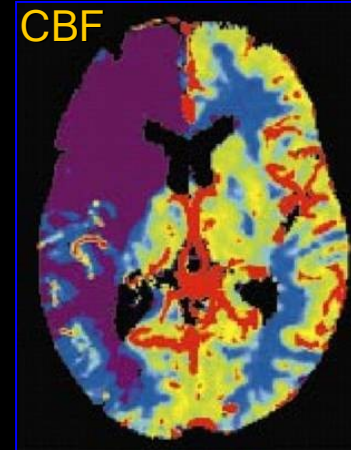
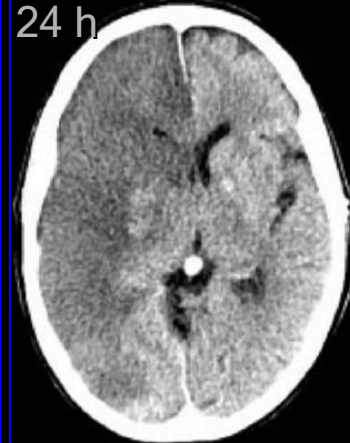
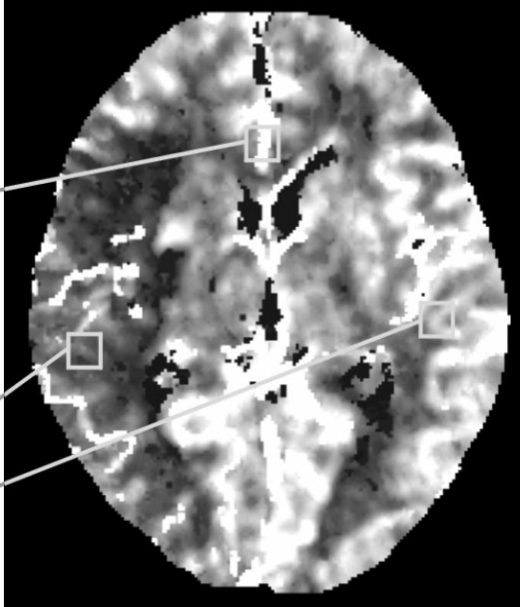
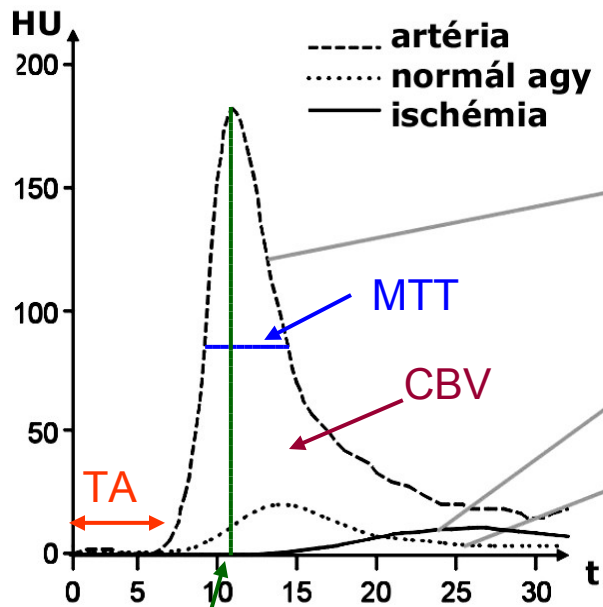
3 dimenziós (3D) rekonstrukció



CT angiográfia



Perfúziós CT



Siemens brossura

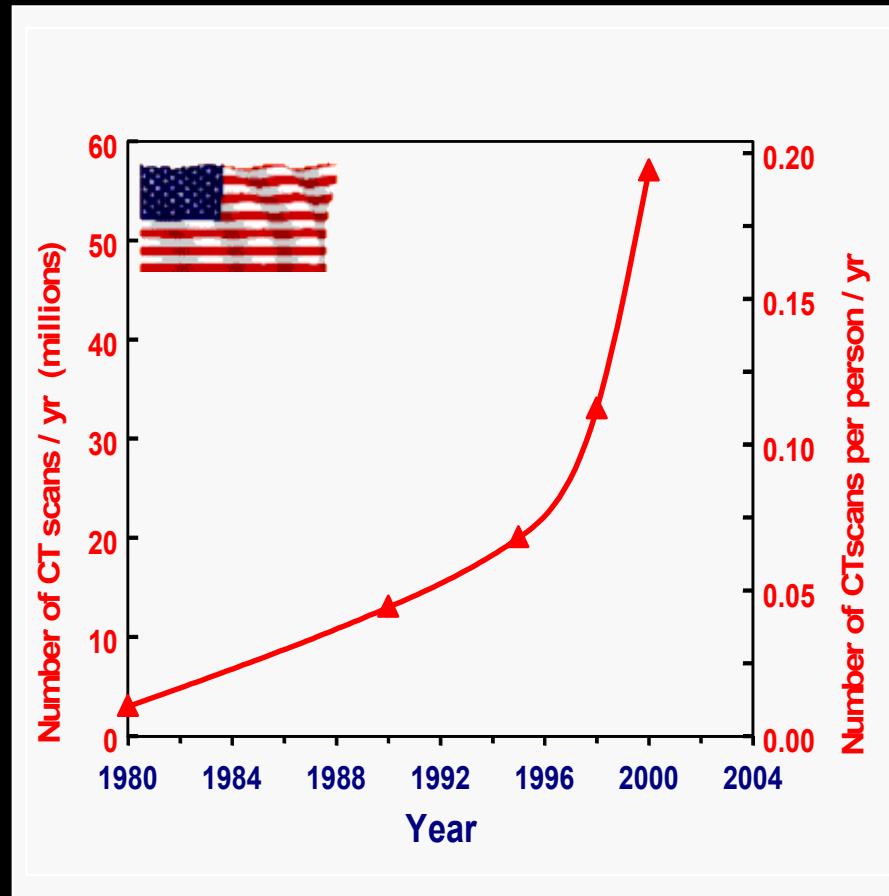
CBV~area under the curve (AUC) [parenchyma/artéria]

$$CBV = \int C dt / \int C_{AIF} dt$$

$$MTT = \int C dt / C_{max}$$

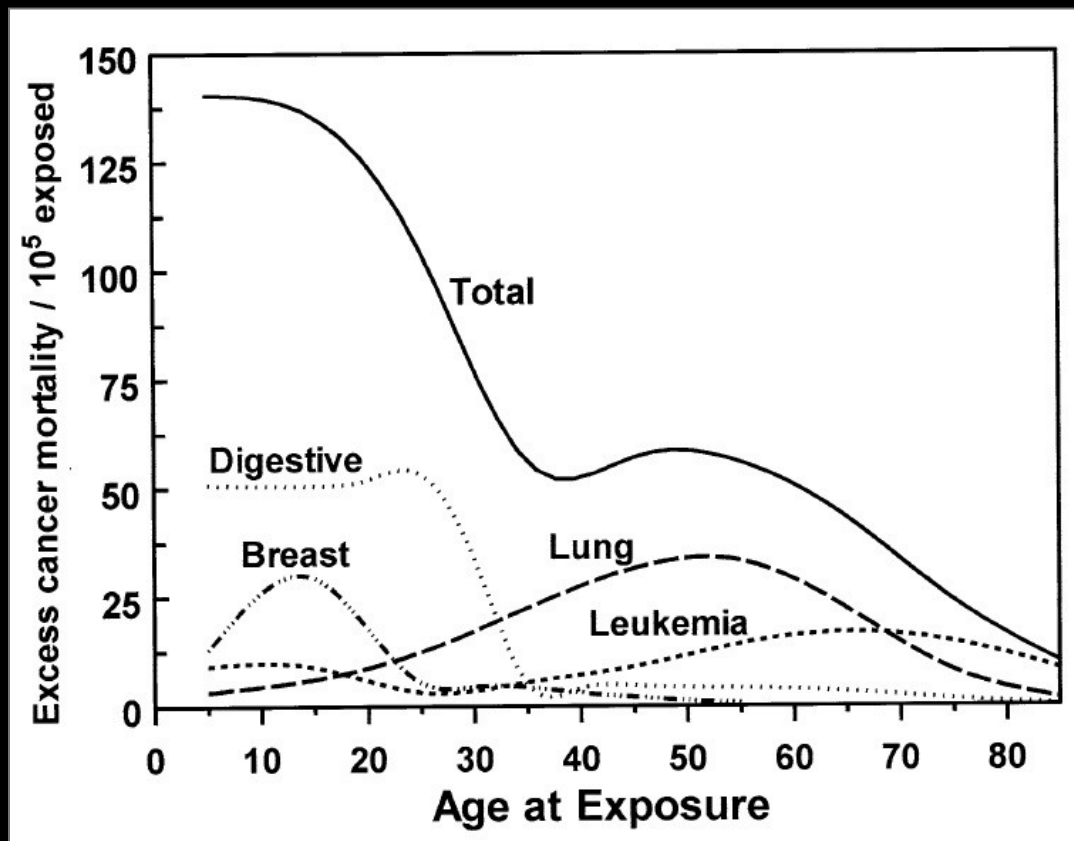
$$CBF = CBV / MTT$$

CT vizsgálatok gyakorisága



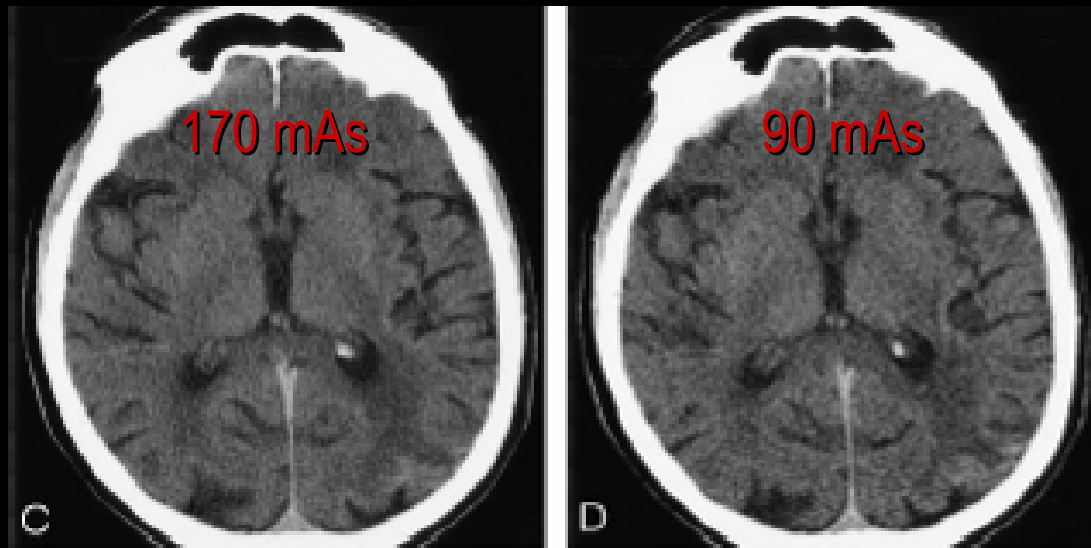
- Az USA-ban a radiológiai vizsgálatok 11%-a CT ...
- de részesedése a kollektív dózisban ~ 67%!

Sugárzás által okozott malignus daganat rizikója életkor szerint



Spekulatív statisztikai adatok alapján.

Dóziscsökkentő eljárások



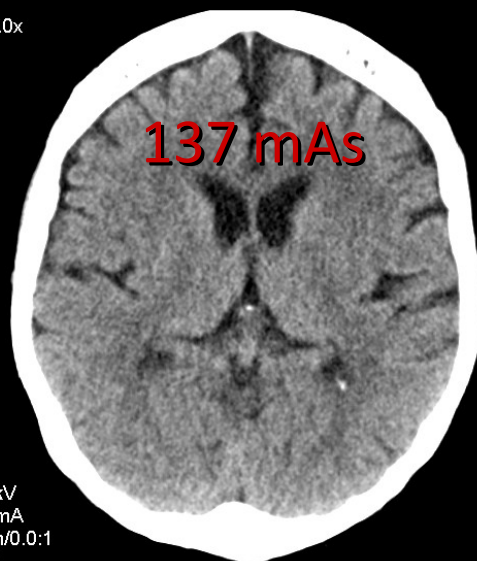
Dózis moduláció

Iteratív
rekonstrukció

Mag: 1.0x

R_A

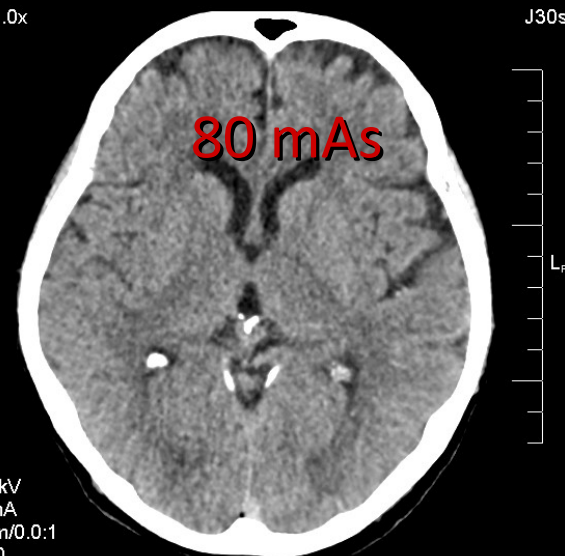
120.0 kV
137.0 mA
5.0 mm/0.0:1
Tilt: 0.0



H31s Mag: 1.0x

L_p R_A

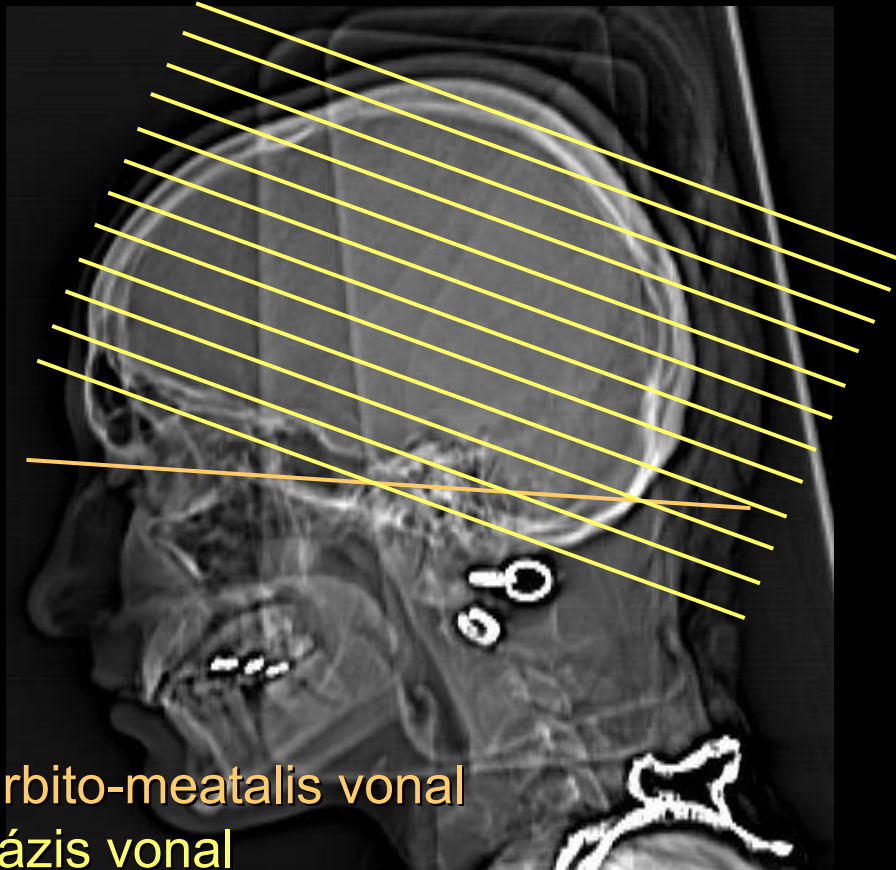
120.0 kV
90.0 mA
5.0 mm/0.0:1
Tilt: 0.0



J30s

L_p

Koponya CT orientáció



Spirál üzemmód döntött gantry-vel!

MR

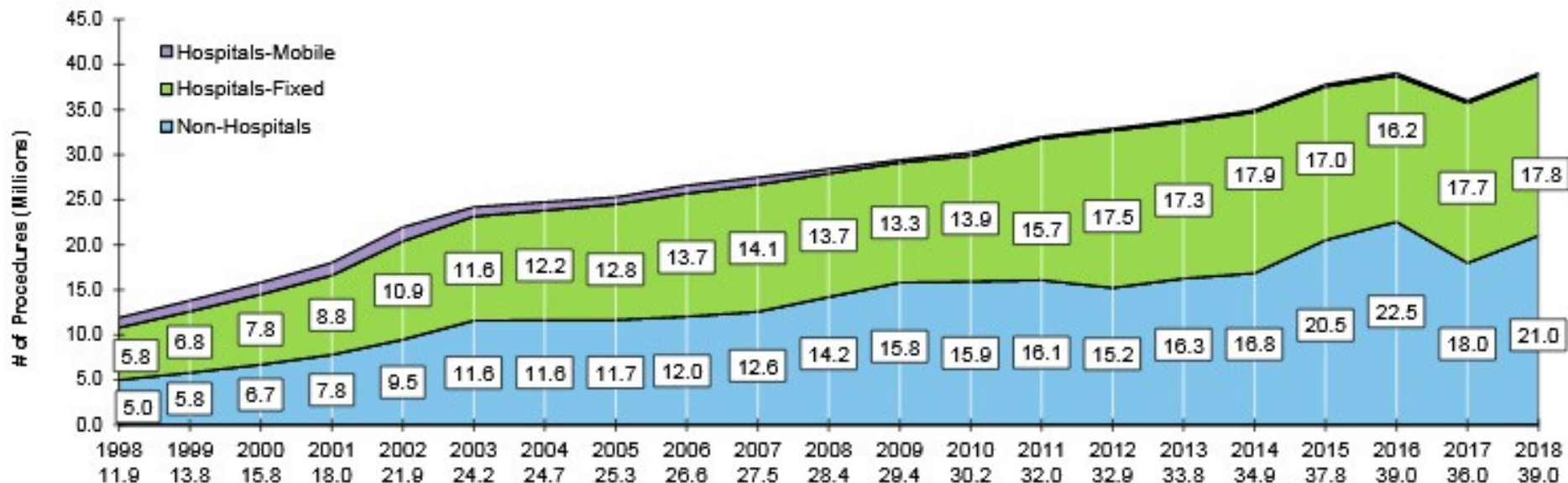
A műtőben!



Az MR vizsgálatok száma

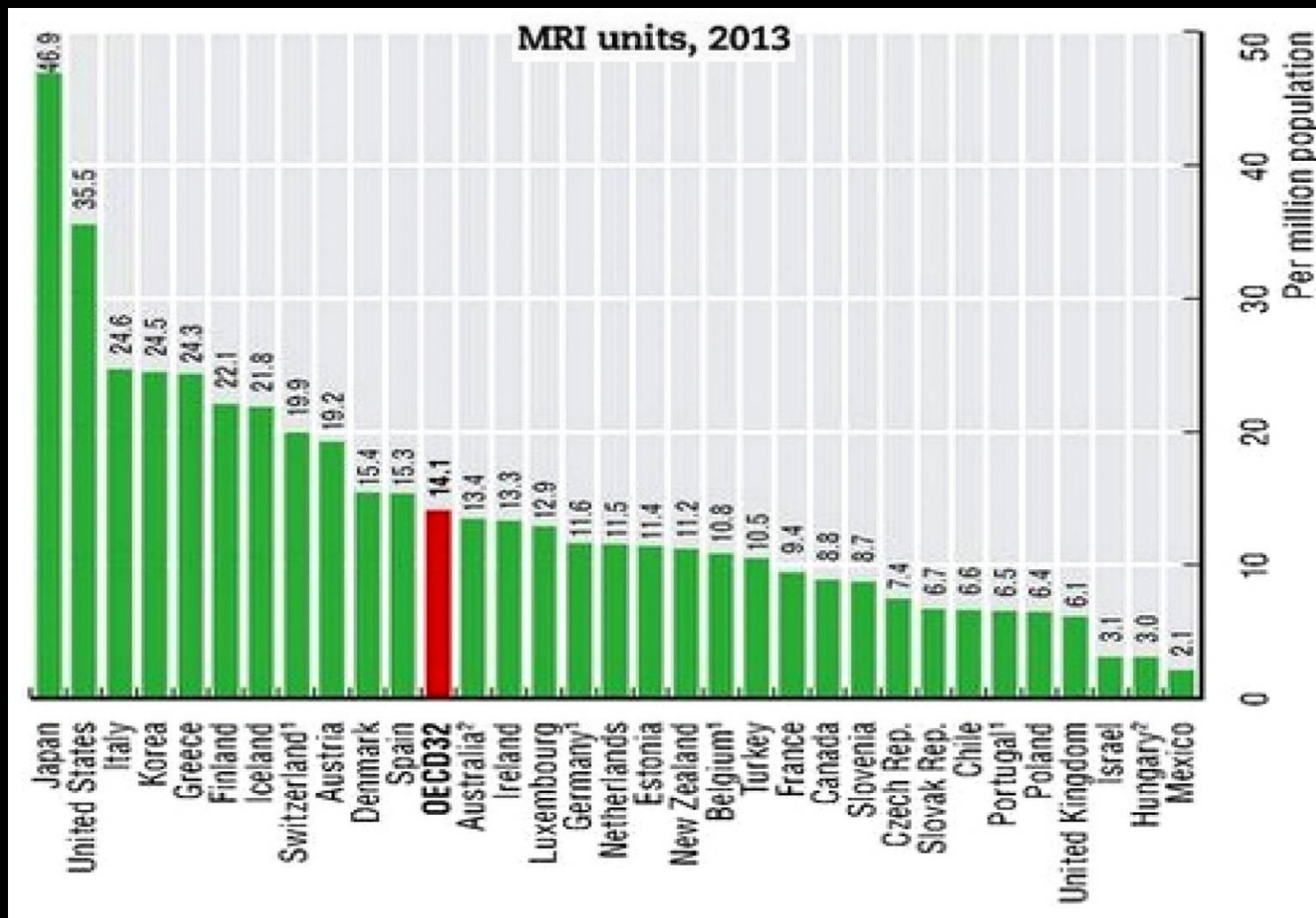
A képkötő vizsgálatok képanyagának mennyisége évente duplázódik.
A világon jelenleg kb. 50 billió gigabyte/év.

**Total MR Procedure Volume (Millions),
Hospital and Non-Hospital Sites, 1998-2018**



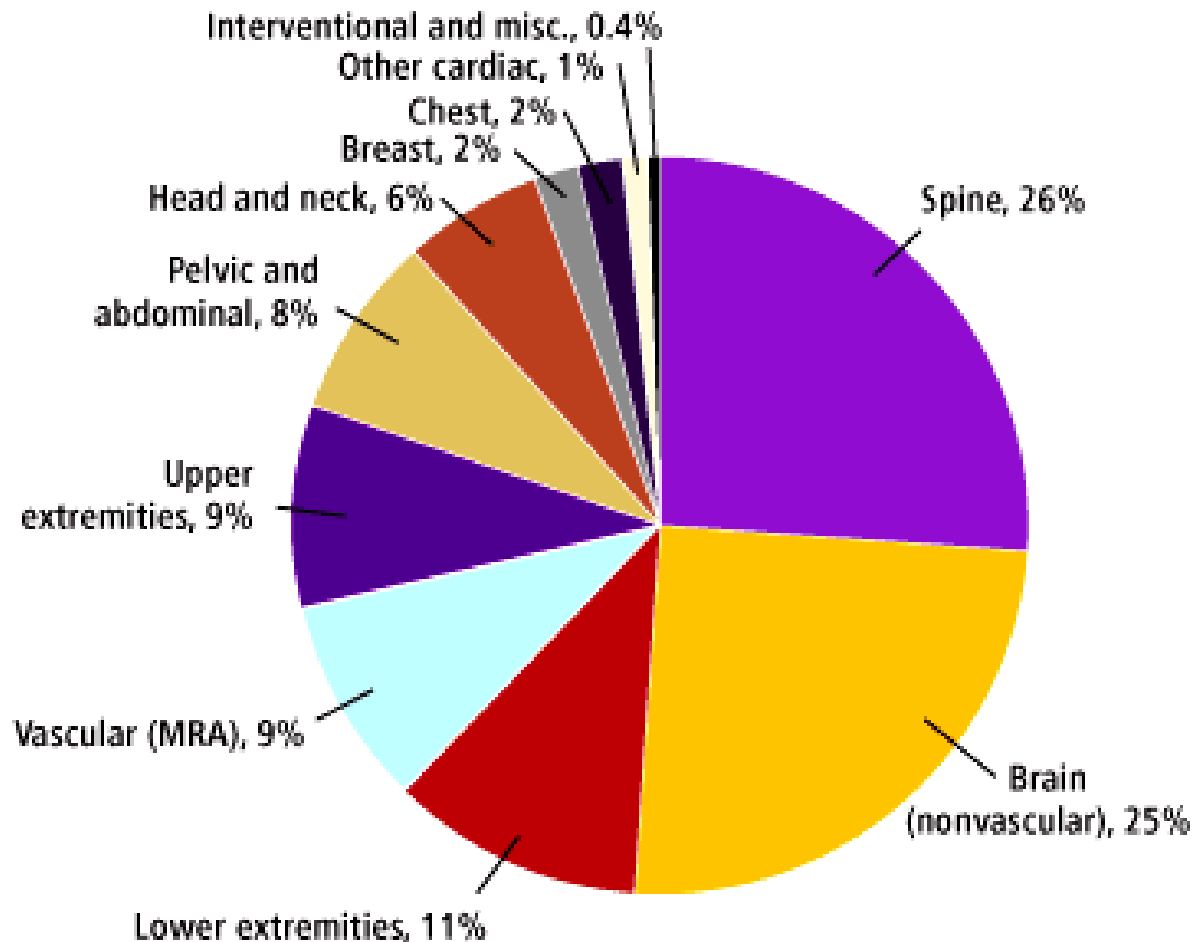
Az MR készülékek száma

2017. július: **104 CT** és **65 MR** Magyarországon



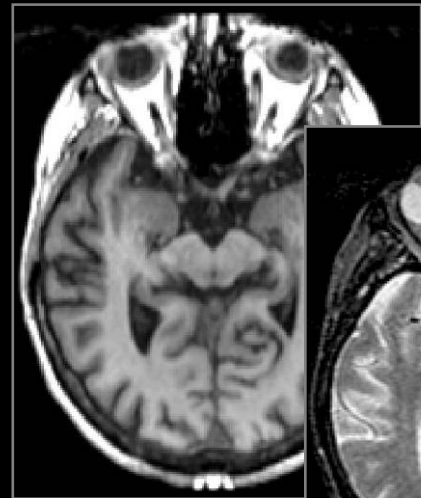
A neuroradiológiai MR vizsgálatok aránya

MRI procedure mix, 2007, all sites

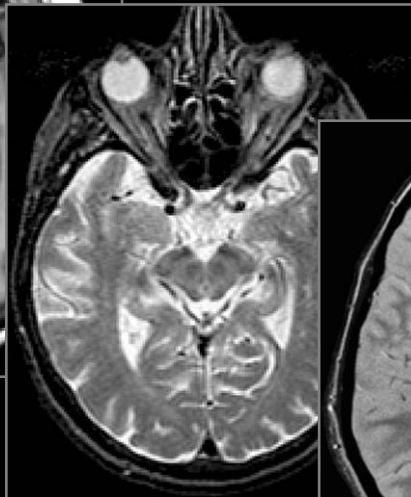


MR: multiparametrikus képalkotás

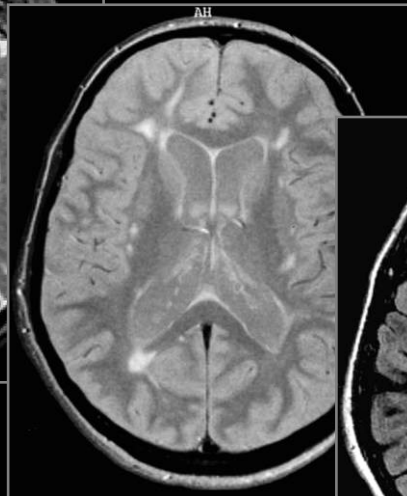
- T1 és T2 relaxivitás
- protonszűrűség
- áramlás, mozgás
- diffúzió
- inhomogenitás
- hőmérséklet
- inverzió
- preszaturáció



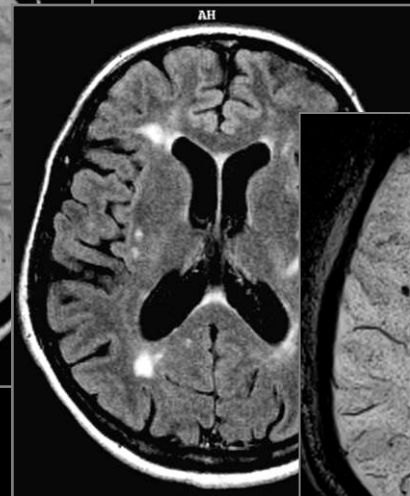
T1-súlyozott



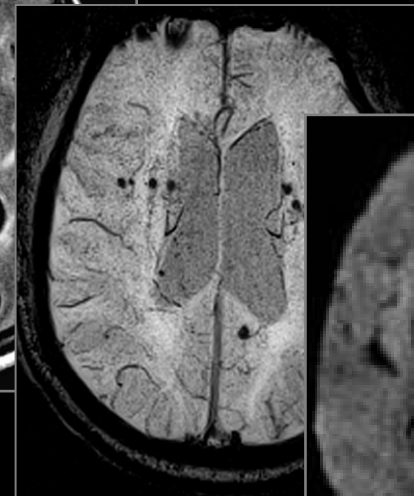
T2-súlyozott



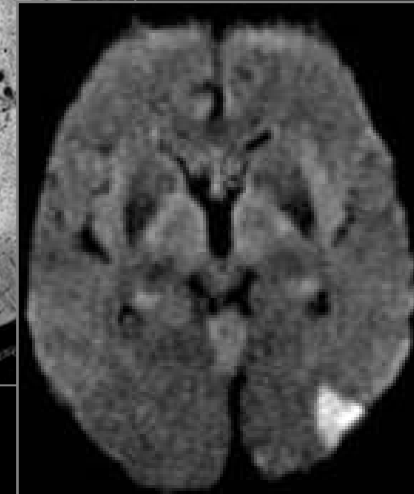
Protodenzitású



FLAIR



SWI



DWI

Legújabb MR technikák

Nagy térerejű MR (3-7 Tesla)

Párhuzamos képalkotás

Mozgáskorrekciós eljárások (BLADE, PROPELLER, Biomatrix, stb.)

3D adatszerzés (3DFT)

Szuszeptibilitás-súlyozott képalkotás (SWI)

Diffúziós MR

diffúzió-súlyozott MR (DWI)

látszólagos diffúziós koefficiens (ADC)

diffúziós tenzor térképe (DTI)

frakcionált anizotrópia (FA)

MR tractographia

DWIBS teljes test MR

MR neurográfia (MRN)

Perfúziós MR/Dinamikus MR

dynamic susceptibility contrast (DSC)

dynamic contrast enhancement (DCE)

arterial spin labeling (ASL, pASL, cASL)

Funkcionális MR (fMRI) (BOLD, ASL, VASO)

MR spektroszkópia (SVS, CSI)

Legújabb MR technikák

Vessel Architectural Imaging (VAI)

Vessel wall imaging

Magnetic Resonance Fingerprinting

Diffusion Kurtosis Imaging

Probabilisztikus Tractográfia

Diffusion spectrum imaging (DSI)

Hiperpolarizáció

Plazma volumetria

PET – MR

MR vezérelt intervenció

Oxygenizáció meghatározása

pH súlyozott képalkotás

Cerebrovascularis reaktivitás

Hypercarbic BOLD

Hypercarbic ASL

Hypercarbic vessel coded ASL

Amide proton transfer (APT) CEST

Lymphatic spin labeling

Neurális hálózat analízis

Kalibrált BOLD fMRI

Multiband fMRI

Functional connectivity maps

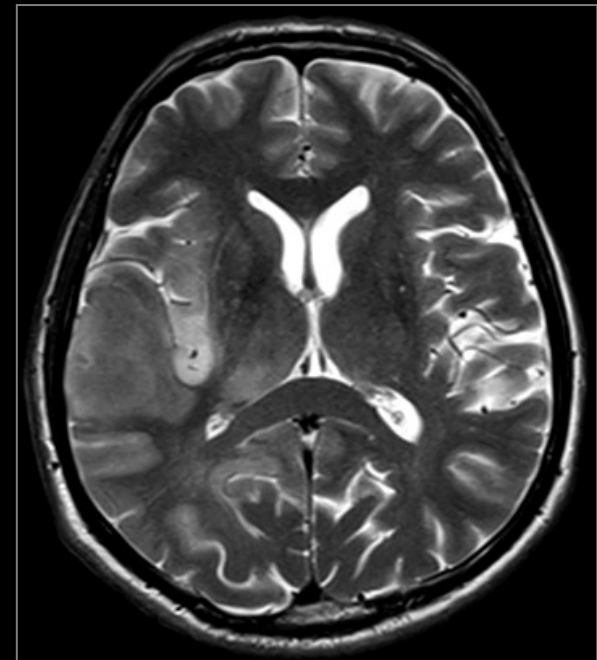
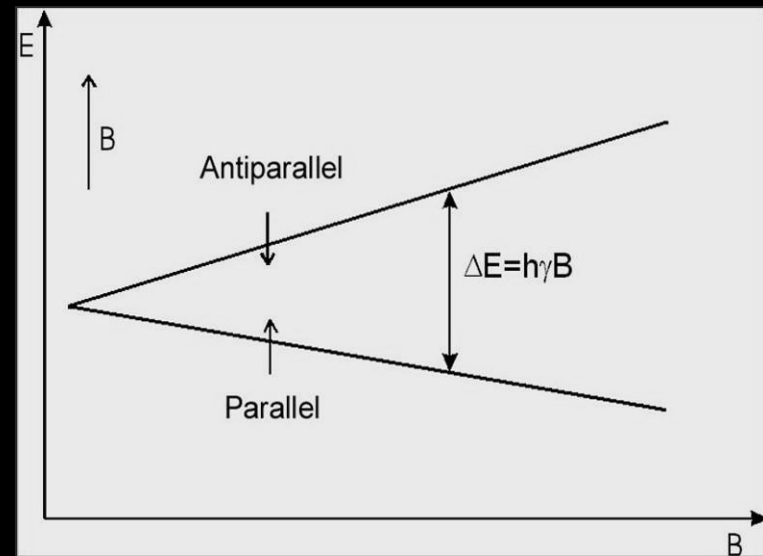
A nagy mágneses térerő előnyei

≥ 3 Tesla

$$\text{SNR} = fB$$

- ↑ SAR (specific absorption rate) 4x
- ↑ Chemical shift
- ↑ Suszeptibilitási műtermékek
- ↑ B1 inhomogenitás problémák

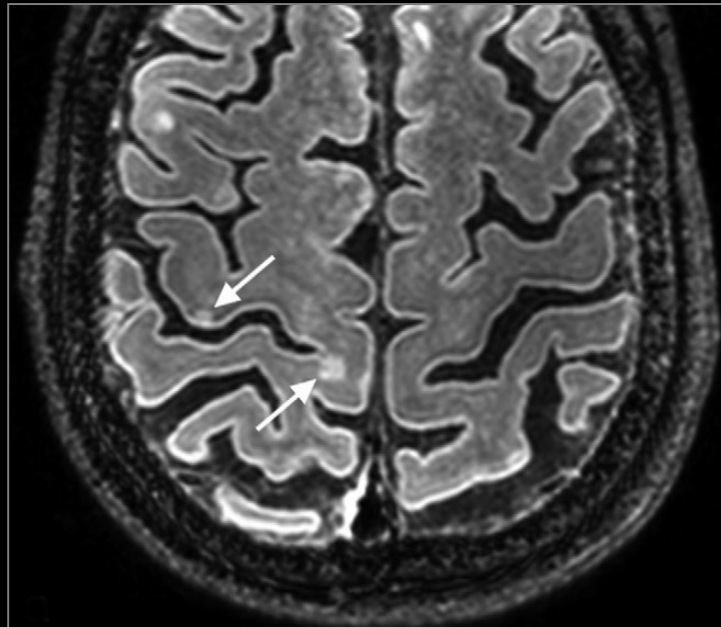
- ☞ Jobb kép gyorsabban
- ☞ Speciális kontraszt
- ☞ Jobb kontrasztanyag érzékenység
- ☞ Nagyobb felbontás



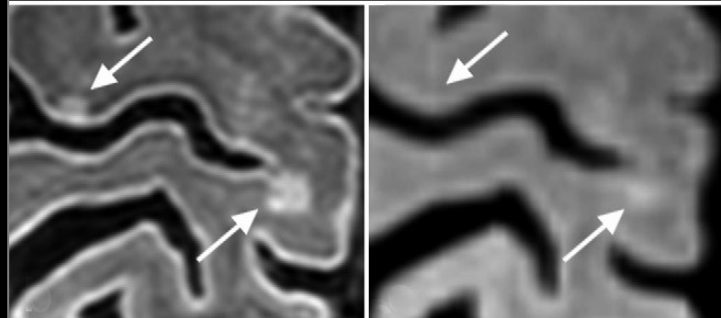
A nagy mágneses térerő előnyei

Kolk, 2013

3D-FLAIR

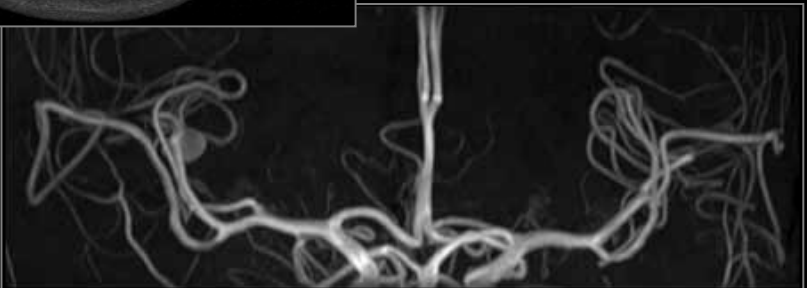


7 Tesla

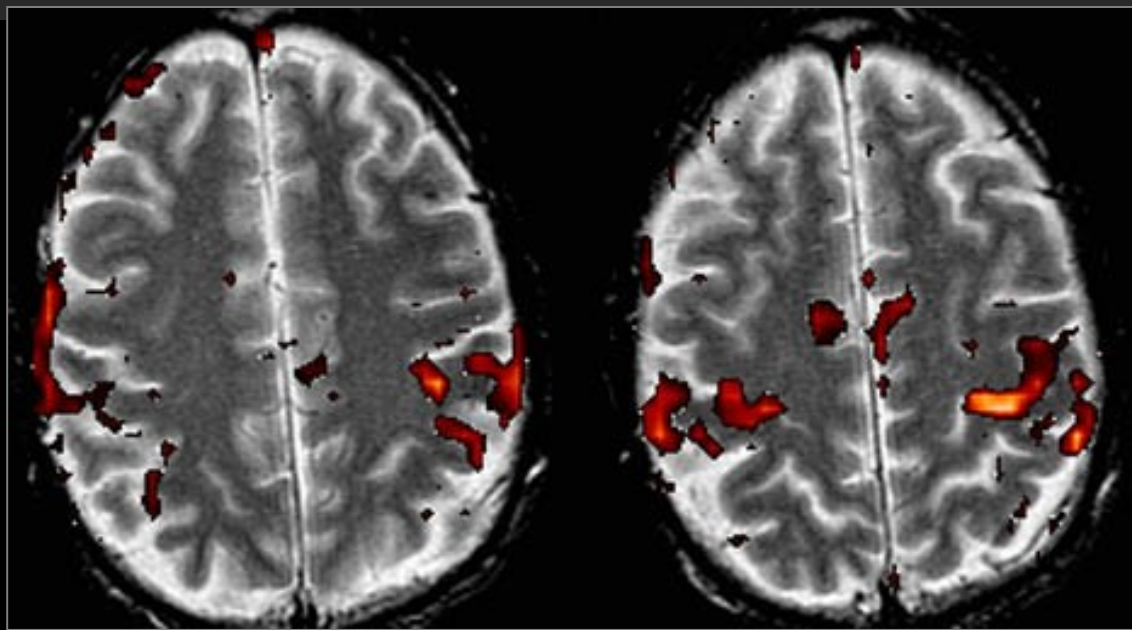


7T

3T

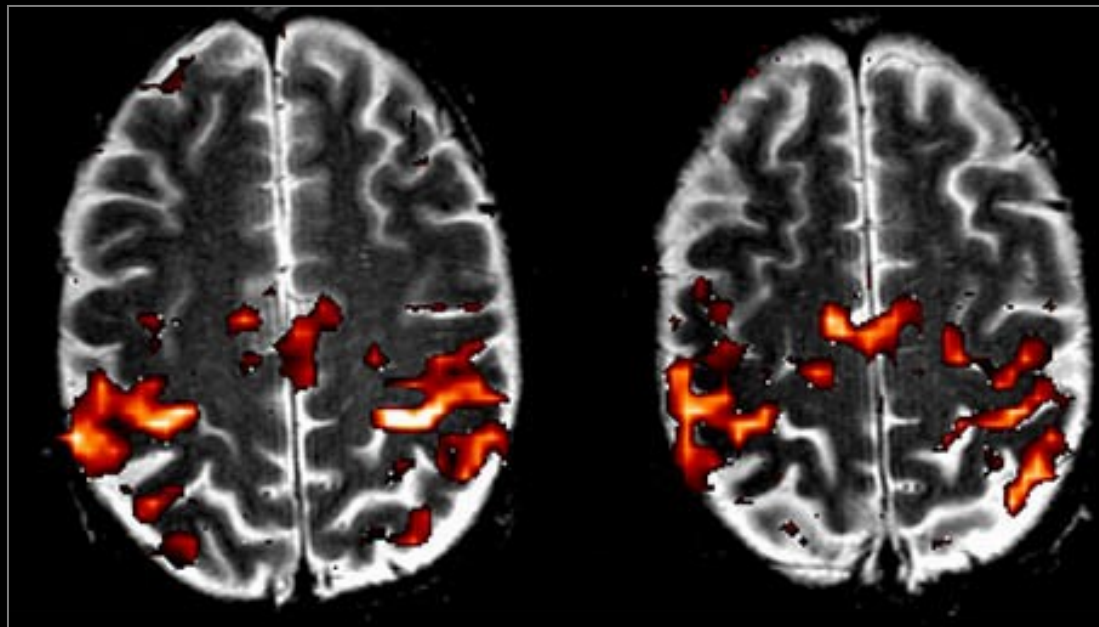


Funkcionális MR (fMRI)



1,5 T

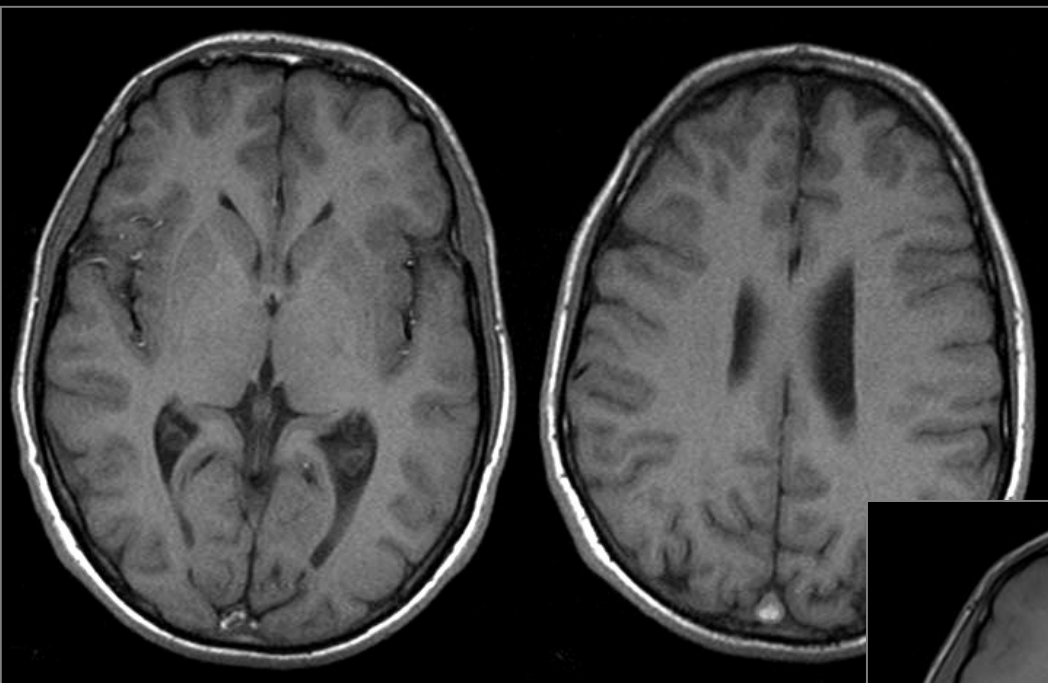
3,0 T



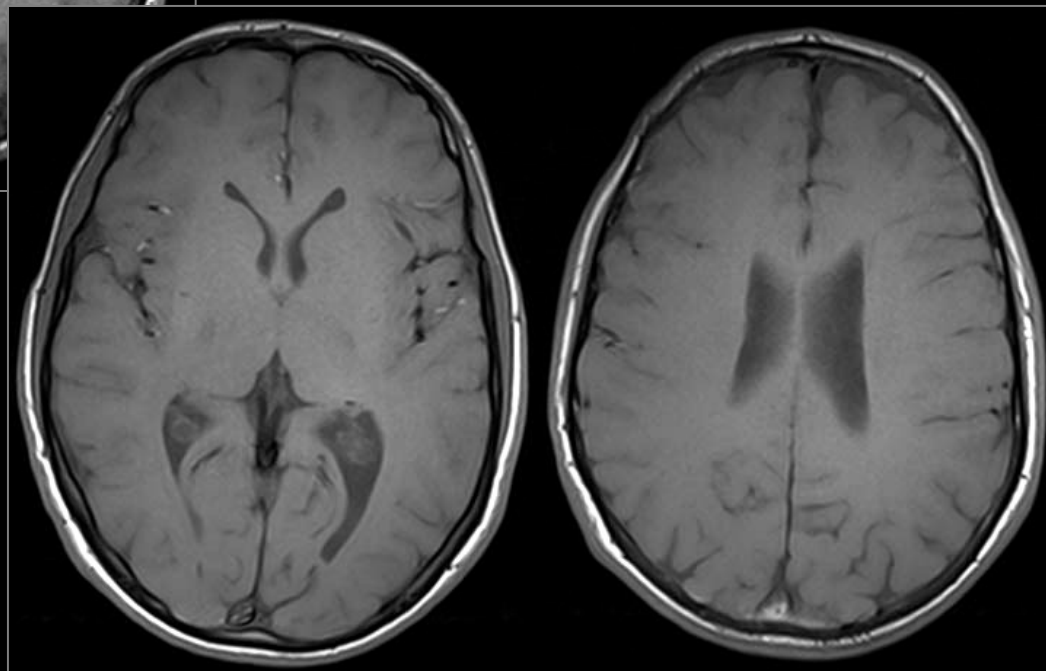
Noseworthy

T1 kontraszt probléma

1,5 T (TR = 500ms, TE = 11 ms)

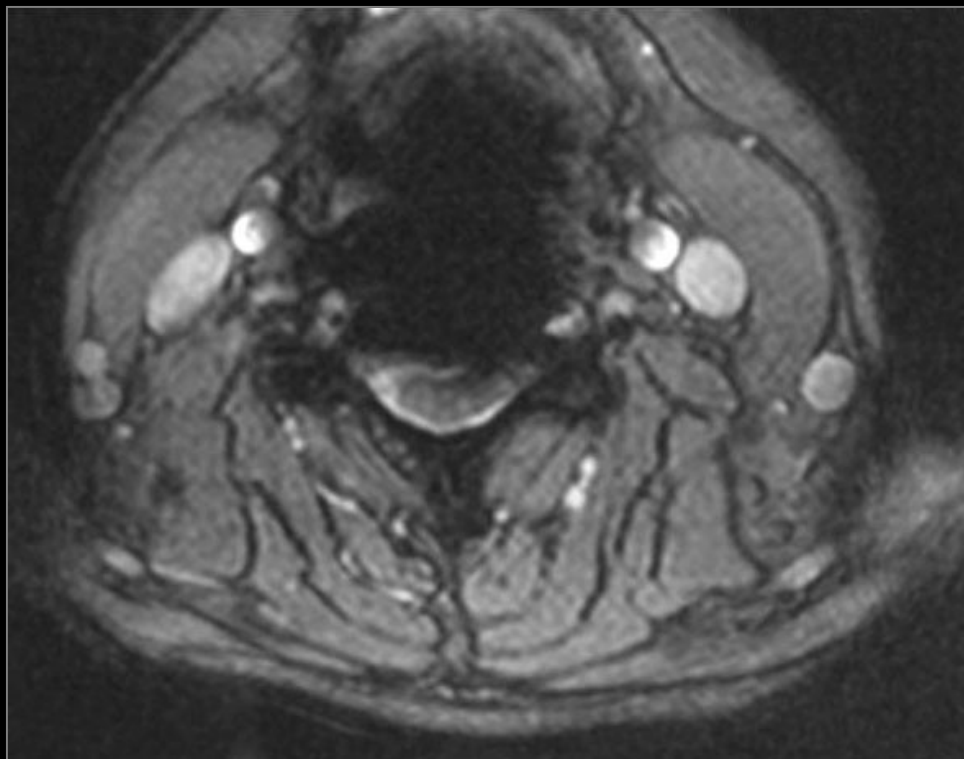


3,0 T (TR = 620 ms, TE = 9 ms)

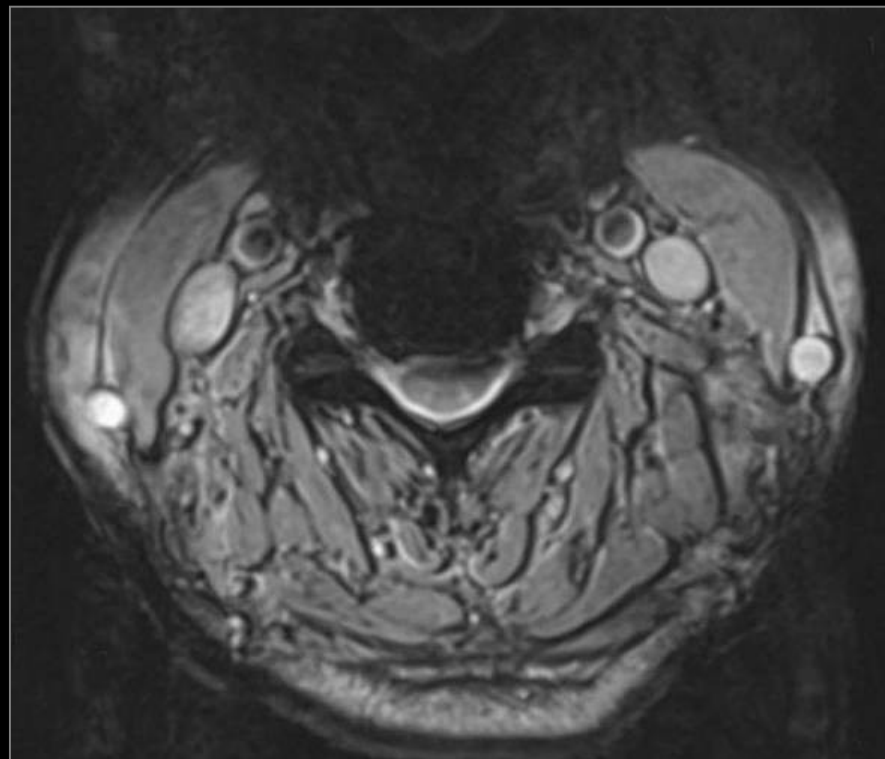


Szuszeptibilitás műtermék

1,5 T



3,0 T



Párhuzamos képalkotás

Single-Shot SE-EPI - GRAPPA



Normál

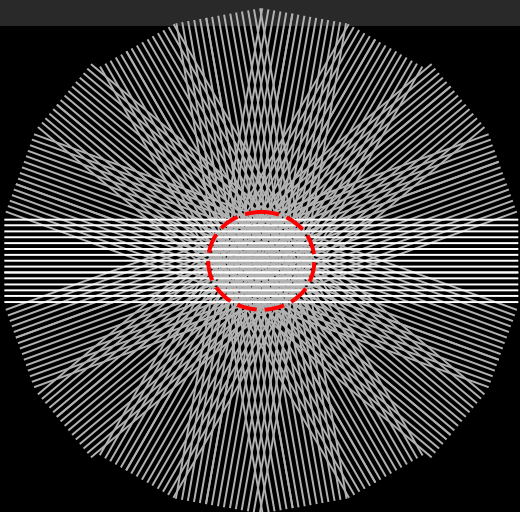
PAT x2

PAT x3

- A vizsgálati idő csökken 2x, 3x, ...
- A torzítás csökken
- Rövidebb a minimum TE

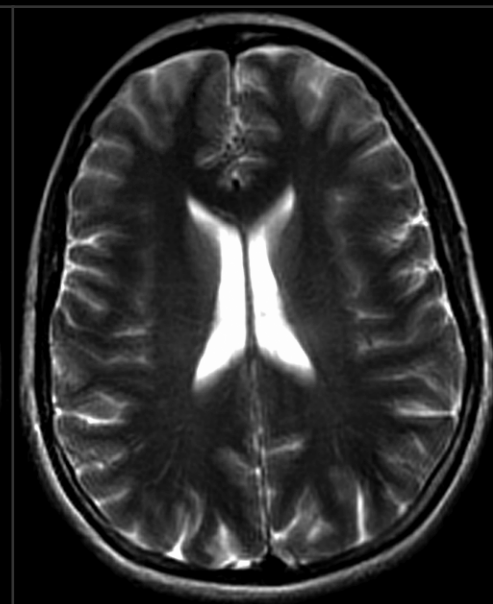
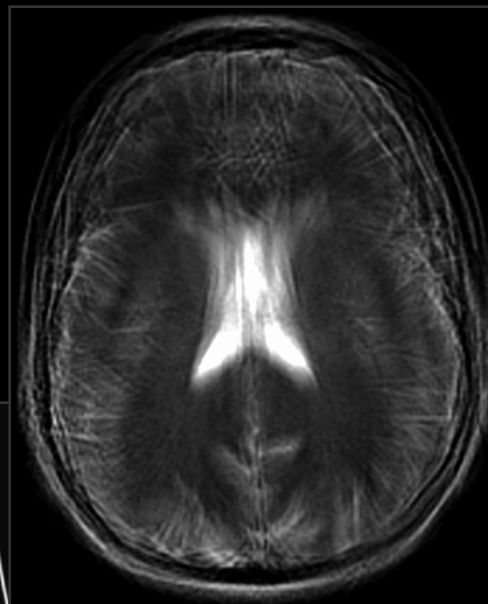
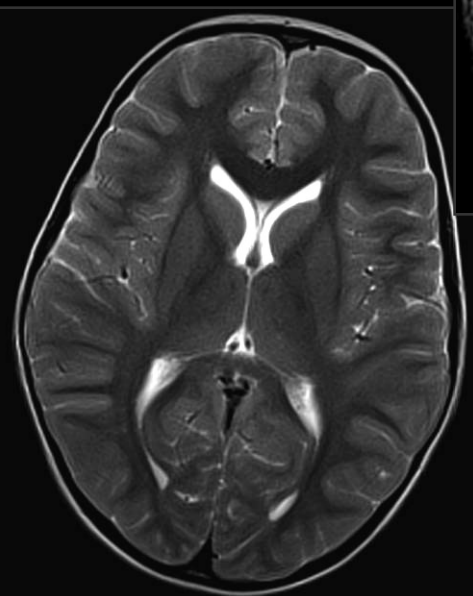
Valós idejű mozgáskorrekció

PROPELLER_(GE) / BLADE_(Siemens)



Conventional

BLADE



Conventional

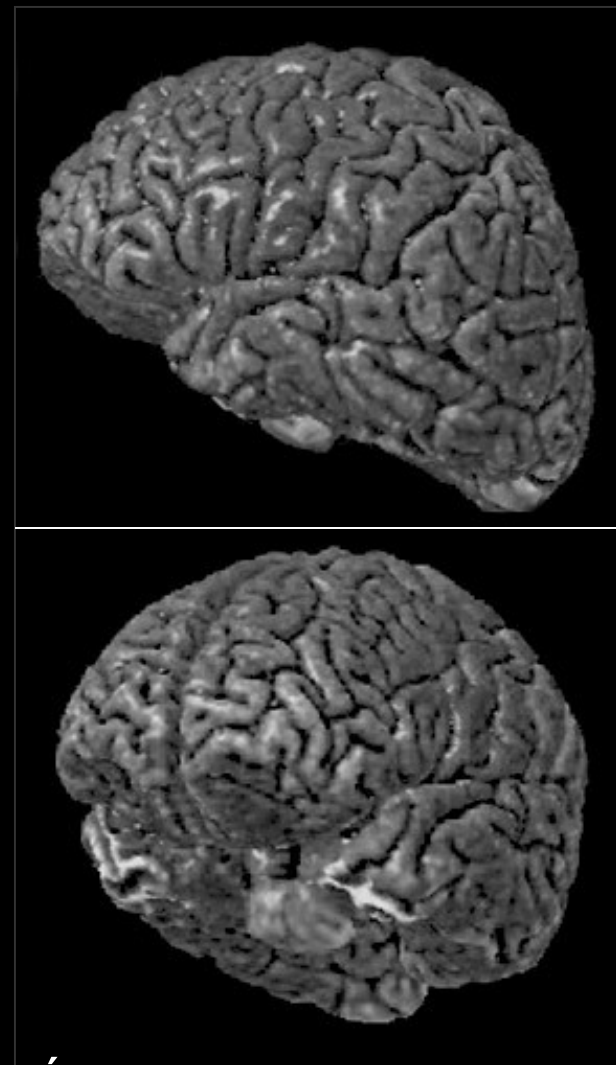
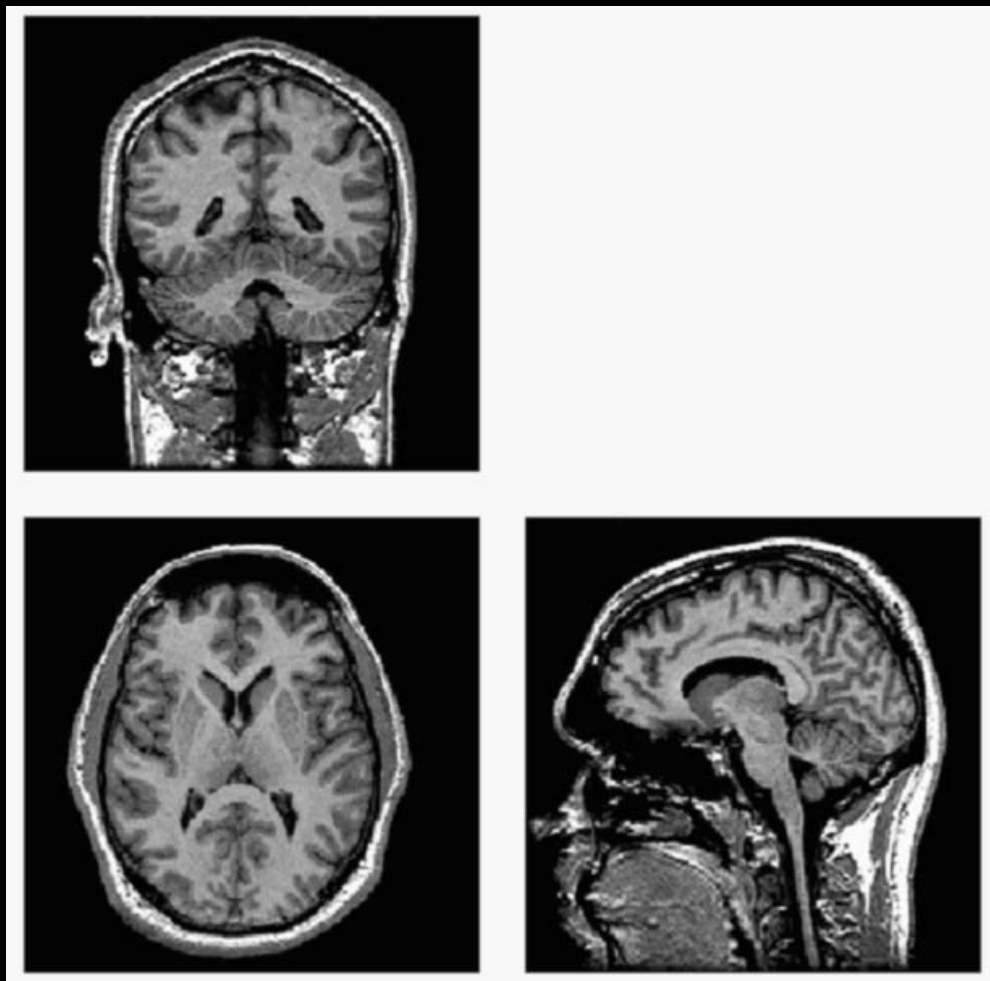
BLADE

Intrauterin MR



SSFSE

3D akvizíció

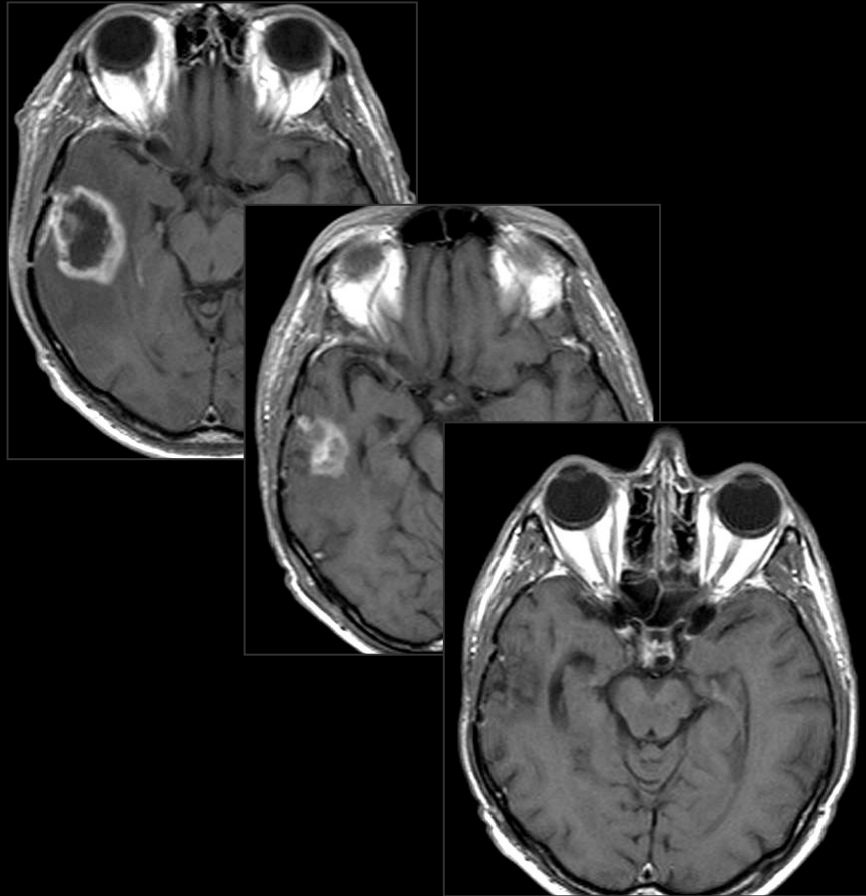


Akár 0,1 mm szeletvastagság

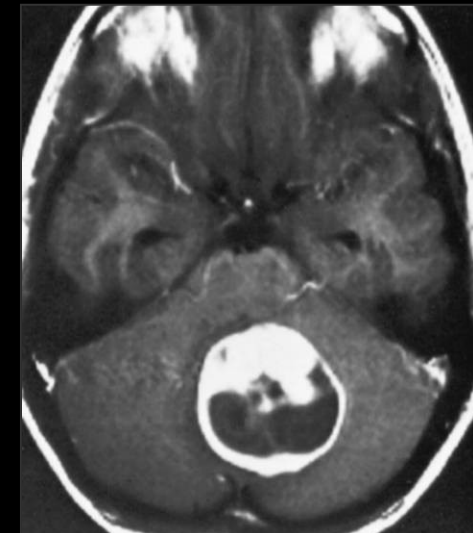
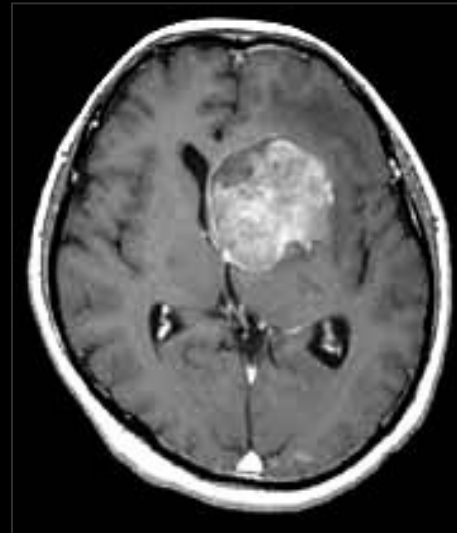
Speciális kontraszt

Gd kontraszt halmozás

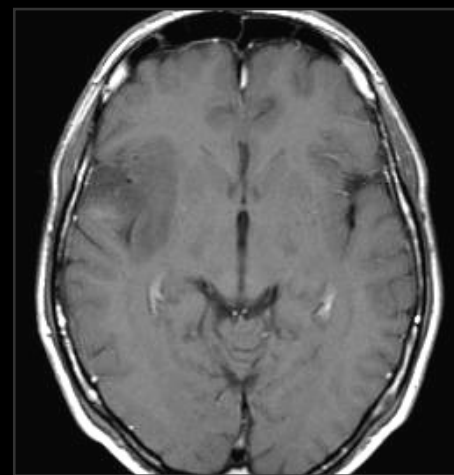
Pszedopgresszió



Anaplasticus astrocytoma



Pilocytás astrocytoma



Benignus astrocytoma

Szuszeptibilitás-súlyozott képalkotás

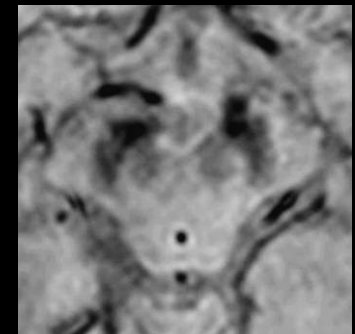
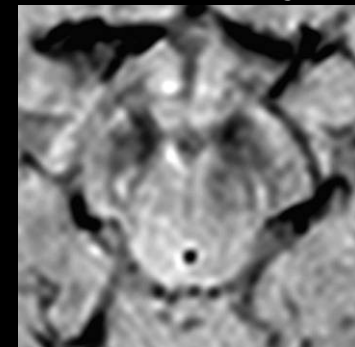
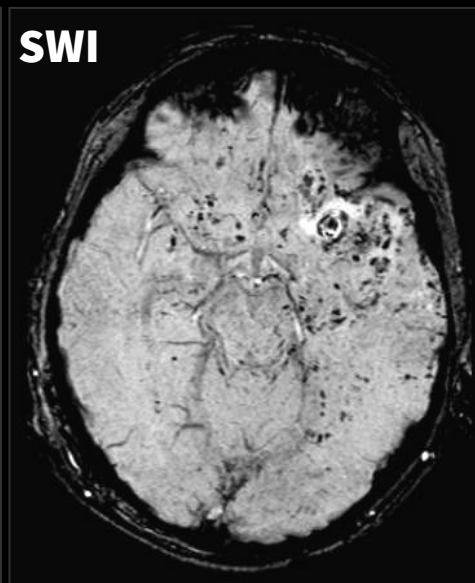
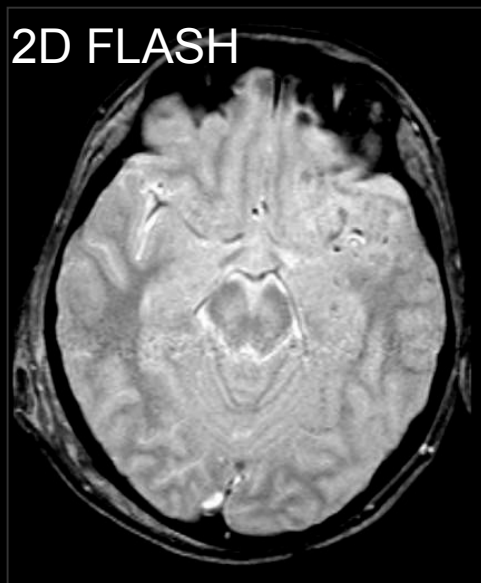
SWI

Áramlás kompenzált, hosszú TE, GRE. A magnitude és a fázis adatok kombinációja. 3DFT adatszerzés.

Diffúz axonális sérülés

Sturge-Weber sy.

fecskefarok jel

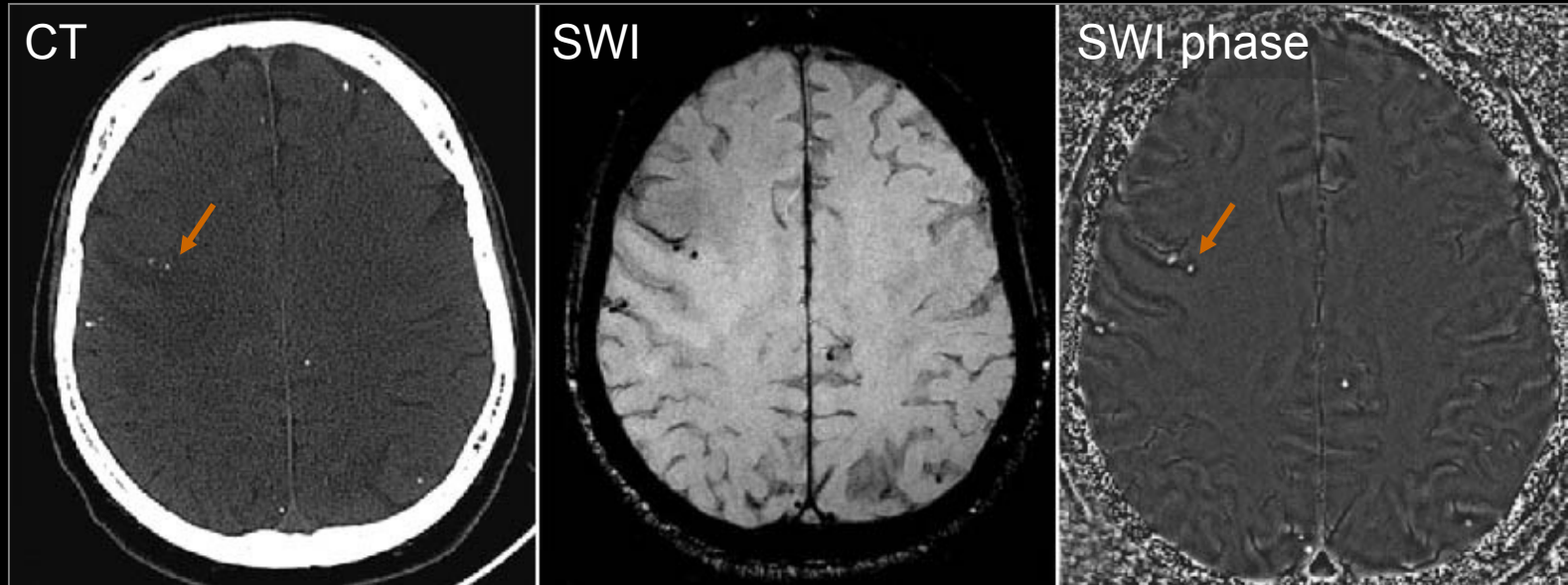


Karen Tong, MD at Loma Linda University

en.wikipedia.org

radiopedia.org

Szuszeptibilitás-súlyozott képalkotás



Double Inversion Recovery Imaging (DIR)



SM

„MR biomarkerek”

Különleges szöveti tulajdonságok leképezése:

Diffúzió-súlyozott MR; DWI: ADC

Diffúziós tenzor képzés; DTI: FA, tractographia

MR spektroszkópia; MRS:

- Single-voxel spectroscopy (SVS): NAA, Cho, Cr, Lip, Lac, Glx, mIn
- Multi-voxel spectroscopy (CSI)

Perfúzió-súlyozott MR; PWI:

- Dynamic Susceptibility Contrast Imaging; DSC: rCBV
- Dynamic Contrast-enhanced T1-weighted Imaging; DCE: Ktrans
- Arterial Spin Labeling; ASL: CBF

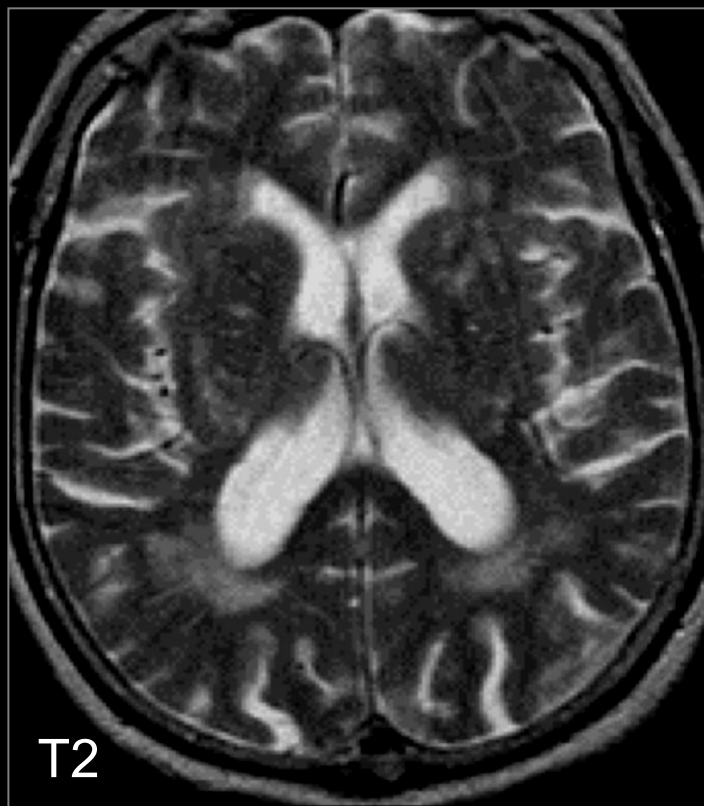
Funkcionális MRI; fMRI:

- Block design – Event-related design
- Resting state fMRI

Diffúzió-súlyozott képalkotás

DWI

Gátolt diffúzió → hiperintenzitás



kb. 30 perccel a stroke után a DWI már pozitív

Diffúzió-súlyozott képzőanyag

A víz diffúzióját (Brown mozgás) méri

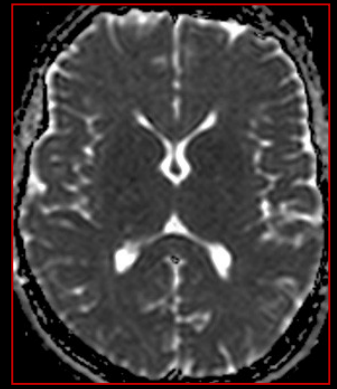
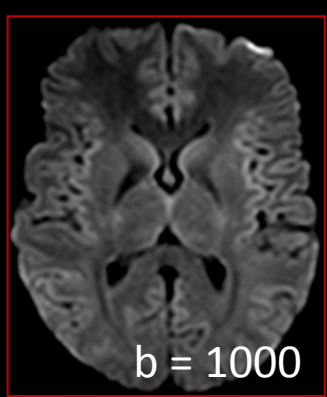
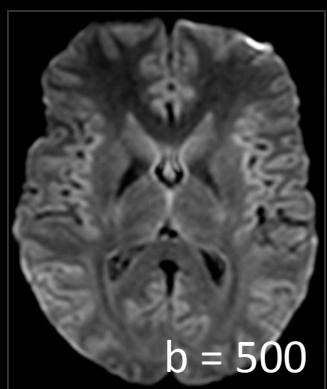
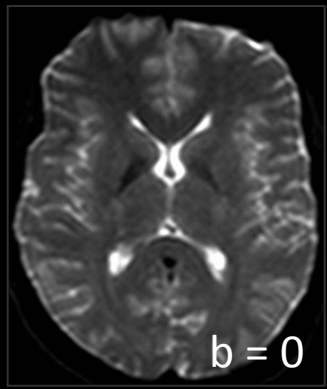
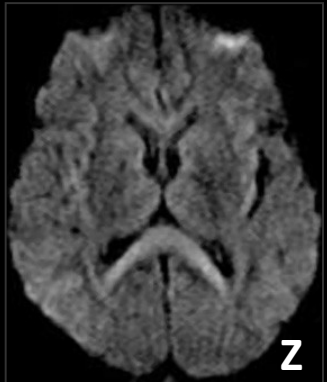
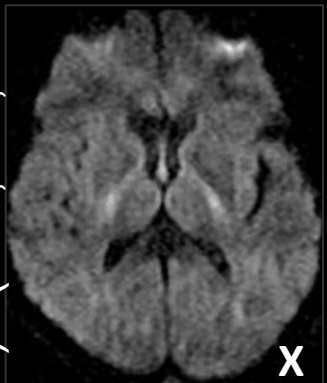
A diffúziót befolyásoló tényezők:

- sejt sűrűség (cellularitás)
- sejt duzzadás (citotoxicus oedema)
- membrán integritás és permeabilitás
- sejtközötti struktúrák
- szövetközi anyagok összetétele, konzisztenciája

b: a diffúzió súlyozás mértéke

Diffúziós MR

9 mérés: (X, Y, Z) * (B=0, 500, 1000)



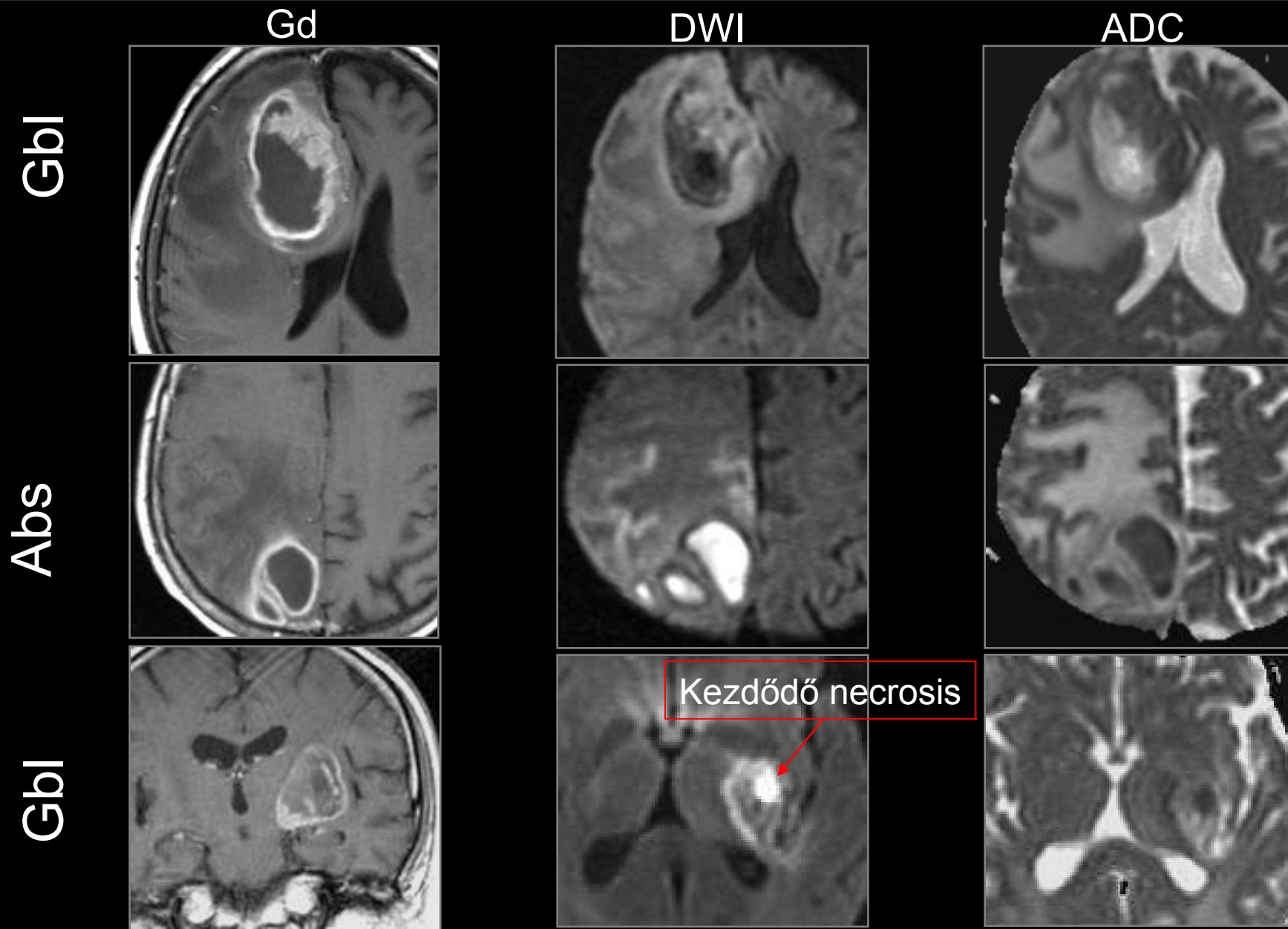
ADC

Lineáris Regresszió
ADC = meredekség

$$D = (D_x * D_y * D_z)^{-3}$$

Trace

Diffúzió-súlyozott MR

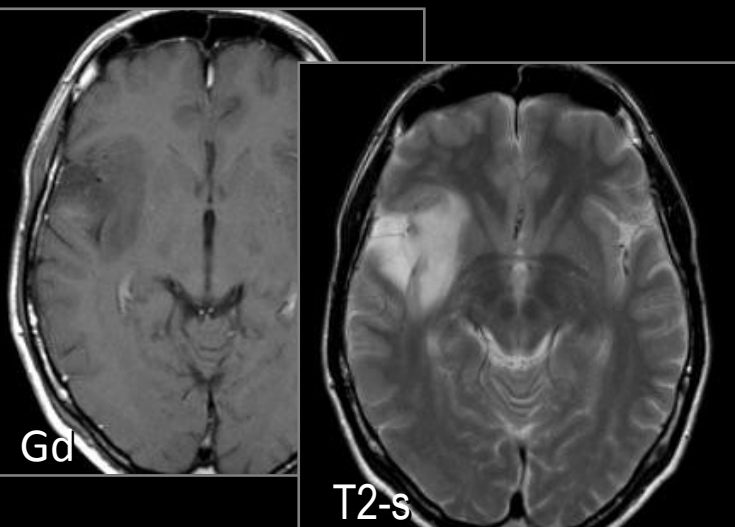


Diffúziós MR tumoroknál

- A nagy cellularitású tumorokban a diffúzió általában gátolt: Pl.: malignus gliomák, lymphoma, PNET.
- Általában a benignus daganatok ADC-je nagyobb a malignus daganatokénál.
- Az ADC lehet az egyik tumor marker (biopsia célterülete, besugárzástervezés, neuronavigációs idegsebészet) és terápia indikátor.

DWI - ADC

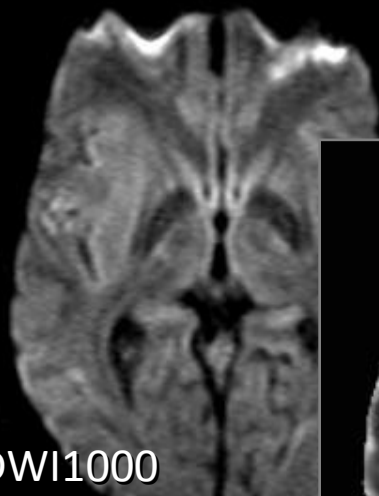
- Az ADC a szürke- és fehérállomány-ban közel egyforma.
- Az astrocytoma területén a DWI gátolt diffúziót mutat, pedig az ADC nagy („T2 shine-through”)!
- A B-lymphoma nagy cellularitása miatt az ADC kicsi.



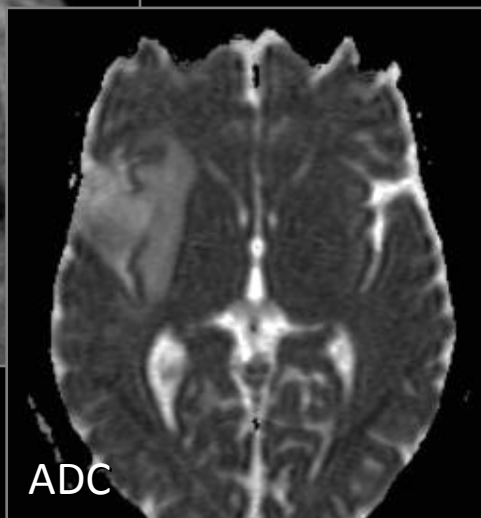
Gd

T2-s

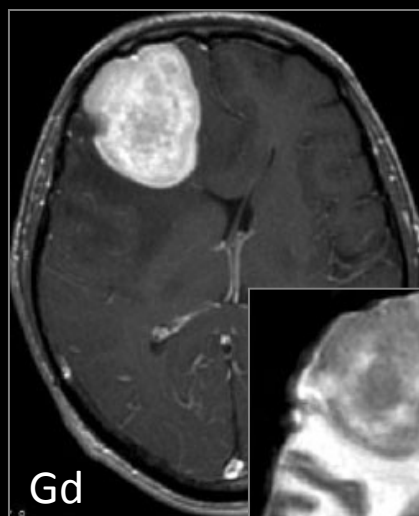
Astrocytoma



DWI1000

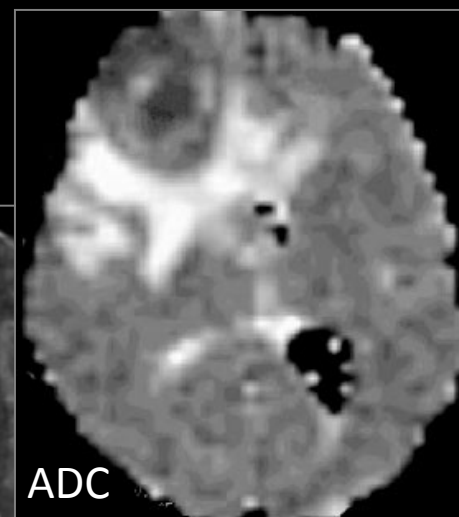


ADC

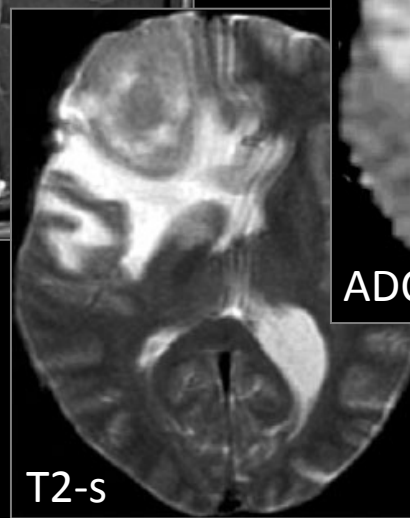


Gd

Lymphoma



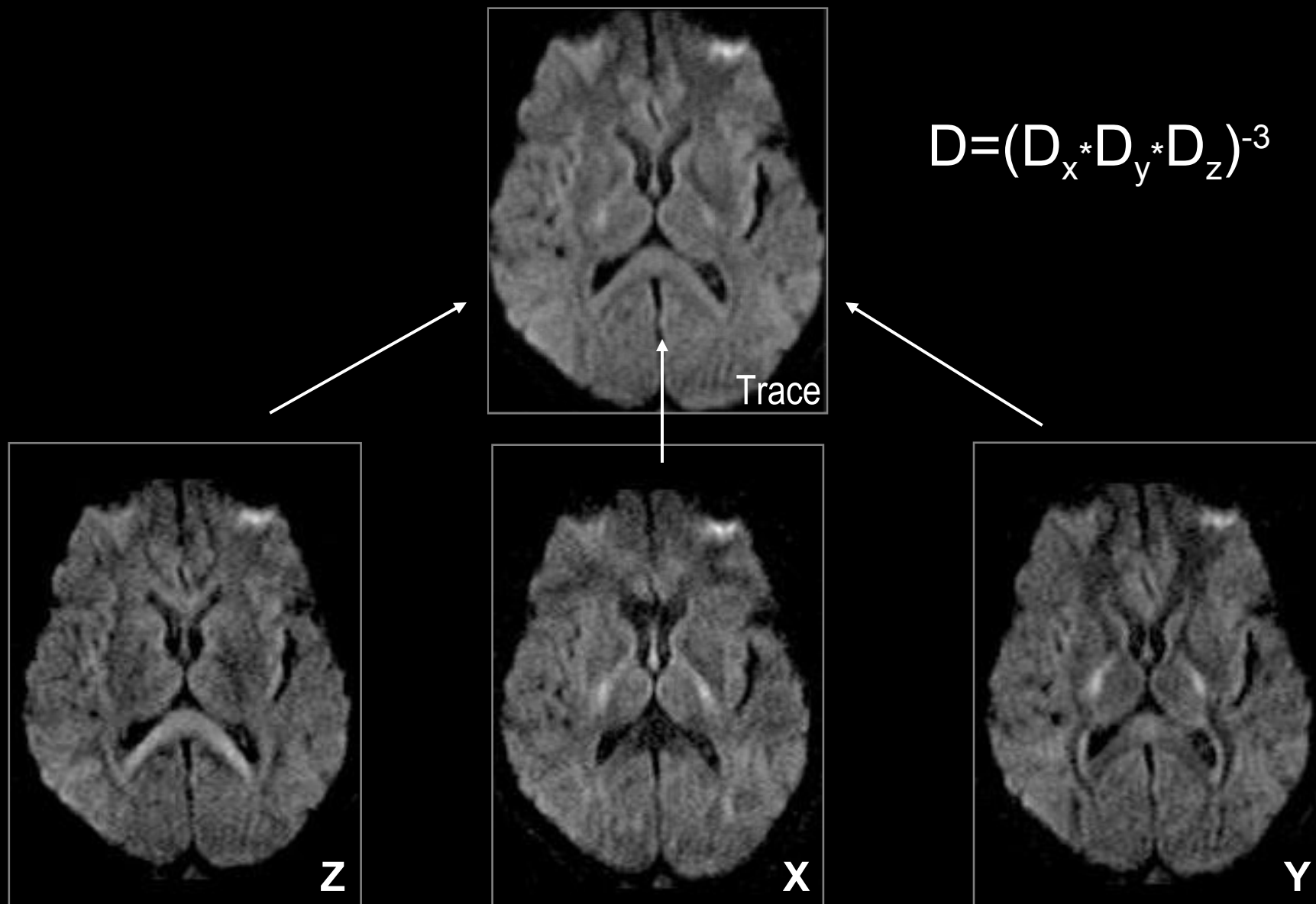
ADC



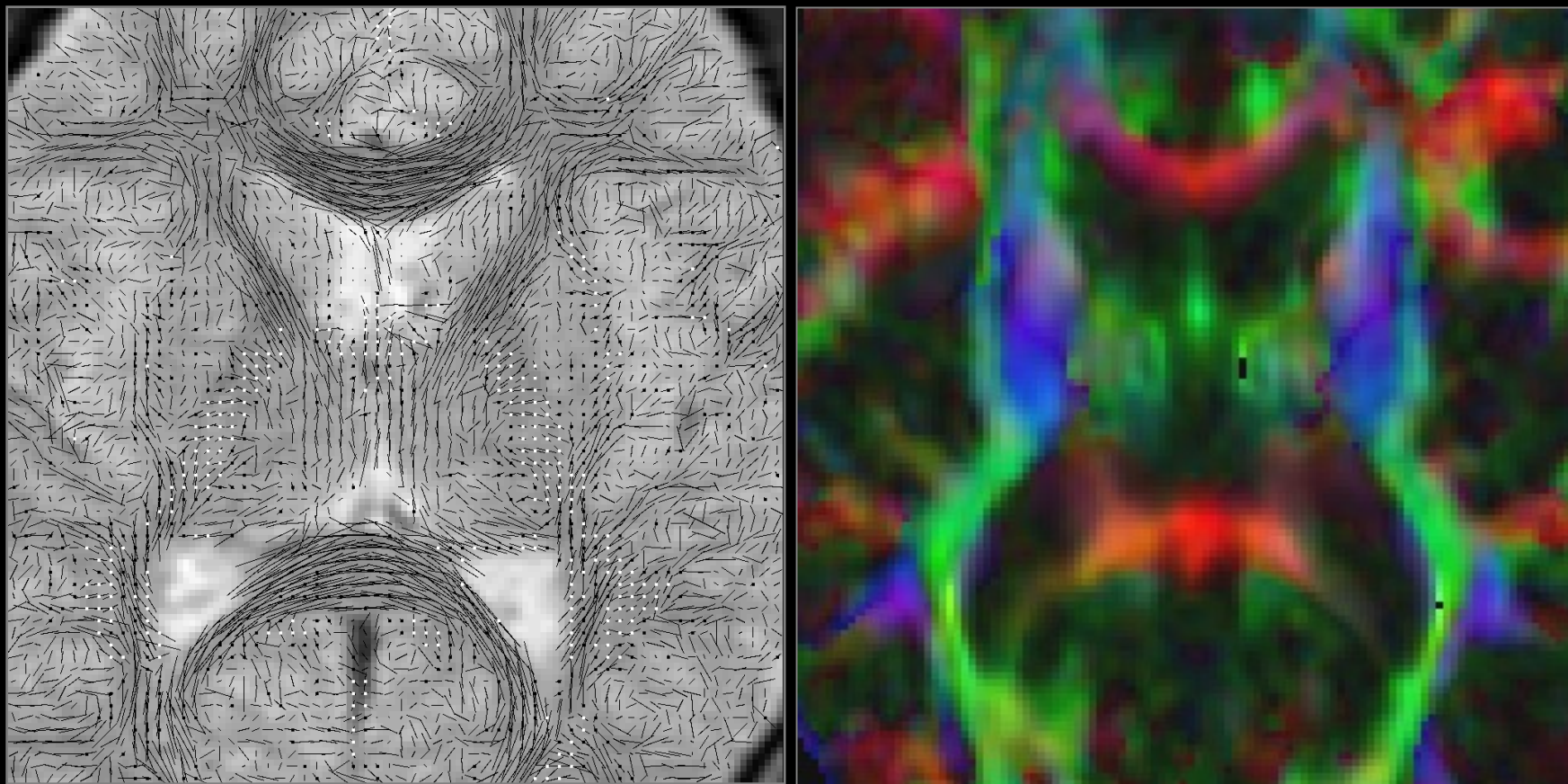
T2-s

Provenzale, 2006

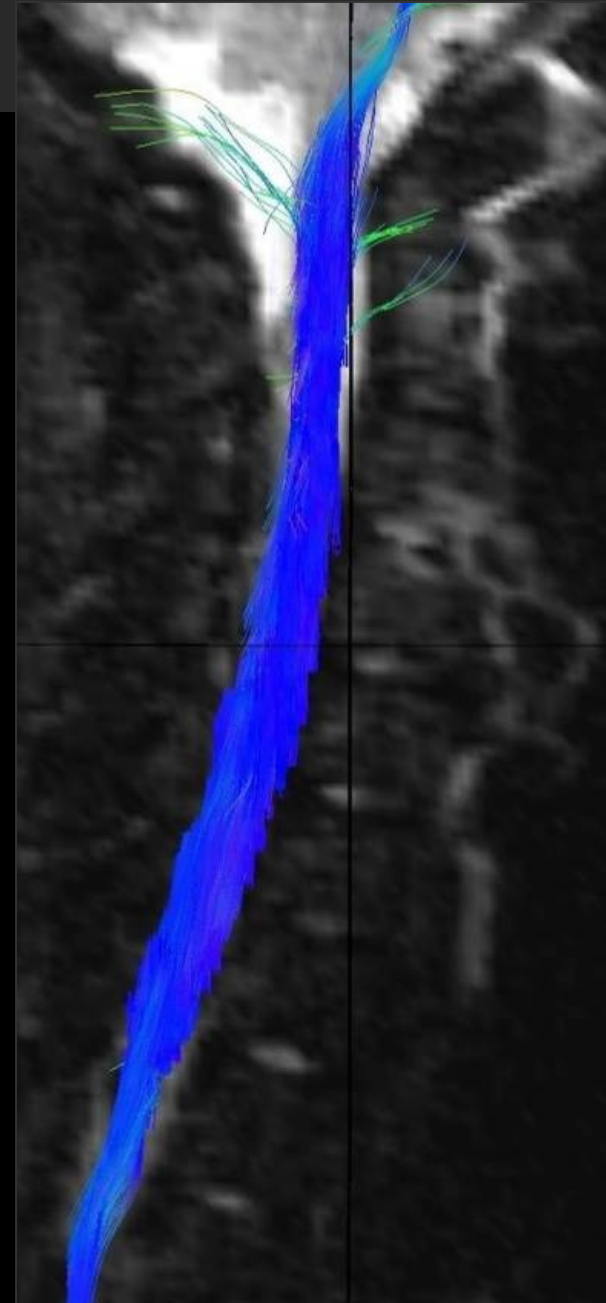
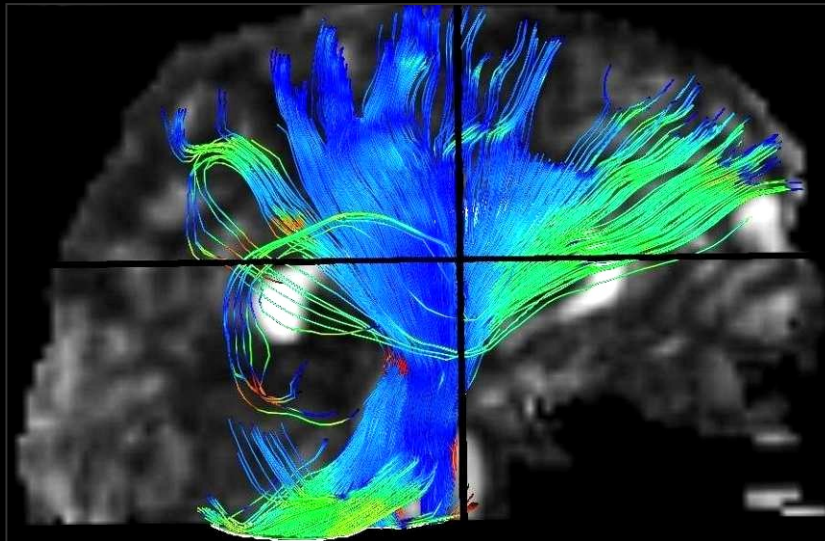
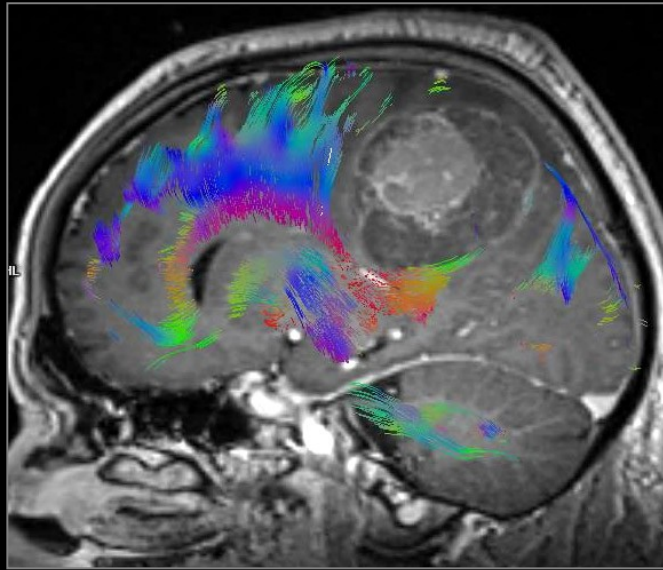
Diffúziós anizotrópia



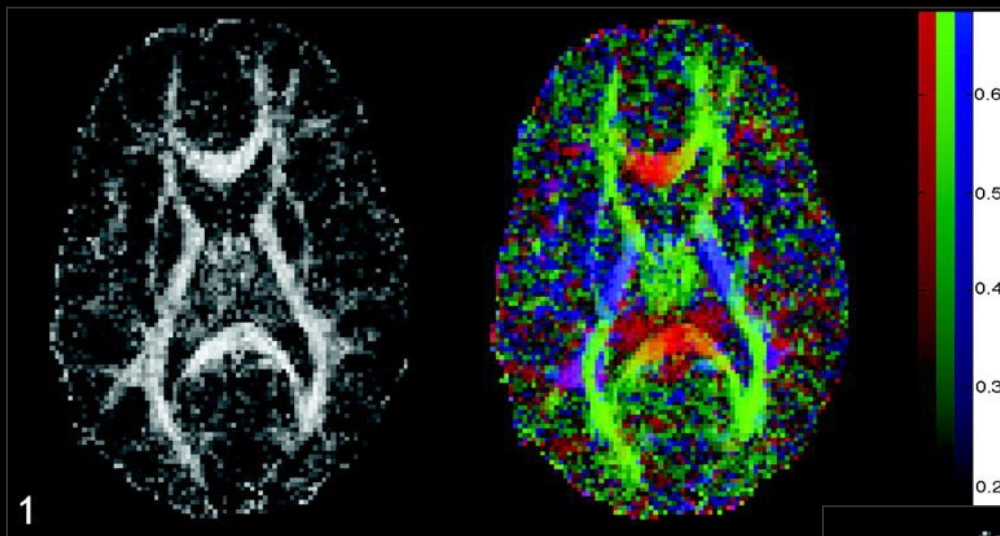
Diffúziós tenzor képalkotás (DTI)



Tractografia

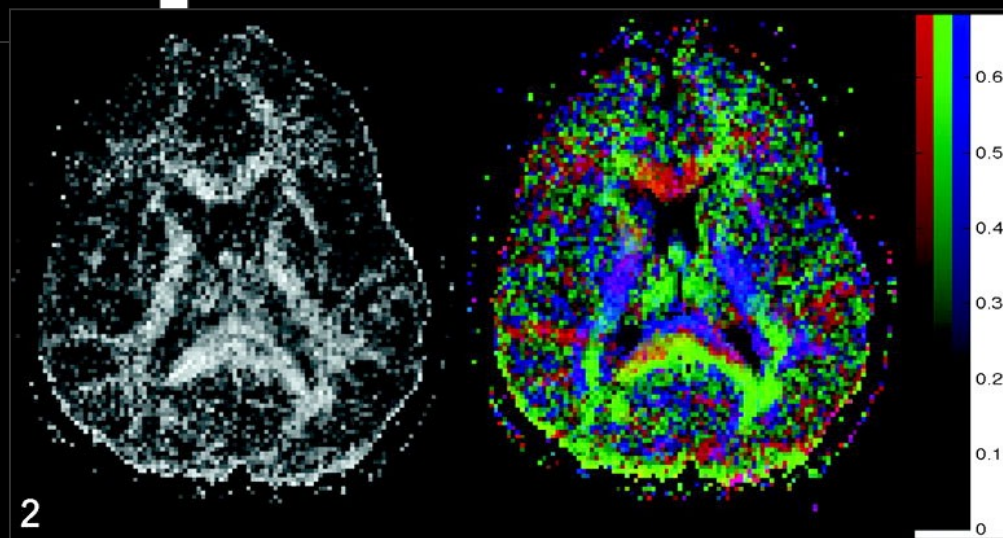


Diffúziós (relatív) anizotrópia MR



A fehérállomány rostos rendezett szerkezetének megbomlása:

- fehérállományi elváltozások
- trauma
- tumorok



Diffúz axonális lézió

Perfúziós MR

A kontrasztanyag követése:

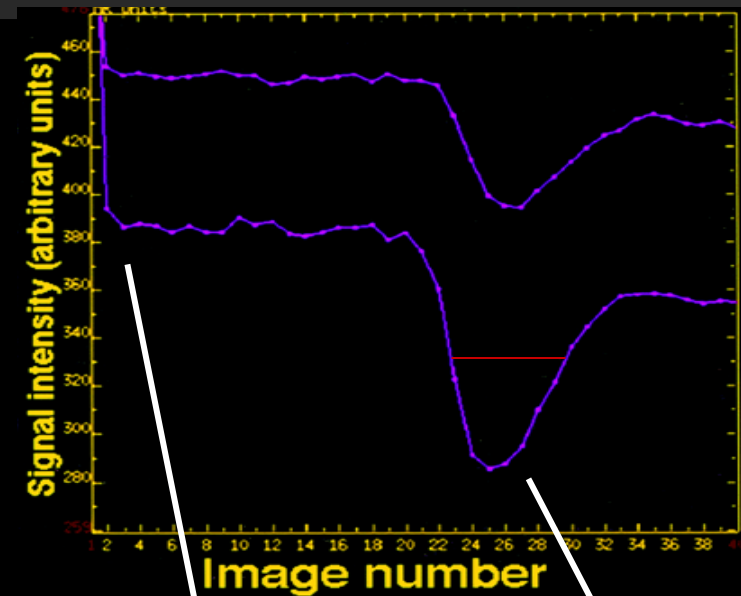
- DSC-MRI, dynamic susceptibility contrast (T2*-súlyozott) → rCBV
- DCE-MRI, dynamic contrast-enhanced (T1-súlyozott) → K^{trans} (volume transfer constant)

Spin jelöléses perfúziós MR: → CBF

- Pulsed ASL (PASL)
- Continuous ASL (CASL)
- Pseudo-Continuous ASL (pCASL)

Perfúziós MR: DSC

I.v. Gd-kontrasztanyag
T2*-súlyozott szeletsorozat

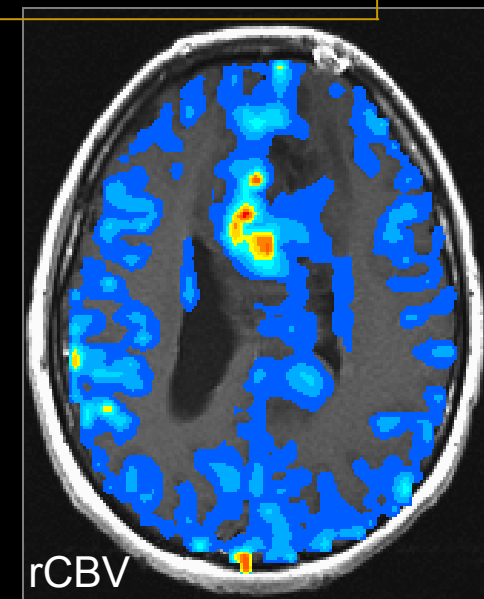
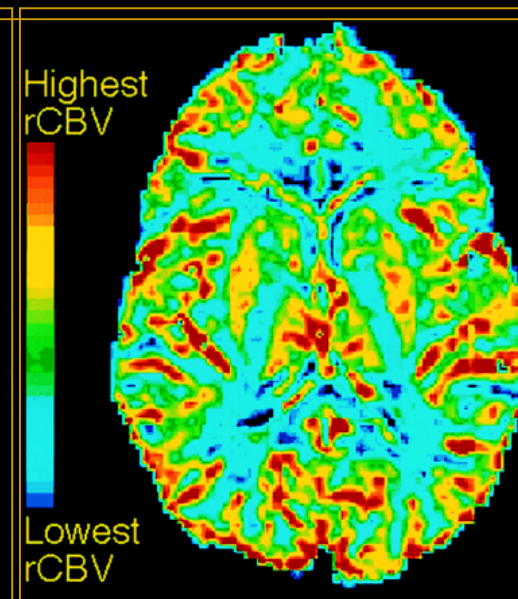
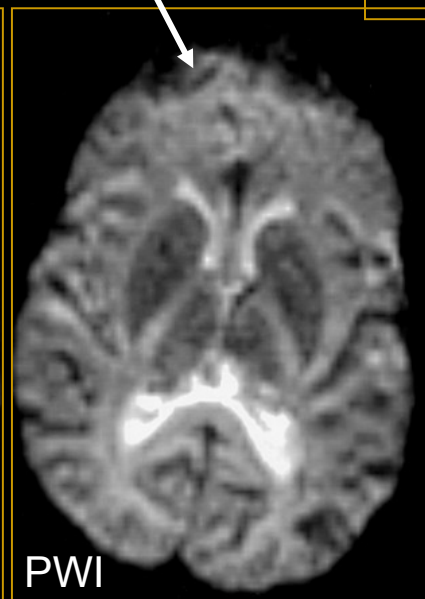
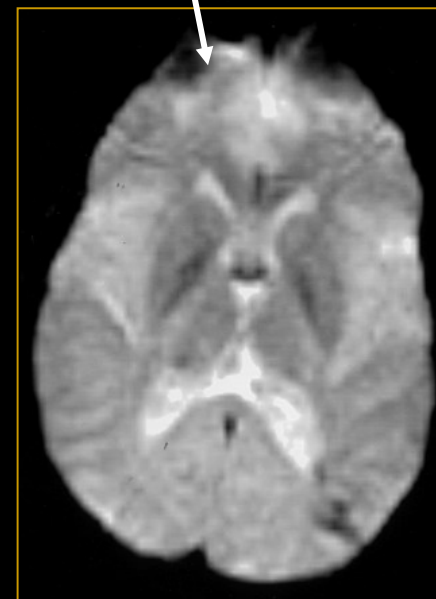


CBV ~ a görbe által bezárt terület

$$CBV = \int S dt / \int S_{AIF} dt$$

$$MTT = \int S dt / S_{max}$$

$$CBF = CBV / MTT$$

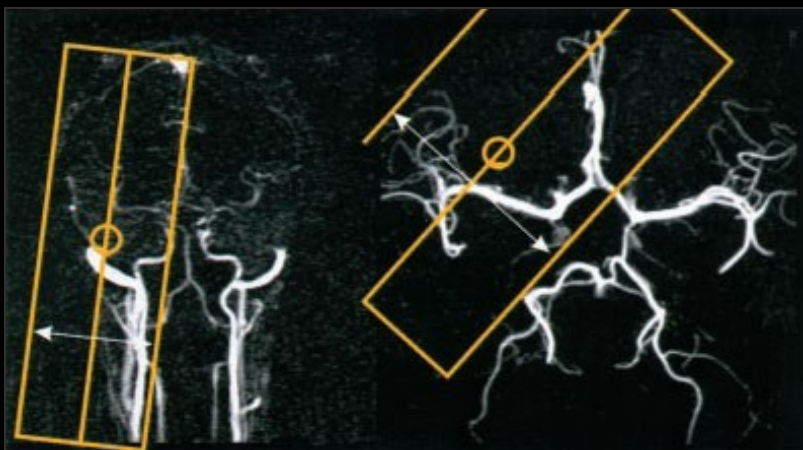


Spin jelöléses perfúziós MR

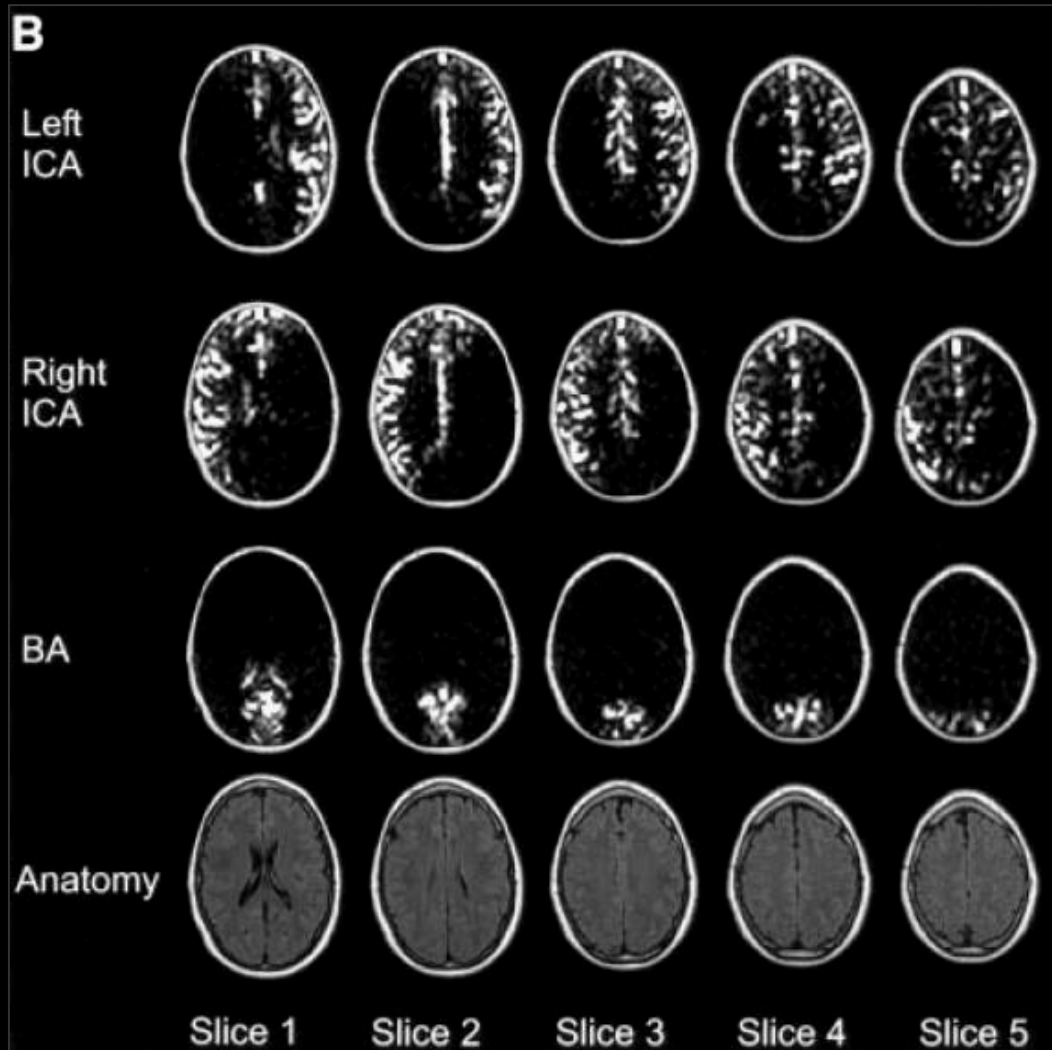
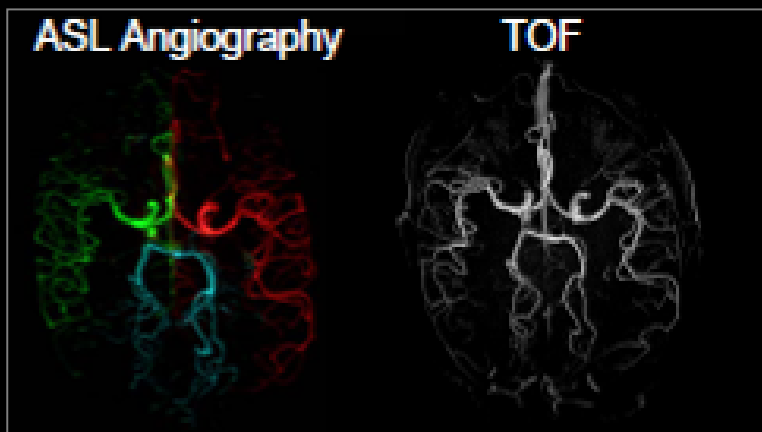
Arterial Spin Labeling (ASL)

→ CBF

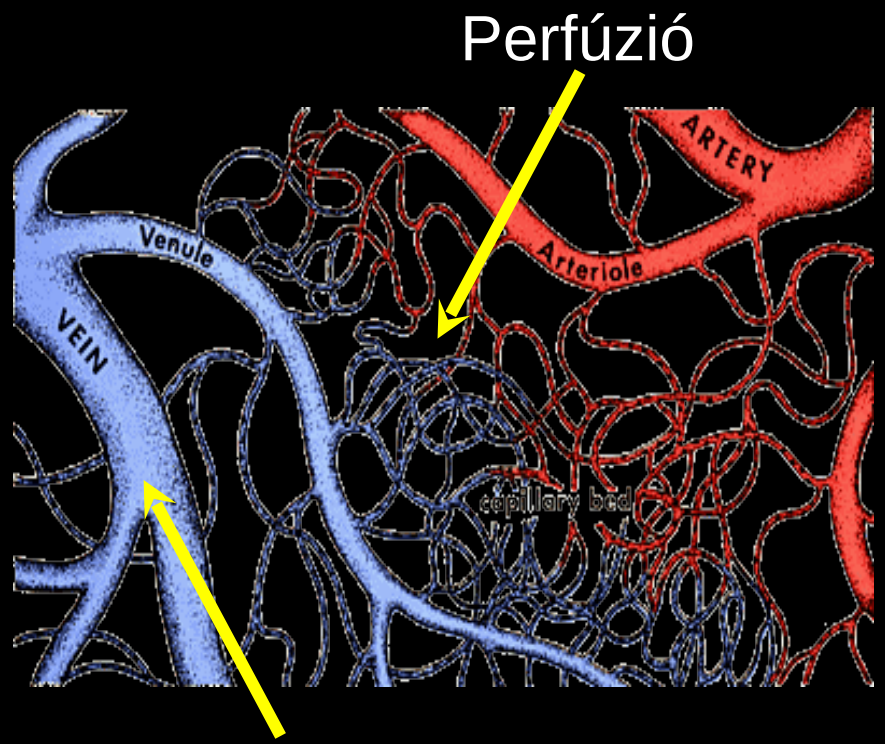
Hendrikse, 2004



Regional Perfusion Imaging (RPI)

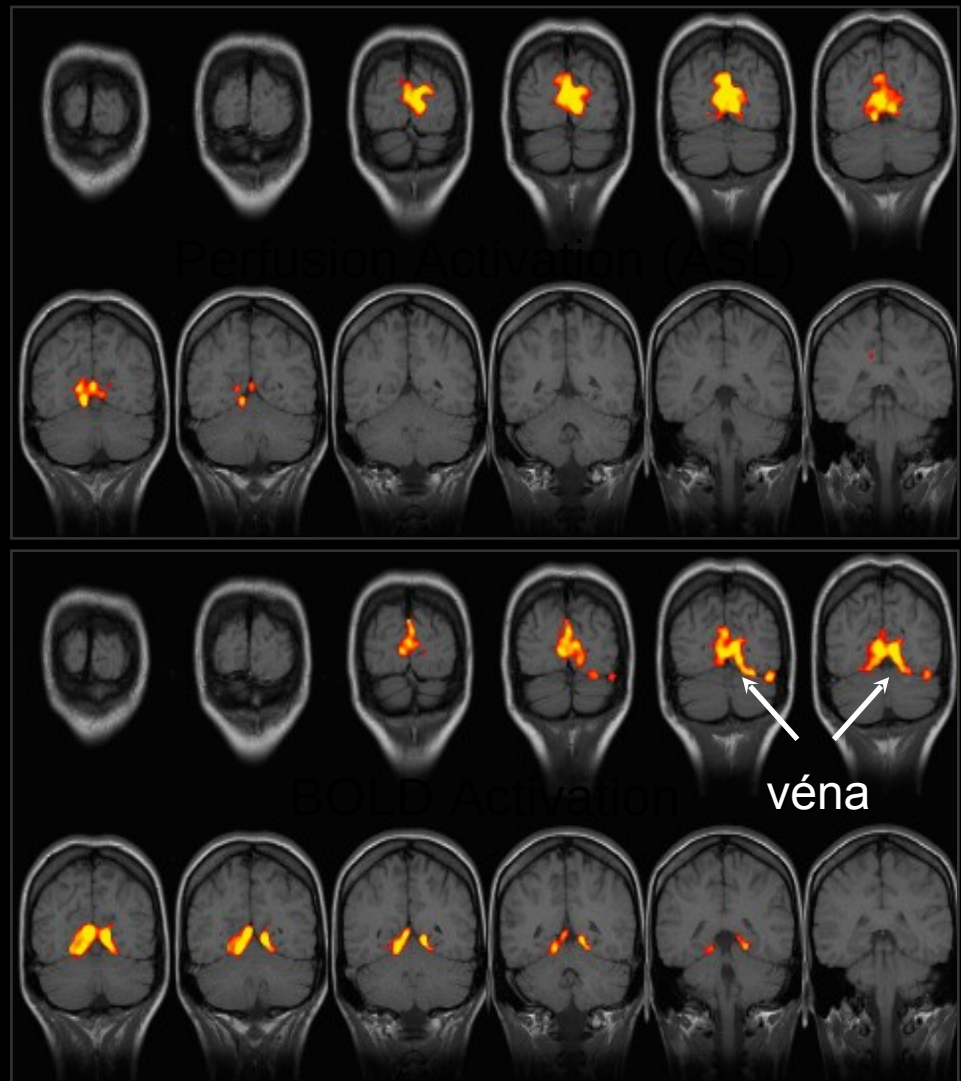


fMRI ASL technikával



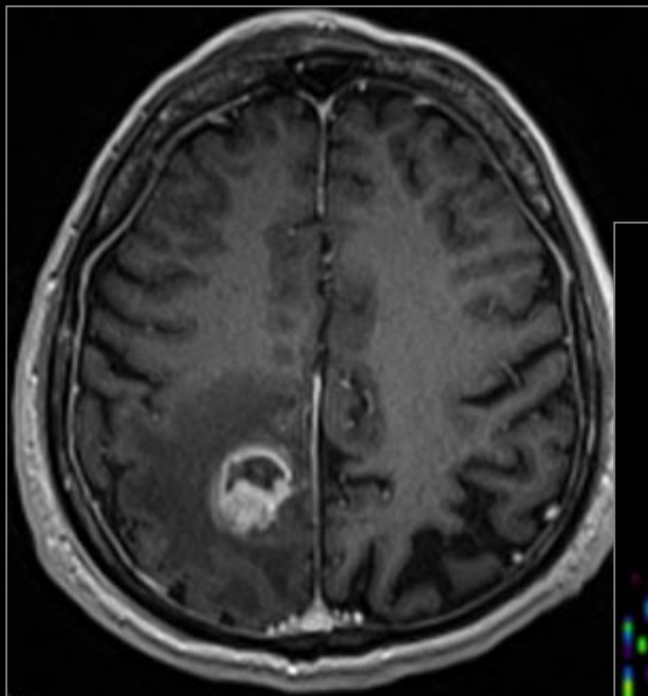
BOLD*

*1.5T / gradiens-echó EPI

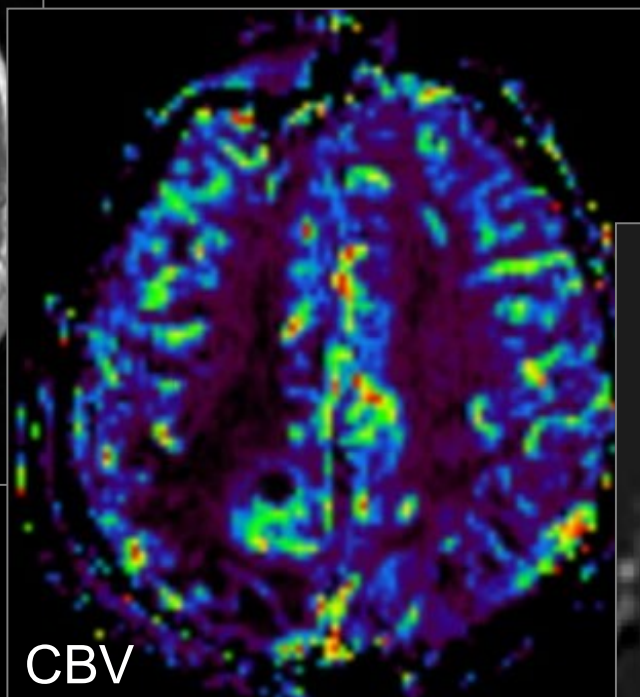


Perfúziós MR

Gd

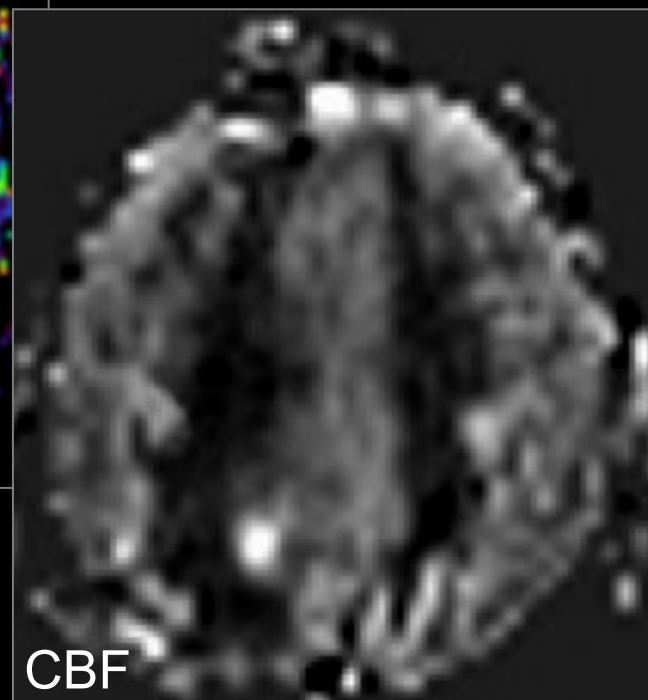


DSC



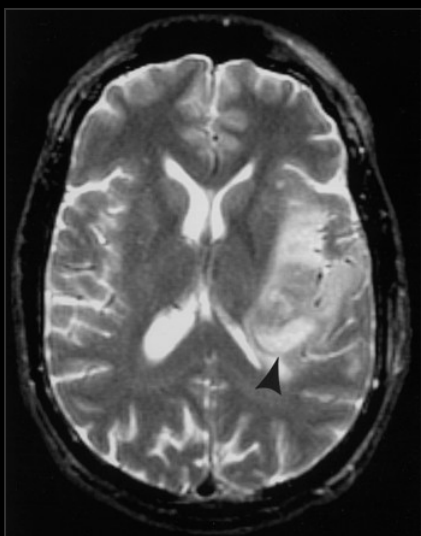
CBV

ASL

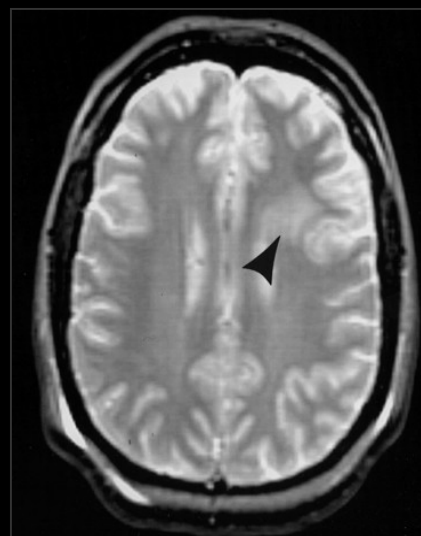


CBF

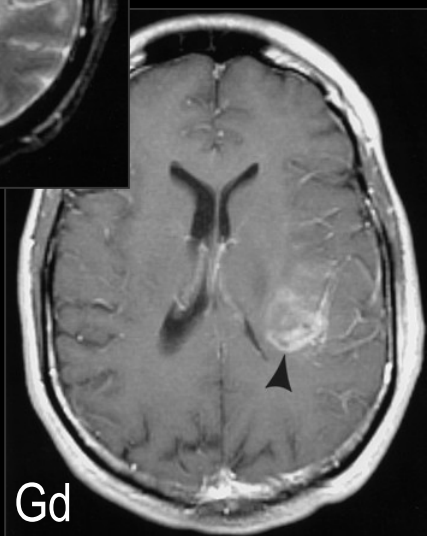
Perfúziós MR (DSC) tumorokban



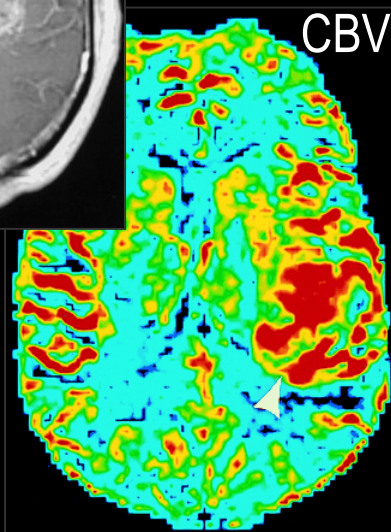
Malignus astrocytoma



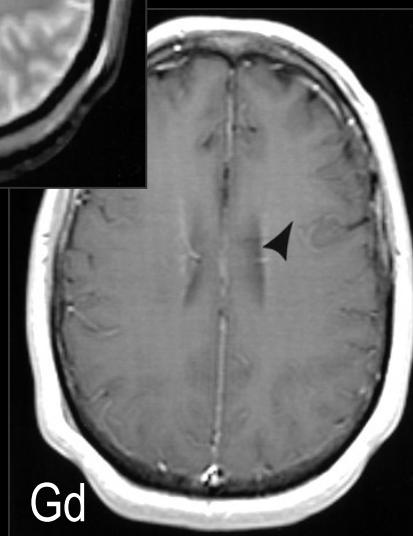
Nem halmozó glioma



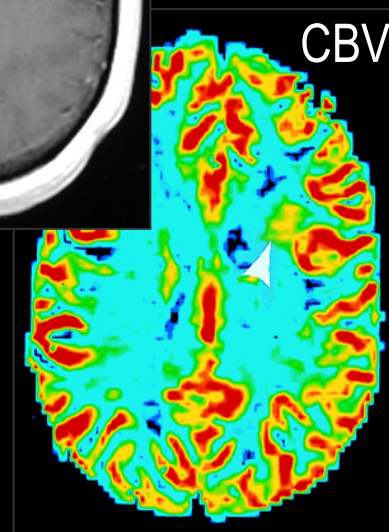
Gd



CBV



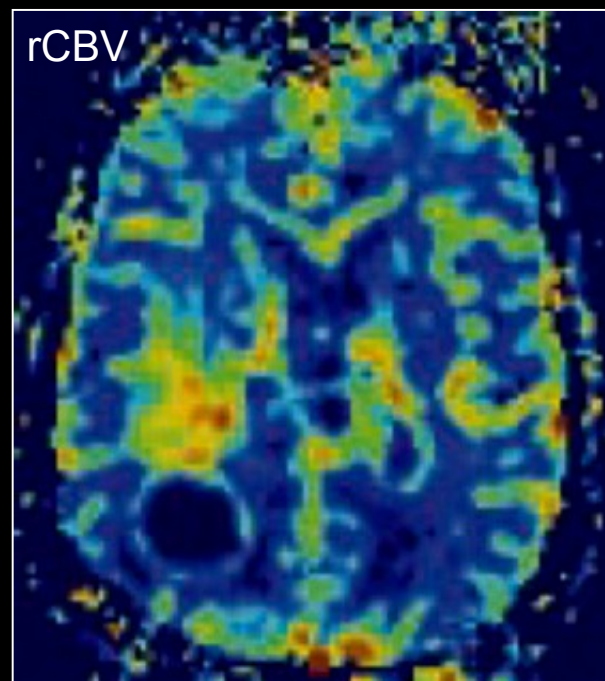
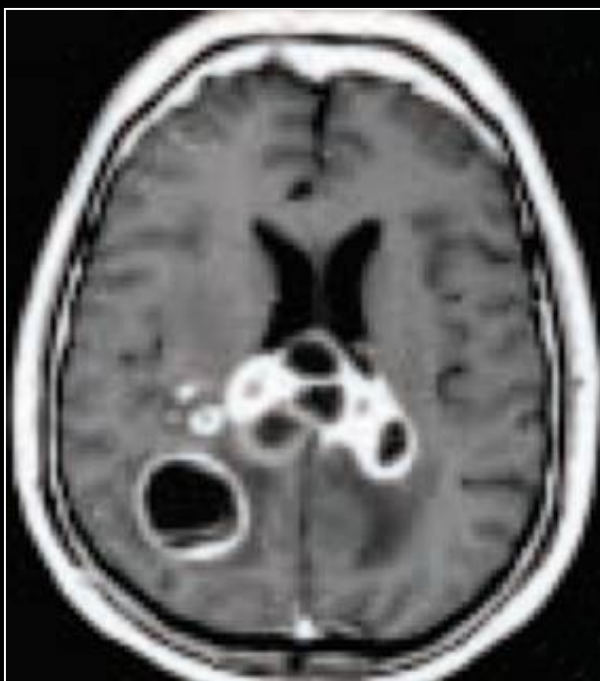
Gd



CBV

Perfúziós MR (DSC)

Glioblastoma multiforme



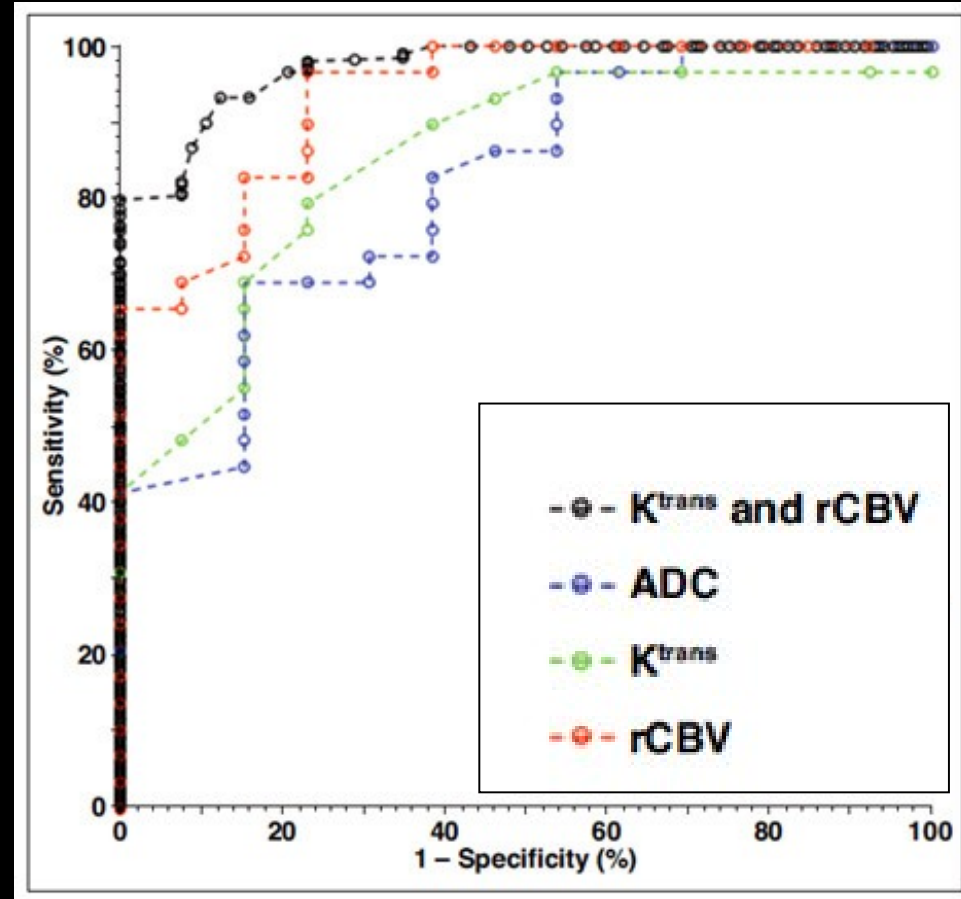
Multi-parametrikus MR

Diffúziós mérések

- ADC térkép: fordítottan arányos a cellularitással és általában a szövetek tömötséggel

Perfúziós mérések

- Dynamic Susceptibility Contrast (DSC):
Cerebral Blood Volume (CBV):
neoangiogenezis és a mikrovaszkuláris denzitás
- Dynamic Contrast-enhanced (DCE):
 K^{trans} : mikrovaszkuláris „szivárgás”



ROC analízis

K^{trans} : volume transfer constant

Multi-parametrikus MR

Necrosis

Recidiva

Gd

ADC

Gd

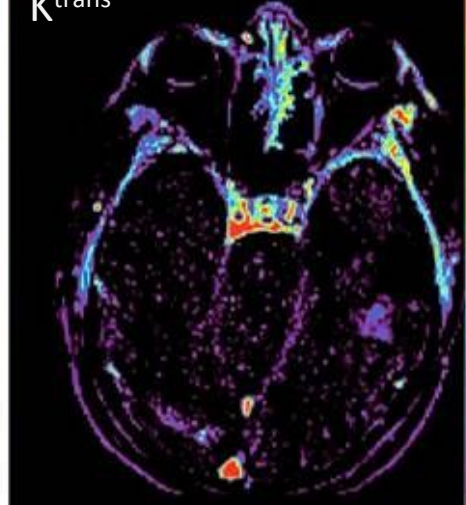
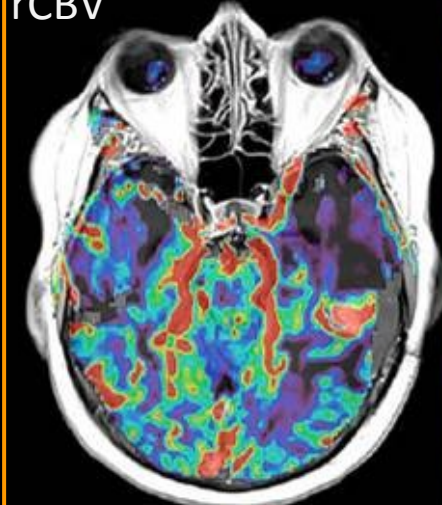
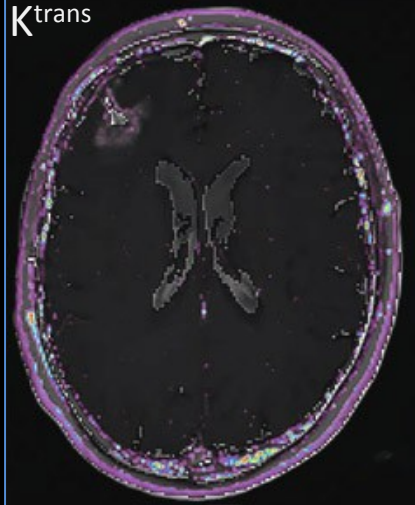
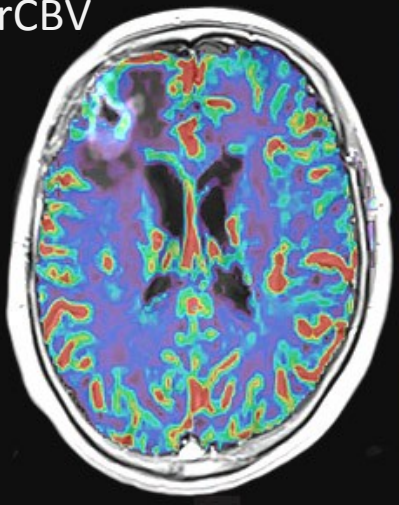
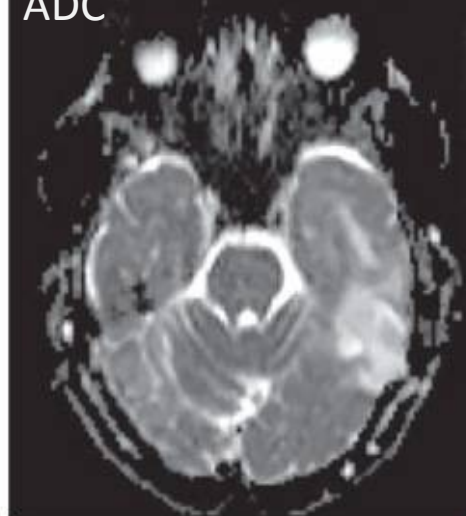
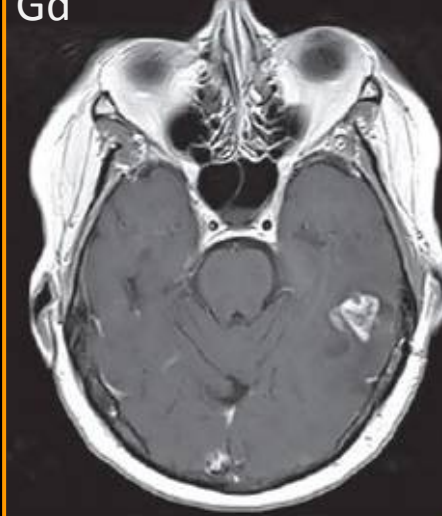
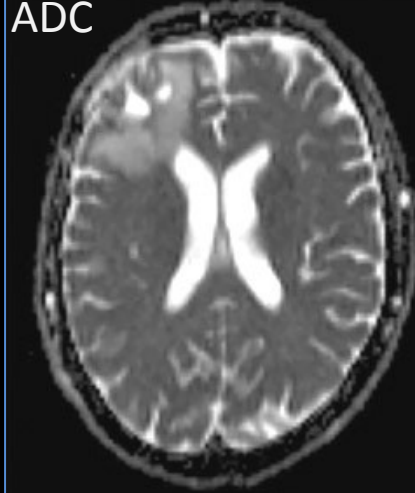
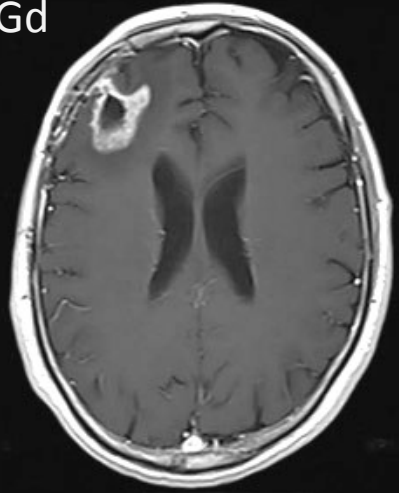
ADC

rCBV

K^{trans}

rCBV

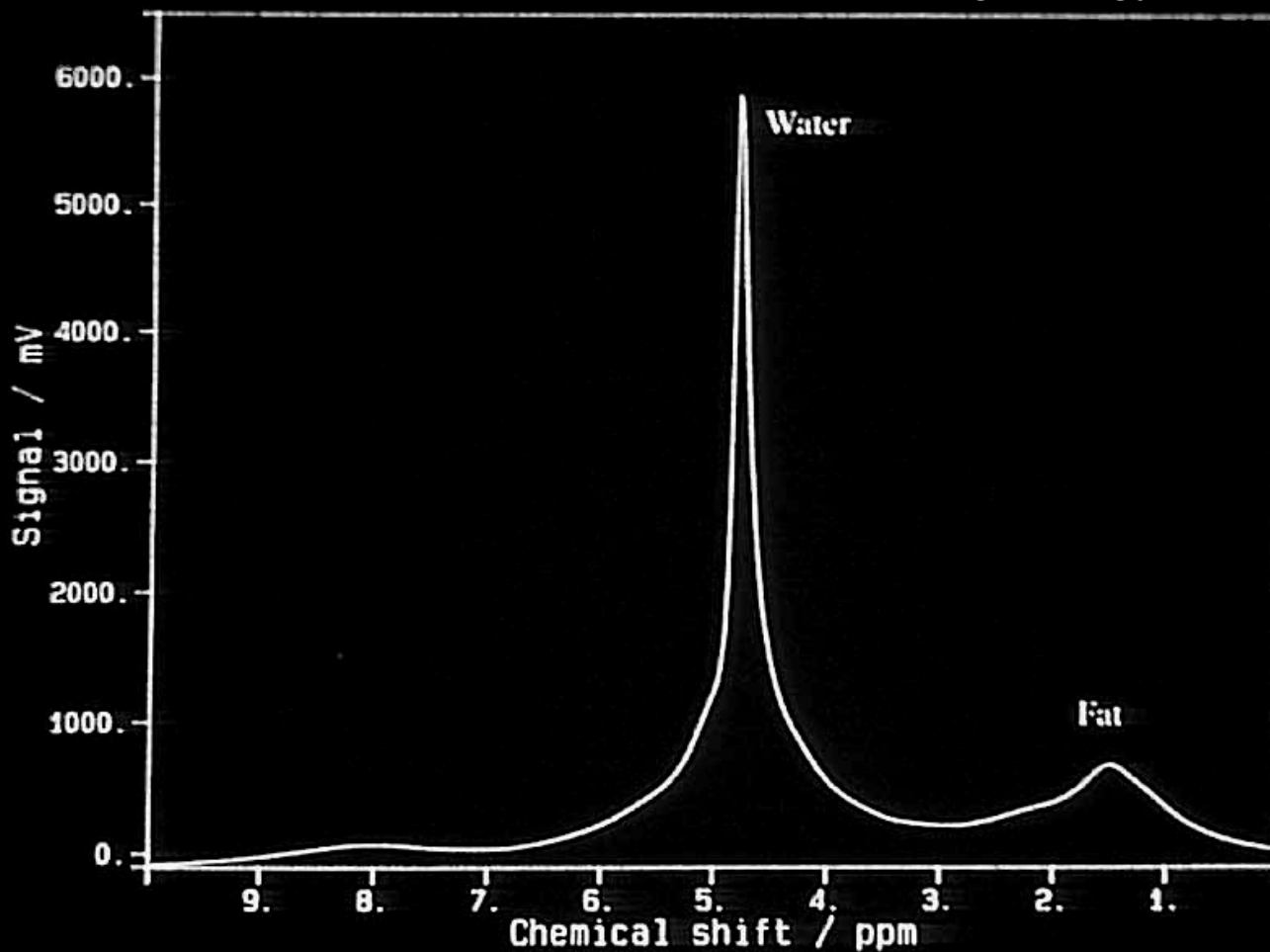
K^{trans}



MR spektroszkópia

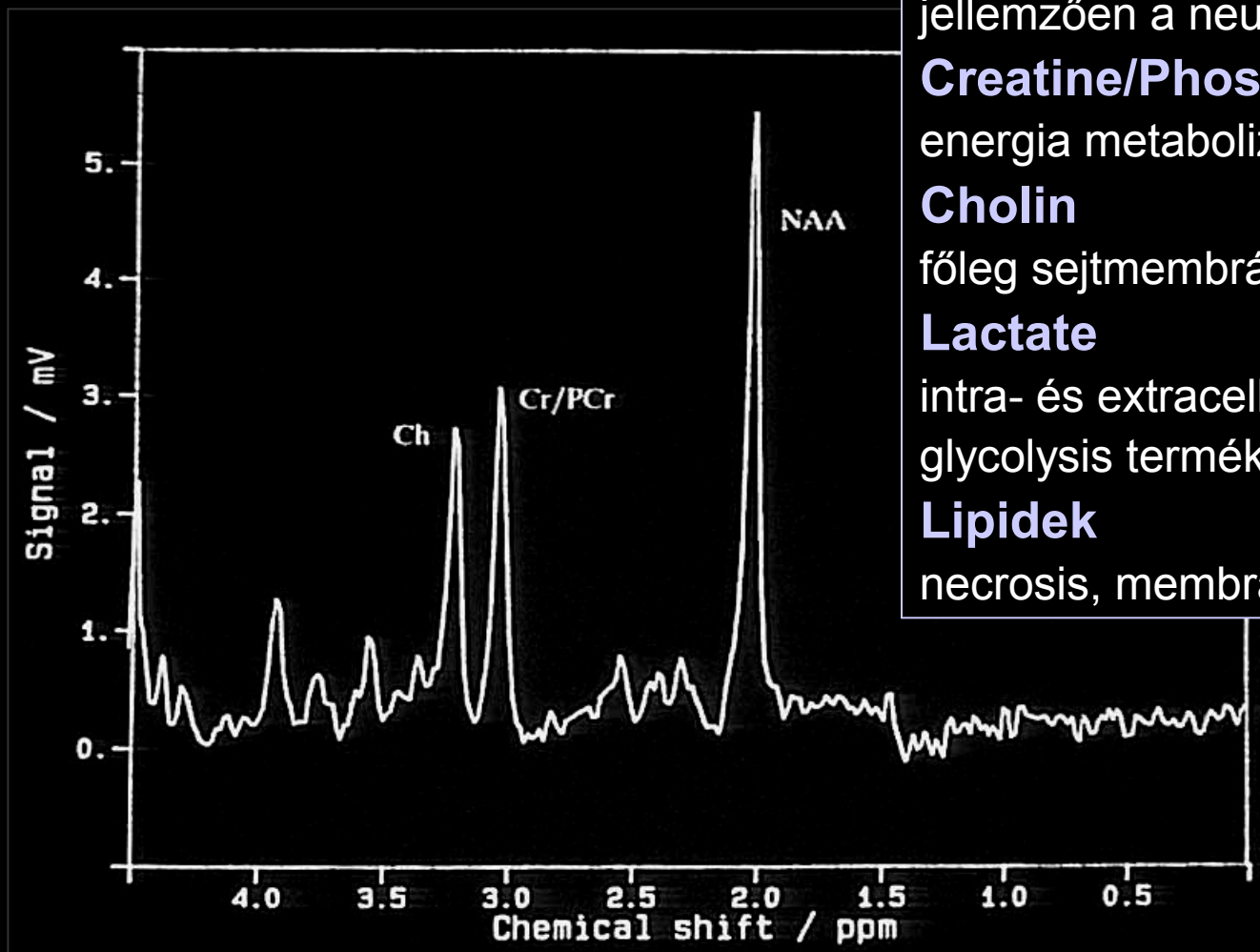


Lokalizálatlan proton spektrum az egész agyról



A normális fehérállomány MR spektruma

Hosszú TE (144 ms)



N-acetyl-asparatate

jellemzően a neuronokban

Creatine/Phospho-Cr.

energia metabolizmus

Cholin

főleg sejtmembránjában - myelin

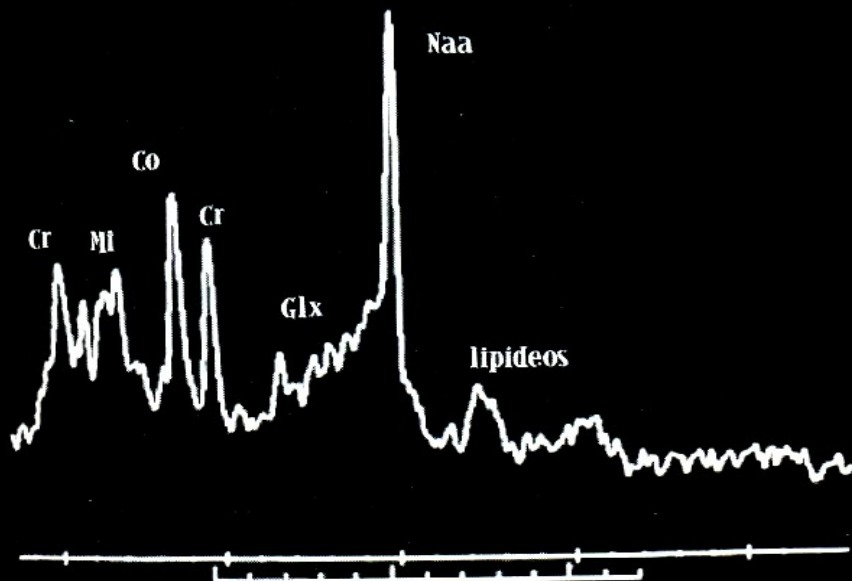
Lactate

intra- és extracelluláris, az anaerob glycolysis terméke

Lipidek

necrosis, membrán és myelin lebomlás

Metabolitok rövid TE (30 ms) mellett



Glx:

Glutamine

Astrocyta marker

Glutamate

Neurotoxin magas koncentrációban

ml:

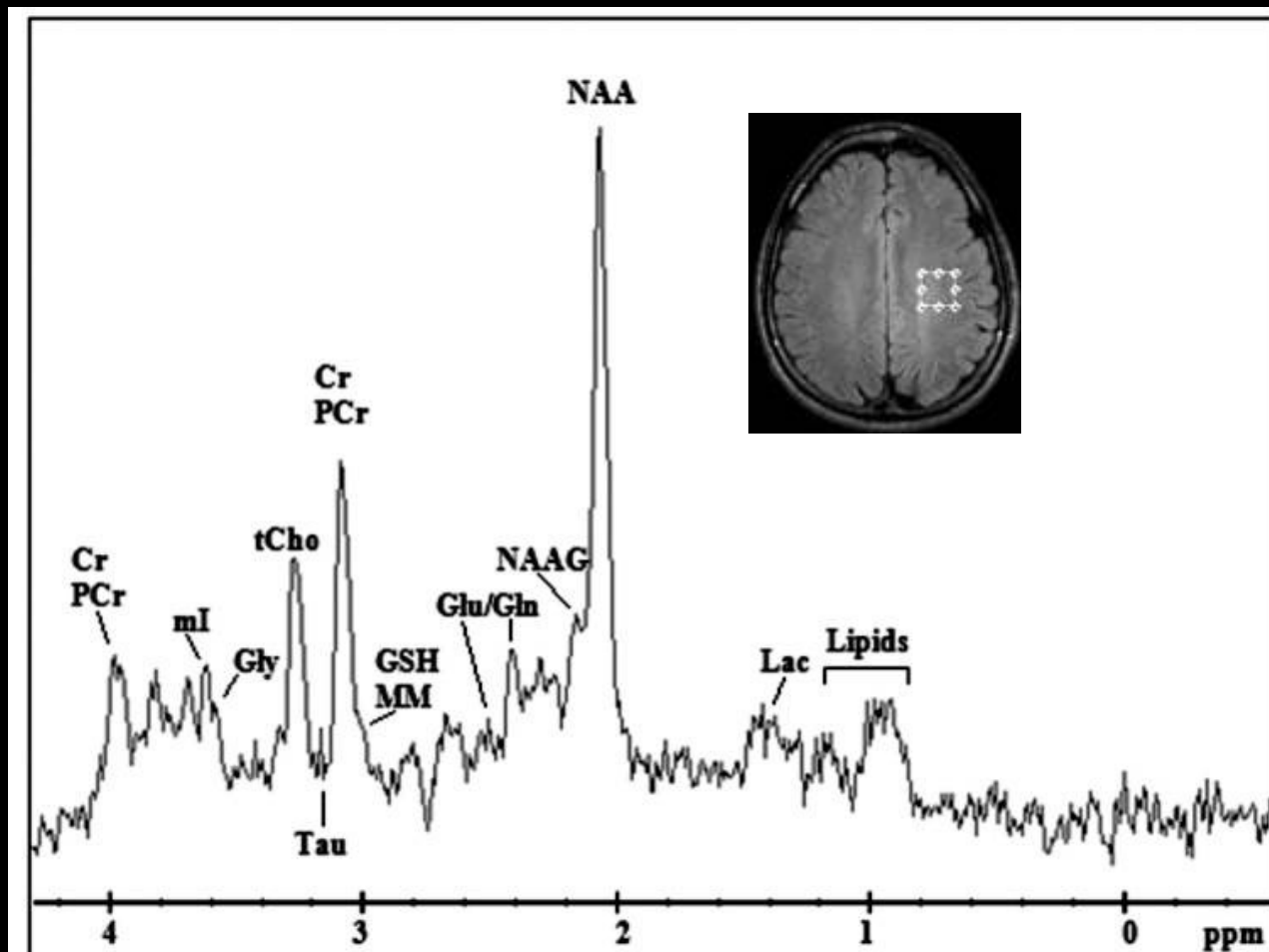
Myo-inositol

glia marker az astrocytákban

myelin lebomlás terméke

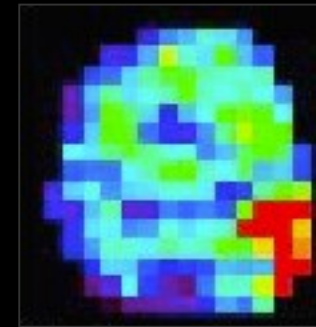
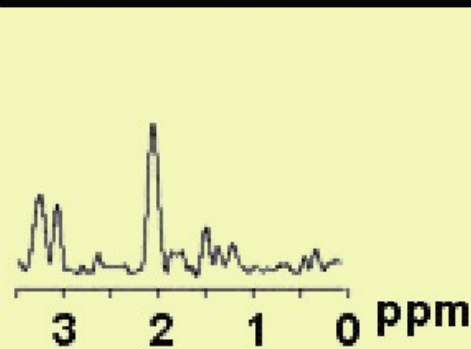
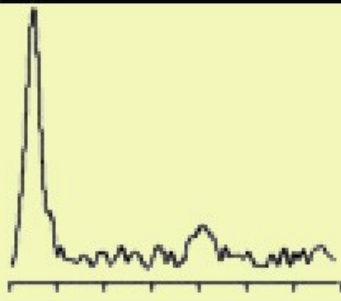
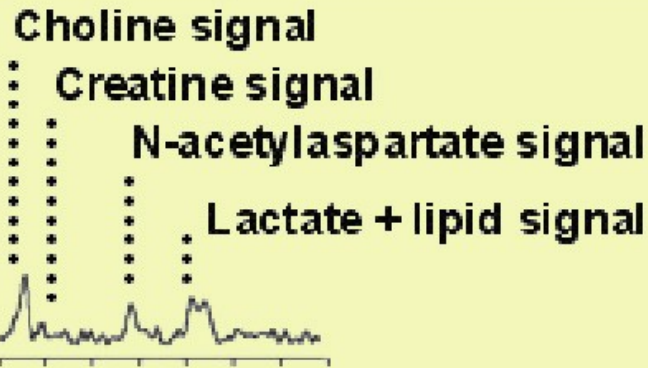
MR spektroszkópia

3,0 T

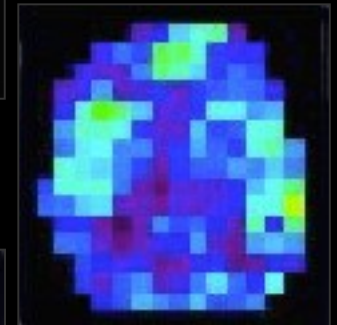


Malignus glioma MR spektroszkópiás képe (CSI)

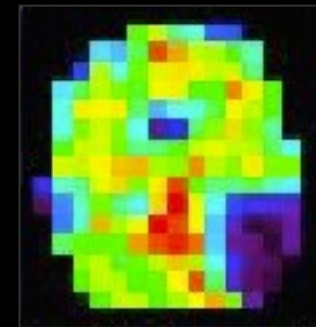
Chemical shift imaging



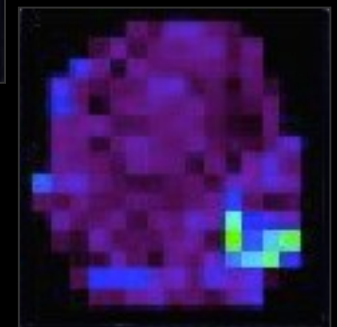
Choline



Creatine



NAA



Lactat

Gerinc MR indikációi



- Musculoskeletalis:
 - Csontvelő
 - Fibroligamentalis
- Neurologiai:
 - Gerincvelő
 - Ideggyökök



Gerincoszlop
Gerinccsatorna

Protokoll



Minimális szükséges vizsgálat

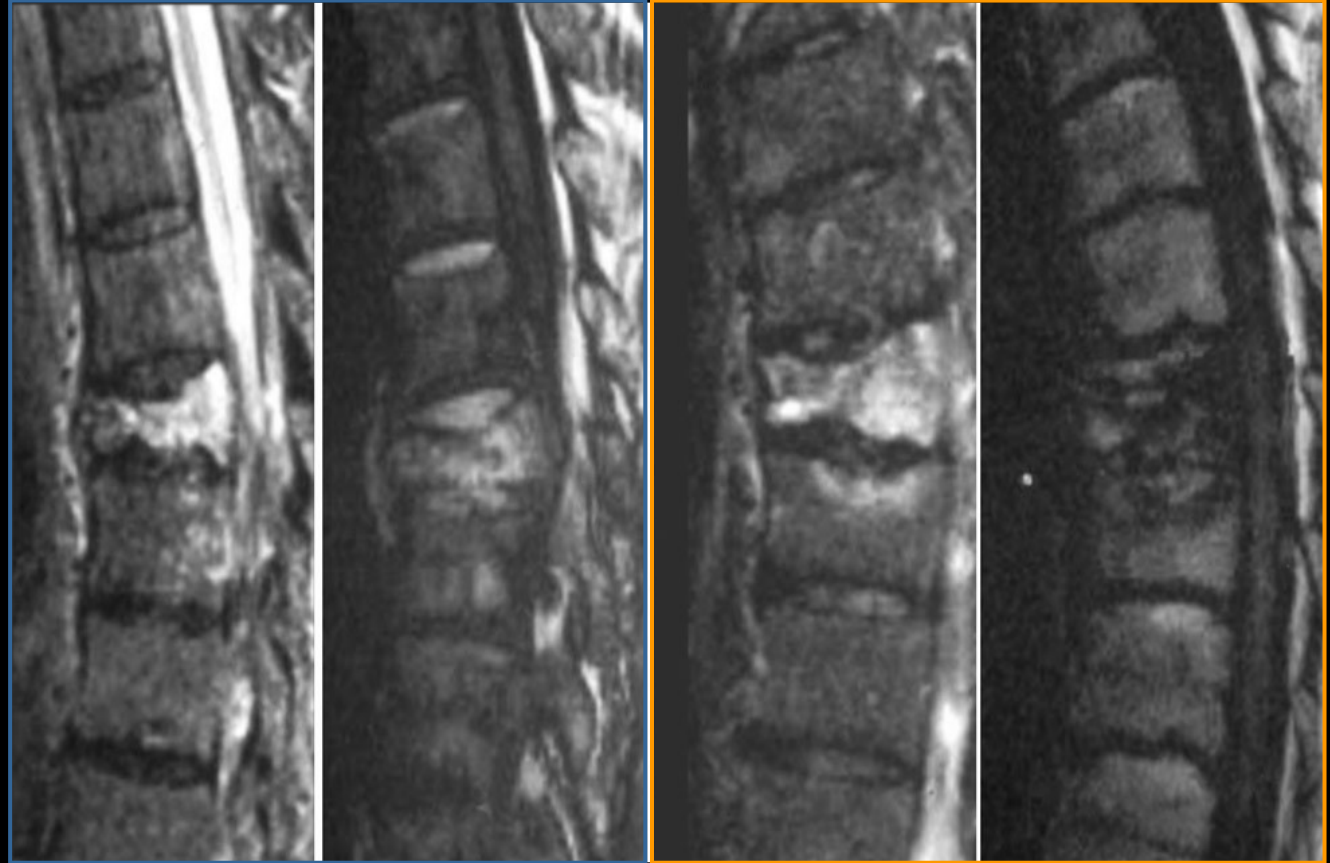
Malignus / benignus kompresszió



GRE alapú DWI

Malignant

Osetoporotic



T2-w

DWI

T2-w

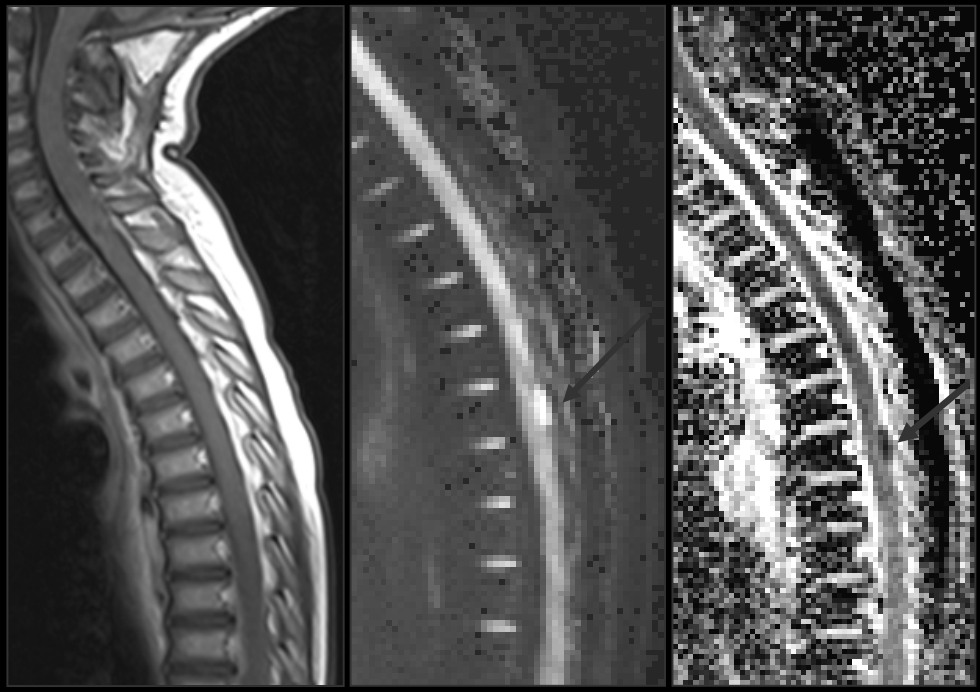
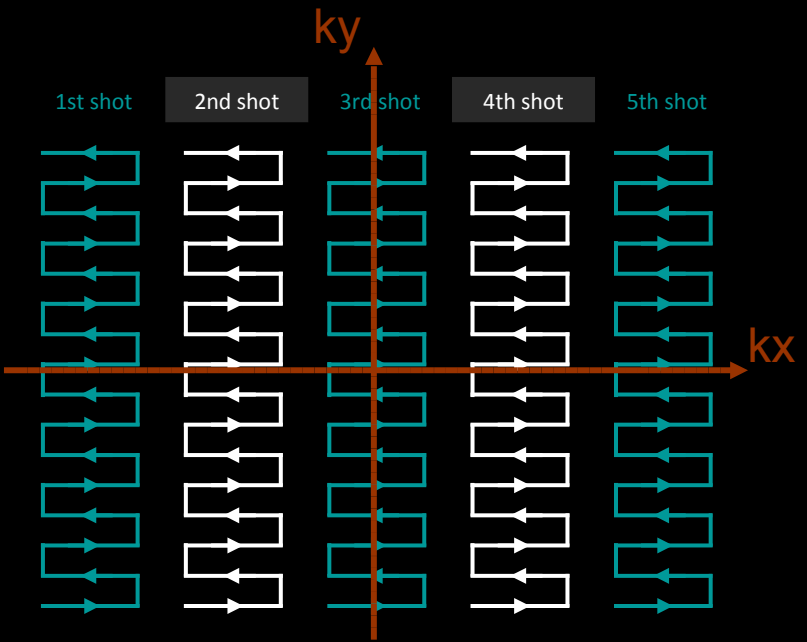
DWI

De:

- 2 hétnél régebbi benignus kompresszió esetén DWI fals pozitív lesz (↑) - fibrosis
- Kezelt malignus törésnél a necrosis miatt DWI fals negatív lesz (↓)

RESOLVE

(REadout Segmentation Of Long Variable Echo trains)



T1-w, Gd

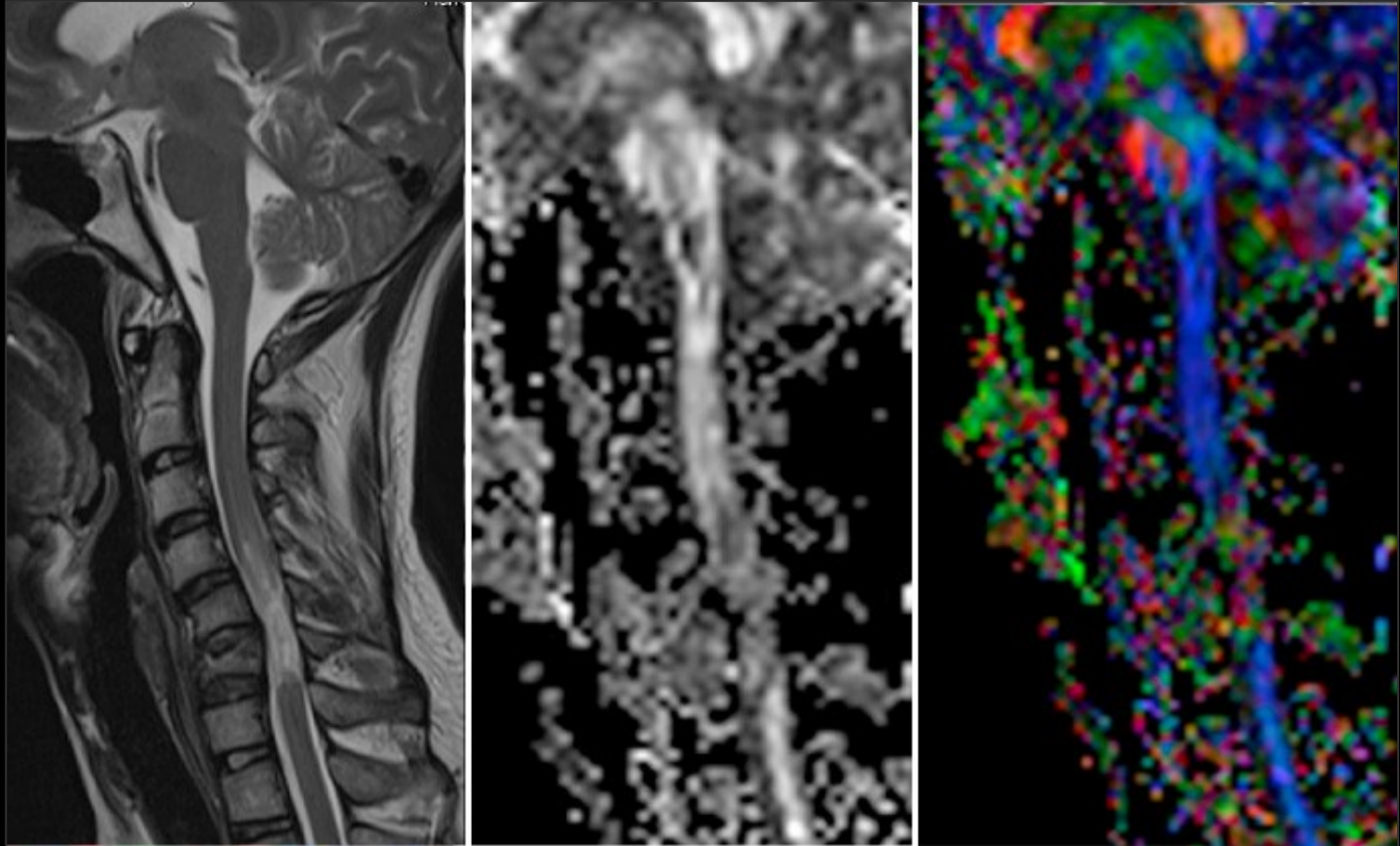
DWI (b500)

ADC

Teratoid rhabdoid tumor metastasis

Diffusion tensor imaging

SSEPI



T2-w

ADC

Tensor

Turbo spin-echo alapú 3D szekvenciák

- 3D izotropikus felbontás $<1\text{mm}$
- Hosszú echo-train (100-250 echo)
- Rövid echo spacing (3-4 msec)
- Kis flip angles ($30^\circ - 120^\circ$)
- Non-selective RF pulzus
- T1-, T2-, Proton, FLAIR képek
- Kevesebb áramlási műtermék
- Hosszú scan idő (3D!)

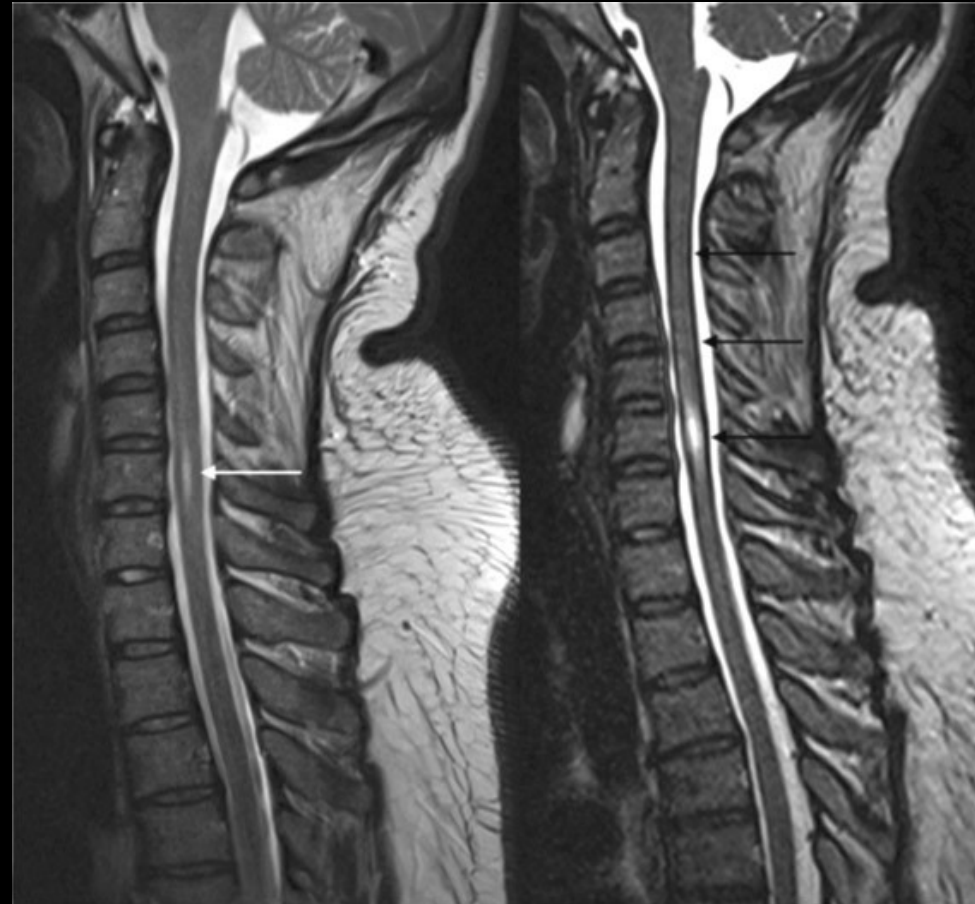
CUBE – GE

VISTA – Philips

isoFSE – Hitachi

3D MVOX – Canon

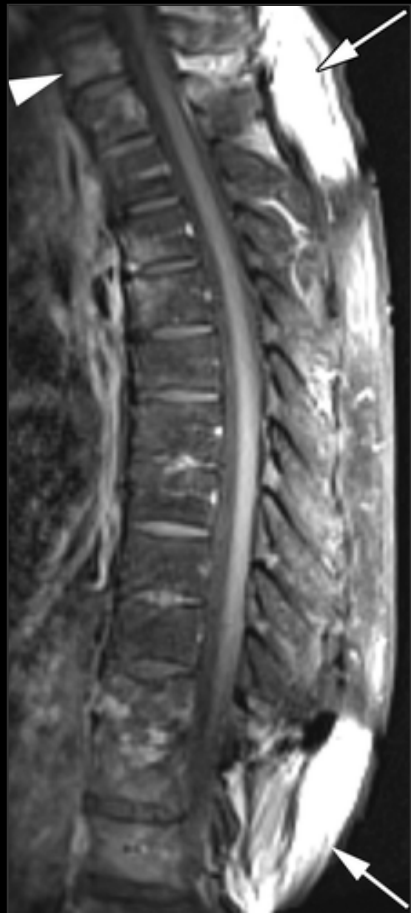
SPACE - Siemens



SPACE - Sampling Perfection with Application optimized Contrasts using different flip angle Evolution (3D T2-súlyozott)

Zsírelnyomás

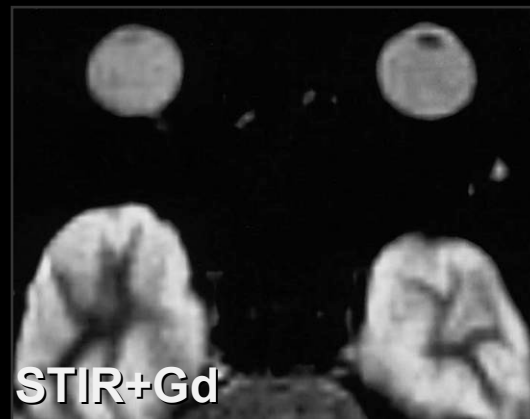
- T1-relaxációs módszer (STIR)
- Kémiai eltolódás módszere:
 - frekvencia módszer (fat saturation, water excitation)
 - fázis módszer (Dixon: 2P, 3P, 6P)
- Hibrid módszer (SPIR, SPAIR)



FATSAT+Gd



STIR



STIR+Gd



STIR

Dixon módszer

IDEAL (GE)
mDixon (Philips)
FatSep (Hitachi)
WFOP (Canon)
DIXON (Siemens)



In-phase



Opposed-phase



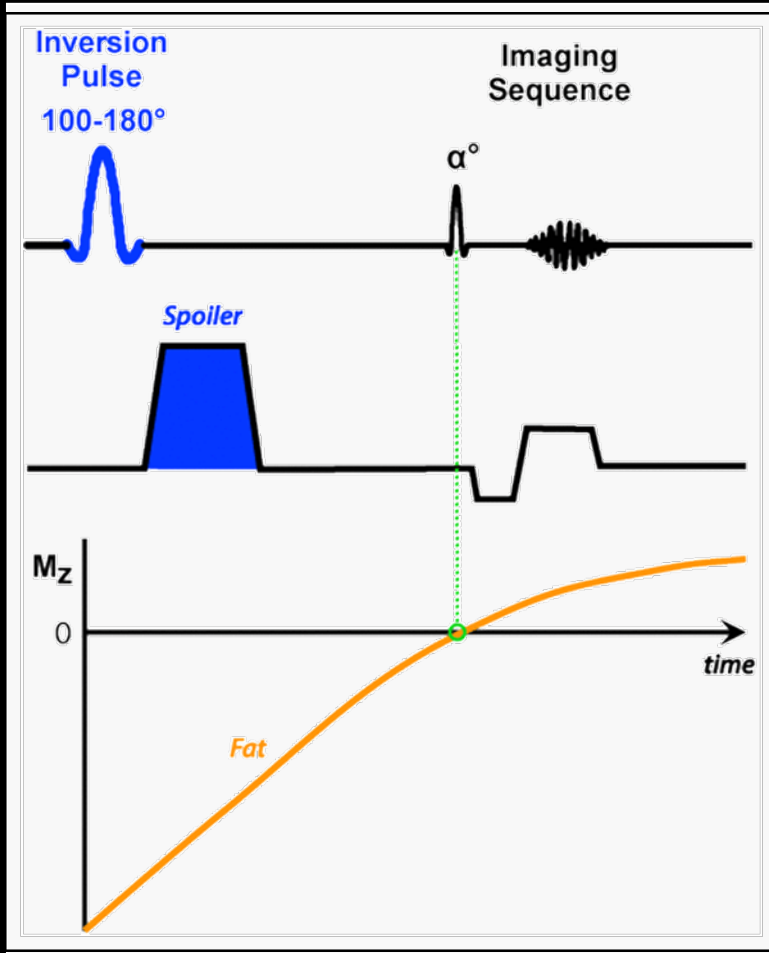
Water only image



Fat only image

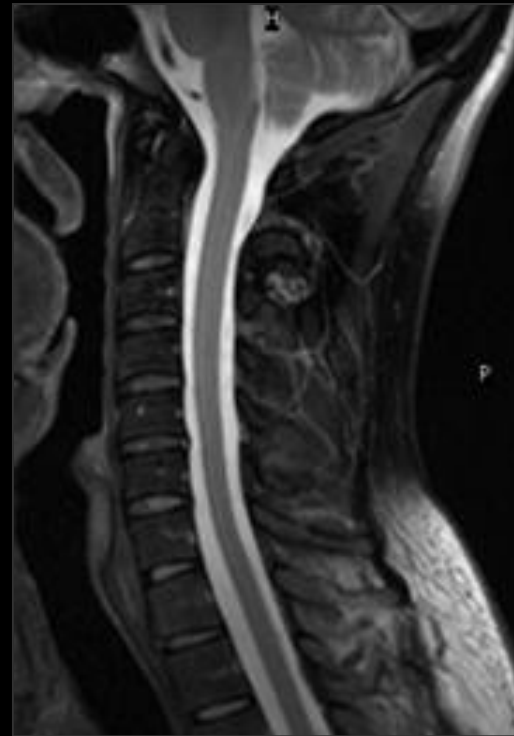
Hybrid módszer

(SPECTral Attenuated Inversion Recovery)

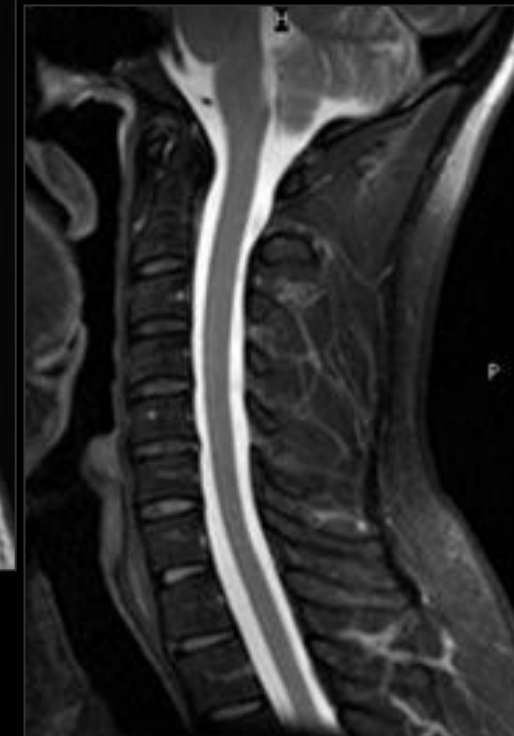


SPIR

(SPECTral Selective Inversion Recovery)



SPIR



SPAIR
(GE: ASPIR)

Szuszeptibilitás műtermék redukció



T2-FSE



syngo WARP

Non-ferromagnetic metals

Siemens brochure

