腦部磁振造影之臨床研究應用

APPLICATIONS OF BRAIN MAGNETIC RESONANCE IMAGING

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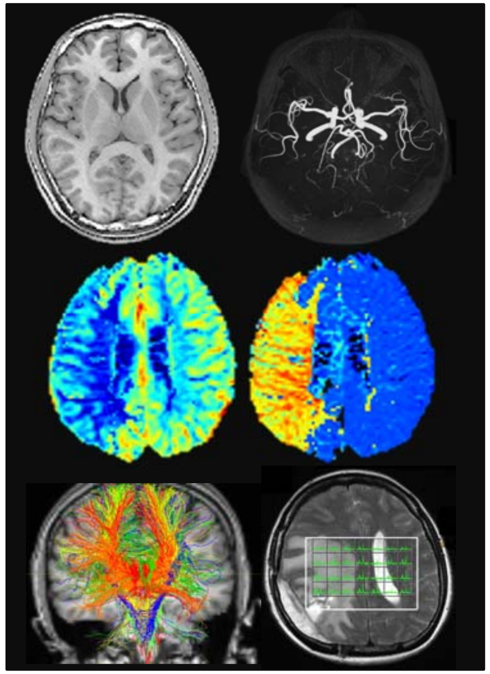
alvin4016@ym.edu.tw
http://www.ym.edu.tw/~cflu

http://www.ym.edu.tw/~cflu/MRIapp_CF.pdf

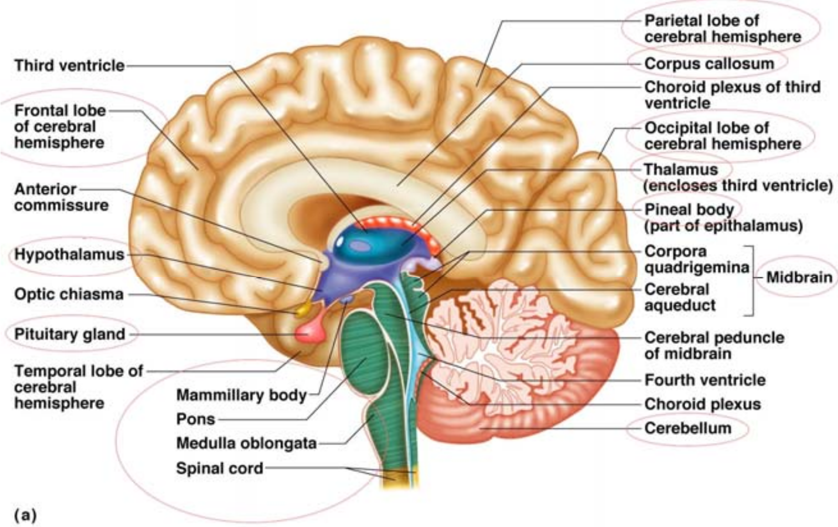
Brain MRI

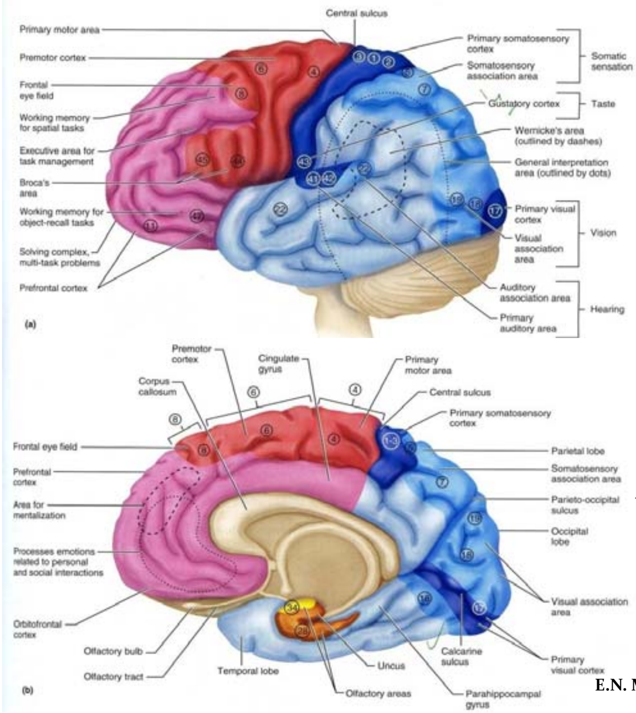
- **Brain anatomy**
  - Cortical regions
  - Vessel structures & circulation
  - Neuronal fiber network
- **Structural MRIs**
  - Structural T1, T2
  - Angiography
  - Tractography
- **Functional MRIs**
  - Brain Perfusion
  - BOLD fMRI
  - Metabolism (MR spectroscopy)



Basics Of Brain & MRI

Brain Anatomy





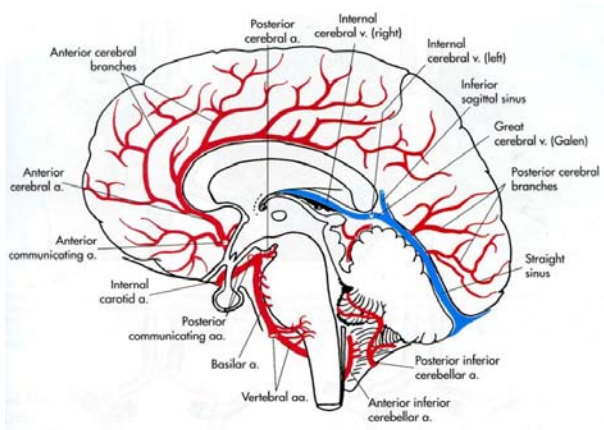
Motor Areas
- Primary motor cortex
- Premotor cortex
- Frontal eye field
- Broca's area

Sensory Areas
- Primary somatosensory cortex
- Somtosensory association area
- Visual areas
- Auditory areas
- Gustatory (taste) cortex
- Olfactory (smell) cortex
- Vestibular cortex

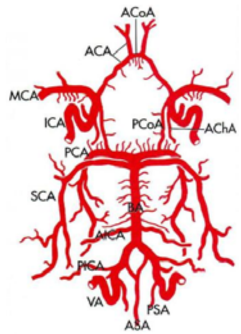
Association Areas
- Prefrontal cortex
- General interpretation area
- Language area
- Insula

E.N. Marieb. Human anatomy, 3rd (2001)

Brain Circulation – arterial system

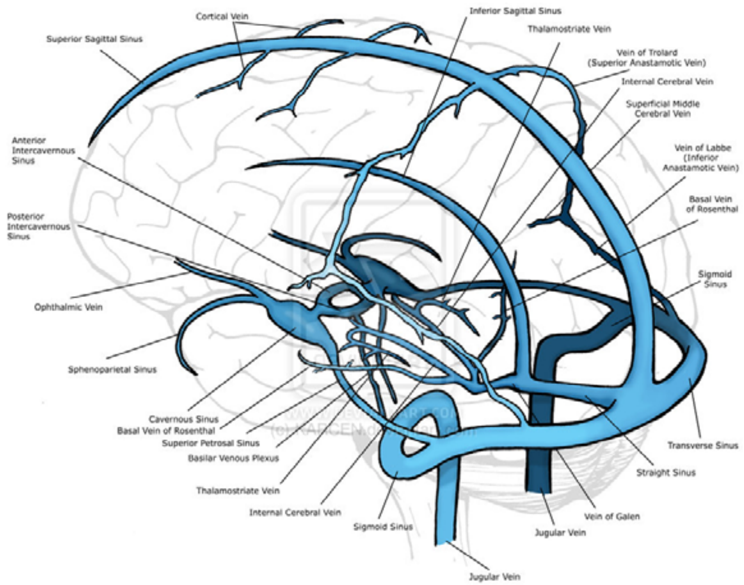


Circle of Willis

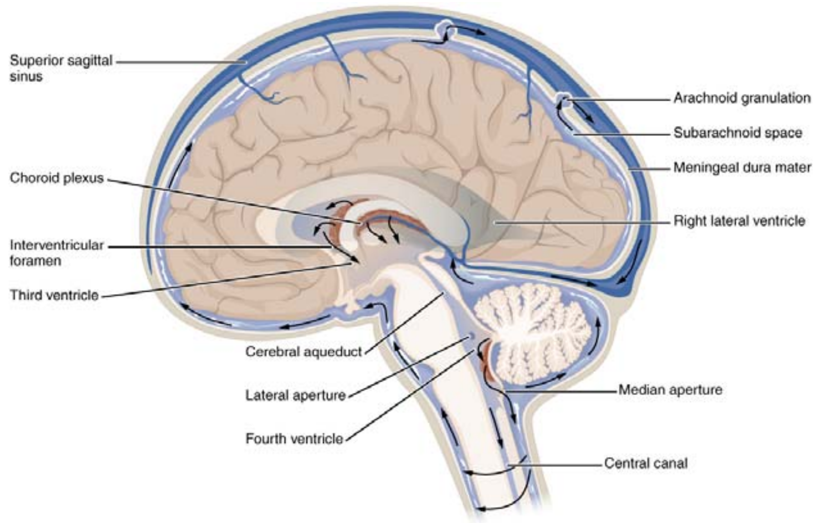


J. Nolte. The human brain- an introduction to its functional anatomy, 5th (2002)

Brain Circulation – venous system

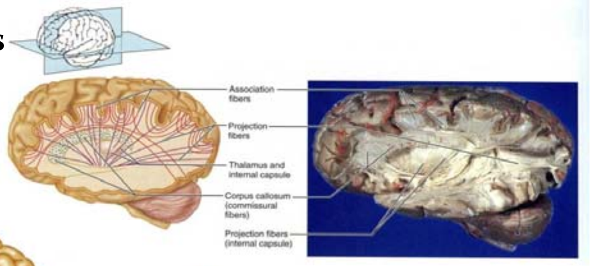
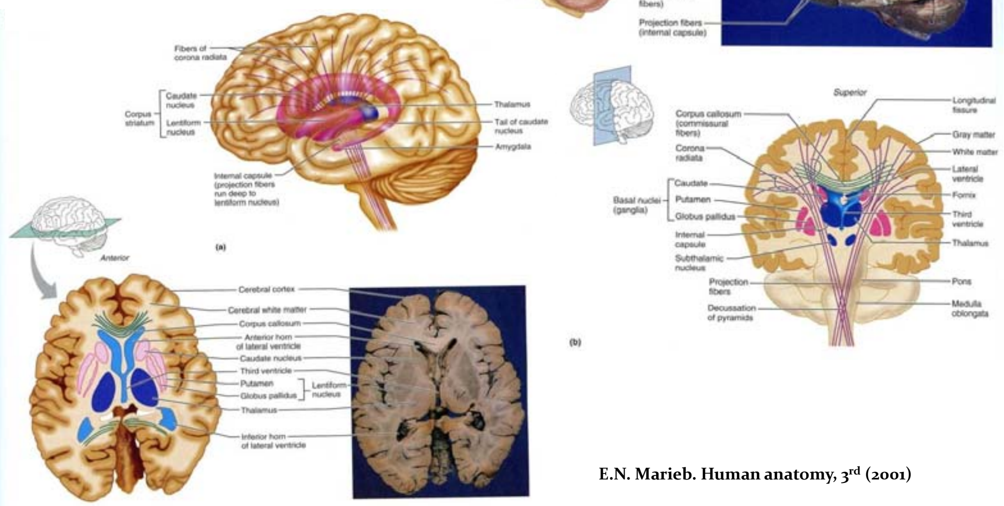


Brain Circulation – CSF system



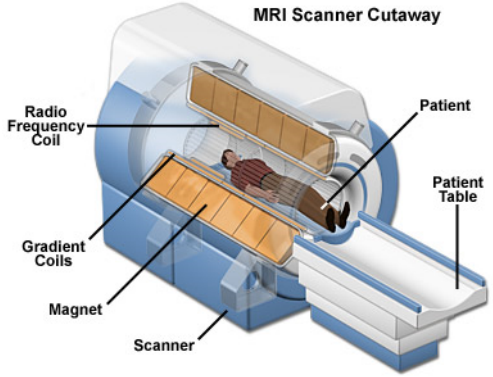
Neuronal Fiber types

- Commissures
- Association fibers
- Projection fibers

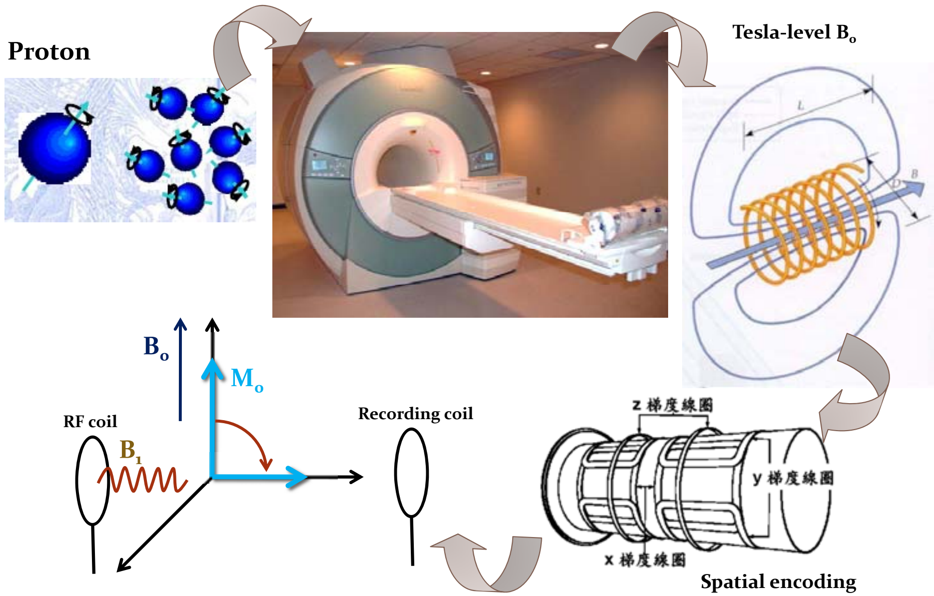
E.N. Marieb. Human anatomy, 3rd (2001)

MRI Scanner

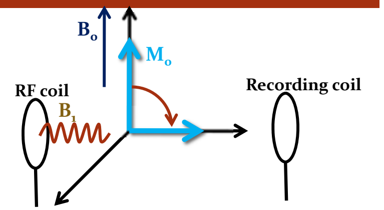


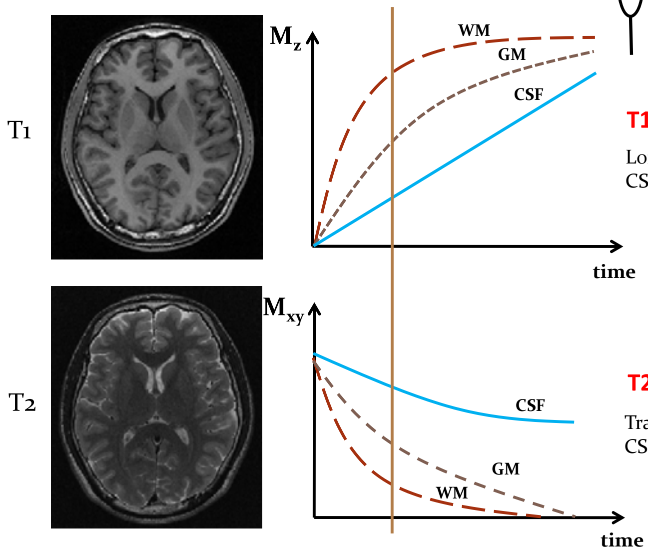
http://www.biomedresearches.com/root/pages/researches/epilepsy/mri.html

Basic idea of MR imaging



Relaxation time





T1 recovery time

Longitudinal relaxation time
CSF >GM >WM

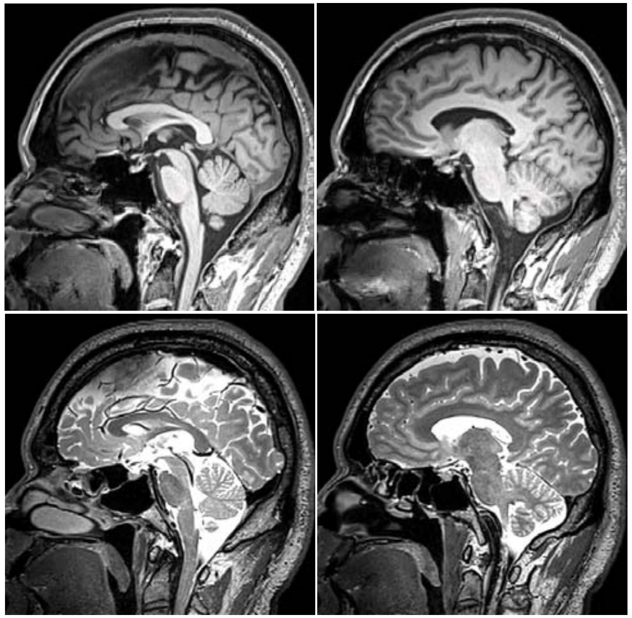
T2 decay time

Transverse relaxation time
CSF >GM >WM

T1 & T2 Weighted Images

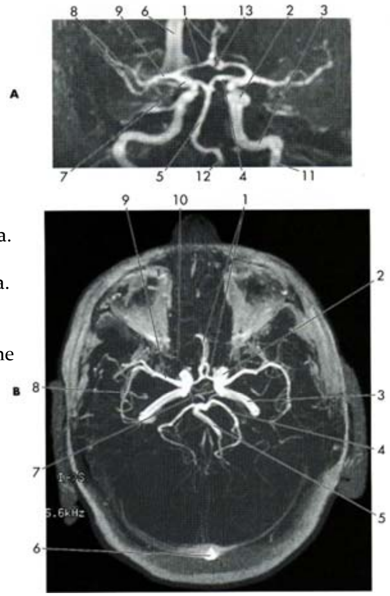
T1W

T2W

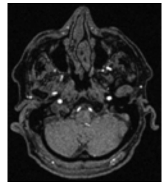


MR Angiography – Time of Flight (TOF)

11. Internal carotid a. (ICA)
  2. Cavernous sinus part
  3. Temporal bone part
1. Anterior cerebral a. (ACA)
4. Posterior cerebral a. (PCA)
13. Anterior communicating a. (ACoA)
7. Posterior communicating a. (PCoA)
9. Middle cerebral a. (MCA)
8. Branch on the surface of the insula
12. Vertebral a. (VA)
5. Basilar a. (BA)
6. Superior sagittal sinus
10. ophthalmic a.



Inflow-related Signal enhancement



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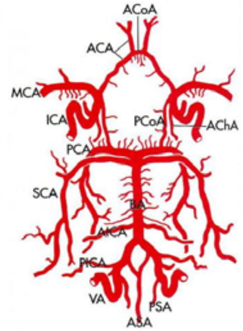
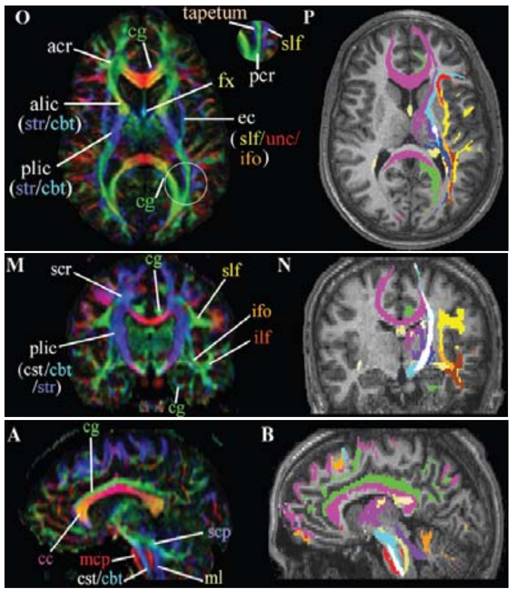


MRIcro – real data (TOF)

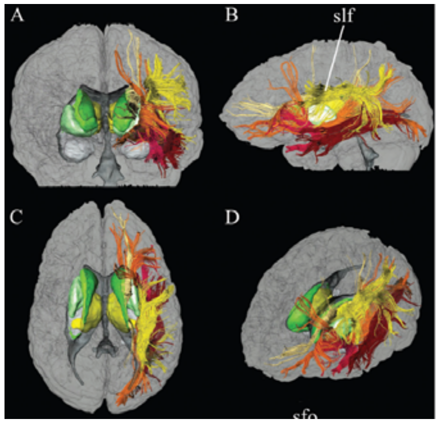
J. Nolte. The human brain- an introduction to its functional anatomy, 5th (2002)

Atlas of the white matter

1st eigenvector color-coded map



Diffusion Tensor Tractography



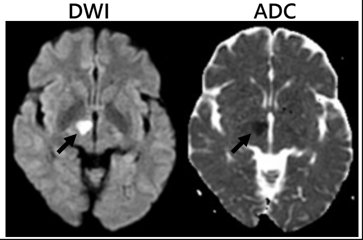
S. Mori. Fiber tract-based atlas of human white matter anatomy. Radiology (2003)

Diffusion Weighted Imaging (DWI) of stroke

- **Acute** (0~7 days)
  - ADC↓(hypo-intensity), maximal signal reduction at 1~4 days
  - DWI↑(hyper-intensity)
  - Ischemia→ cytotoxia edema(intact BBB)→ restricted extracelluar space
- **Subacute** (1~3 weeks)
  - ADC return to near baseline (~2 weeks)
  - DWI↑(hyper-intensity), due to high T2 signal caused by vasogenic edema (disrupted BBB)
  - Irreversible tissue necrosis
- **Chronic** (>3 weeks)
  - ADC↑(hyper-intensity), DWI↓(hypo-intensity)

Acute infarction

DWI ADC



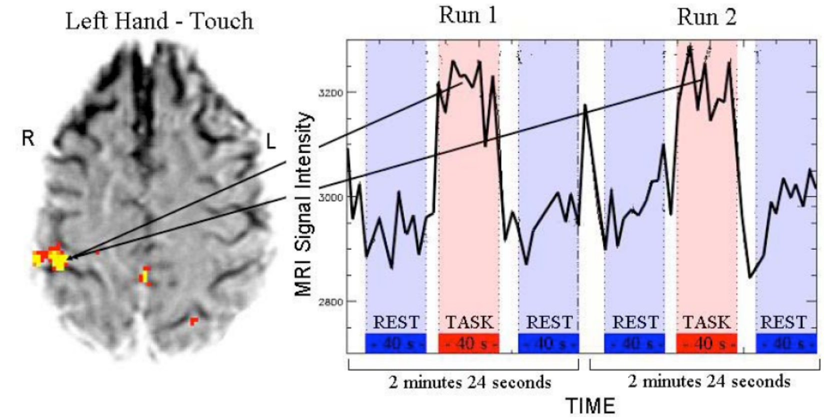
Acute stroke
Sensitivity: 88~100%
Specificity: 86-100%

- http://radiopaedia.org/articles/diffusion-weighted-mri-in-acute-stroke-1
- http://www2.cmu.edu.tw/~cmcmd/ctanatomy/clinical/ischemicinfarction.html

Functional MRI (fMRI) - time series imaging

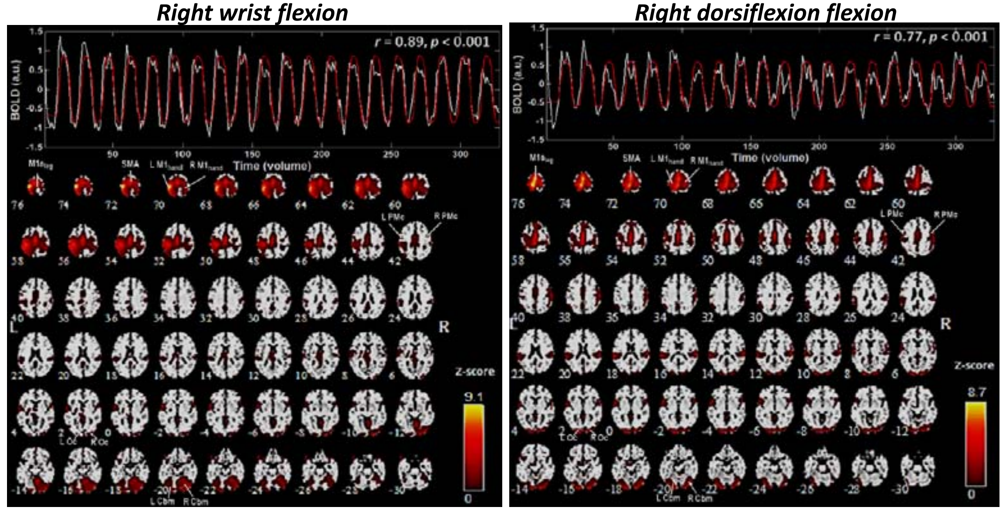
Blood oxygenation level dependent (BOLD) signal

Haemoglobin is diamagnetic when oxygenated but paramagnetic when deoxygenated !!



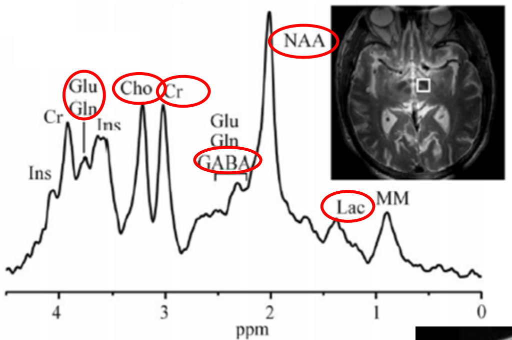
Brain Functional Networks

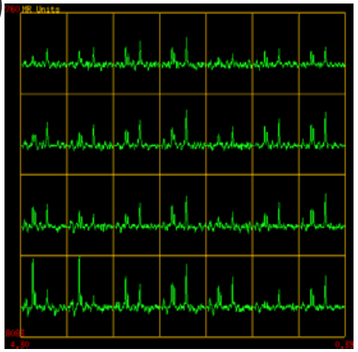
- The motor networks by clustering the blood-oxygenation-level-dependent responses using group-ICA.



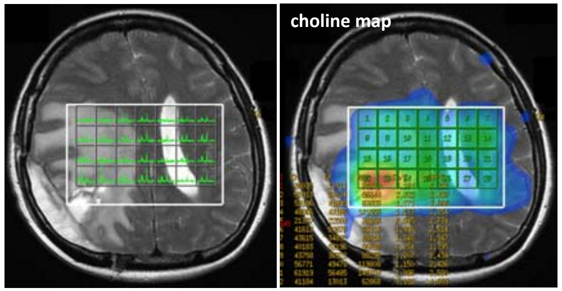
Clinical Neurophysiology, 124:1353-1363, 2013

MR spectroscopy (MRS)





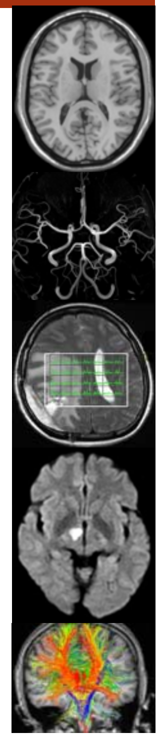
- Shimming the magnetic field
- Water signal suppression
- Spectroscopic technique
  - Single Voxel Spectroscopy (SVS)
  - Chemical Shift Imaging (CSI)



Magnetic Resonance in Medicine 55:296-301 (2006)

Potential of MRI

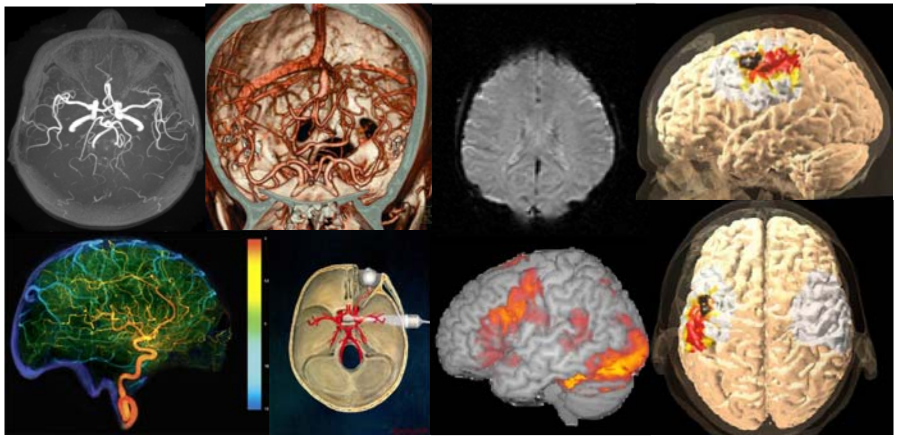
- Imaging techniques
  - Pulse sequences
    - TR,TE, spatial, temporal resolution; SNR; total imaging time;
  - Functional task design
- Brain imaging
  - Cortex ➔ volume, cortical folding/complexity
  - White matter ➔ fiber connection, integrity
  - Blood supply ➔ brain perfusion, vessel structure
  - Volume, Complexity ➔ development, degeneration
  - Matabolism ➔ choline, GABA, glutamate



Perfusion-Weighted Imaging In Cerebral Vascular Diseases

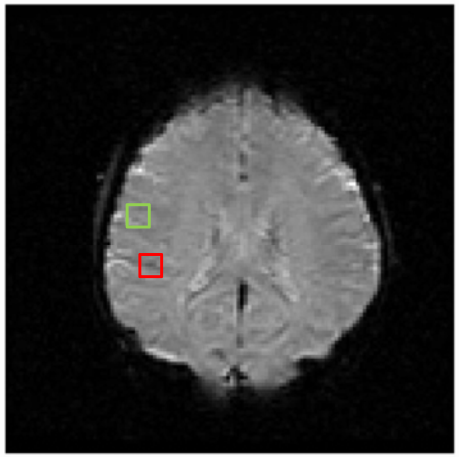
Blood supply and hemodynamics of brain tissues

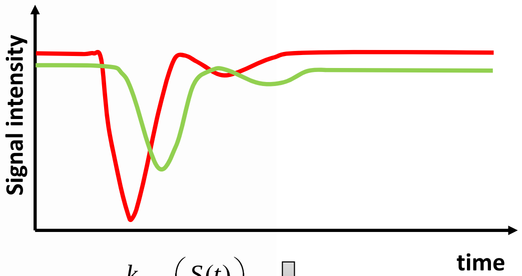
- Digital subtraction angiography，DSA
- MR perfusion imaging (PWI)
- Arterial spin labeling (ASL)
- functional near-infrared spectroscopy (fNIRS)
- transcranial Doppler (TCD)



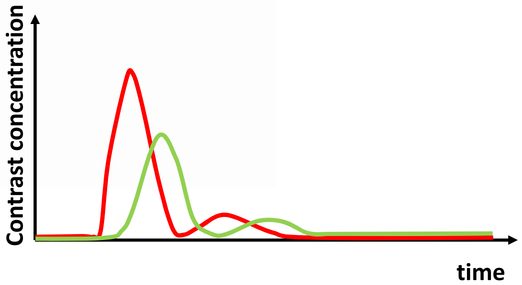
bolus tracking of Gd-DTPA contrast agent (DSC-MRI)

(20 ml of contrast followed by 20ml normal saline, powe injector at a flow rate of 3-4 ml/s in the antecubital vein)

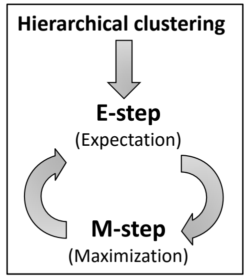




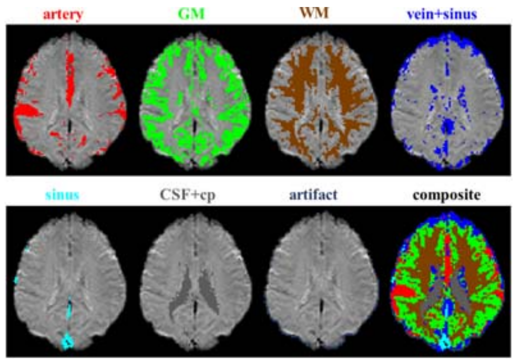
$$C_t(t) = -\frac{k}{TE}\ln\left(\frac{S(t)}{S_0}\right)$$

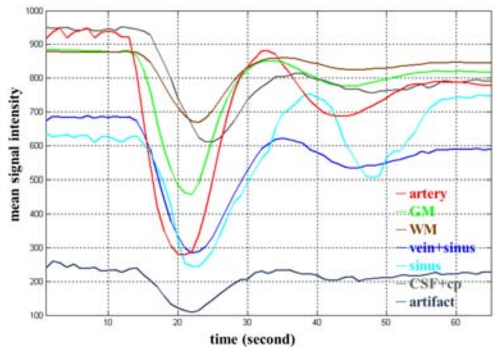


Tissue Classification using the HC-EM algorithm



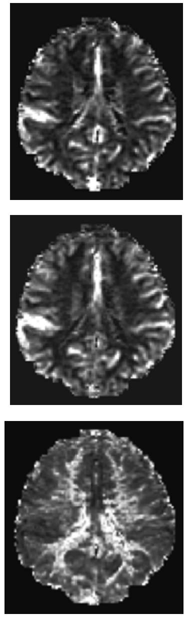
$$p(i \mid x_n, \theta^{j-1}) = \frac{\pi_i^{j-1} g_{x_n}\left[\mu_i^{j-1}, \Sigma_i^{j-1}\right]}{\sum_{l=1}^{K} \pi_l^{j-1} g_{x_n}\left[\mu_l^{j-1}, \Sigma_l^{j-1}\right]}$$





- *Wu et al*, Magnetic Resonance in Medicine, 57:181-191, 2007.
- *Lu el al*, PLoS One, 8(7): e68986, 2013.

Hemodynamic maps



Cerebral blood volume

$$\mathrm{rCBV} = \frac{\int_{first\ pass} c_t(t)dt}{\int_{first\ pass} c_a(t)dt}$$

Cerebral blood flow

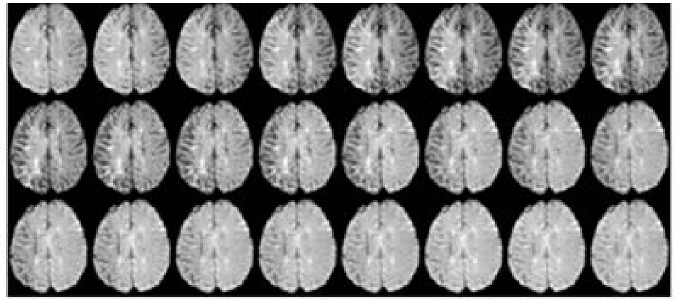
$$C_t(t) = \mathrm{rCBF} \cdot C_a(t) \otimes R(t)$$

Mean transit time

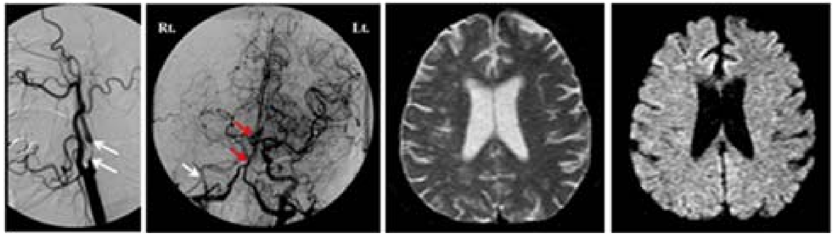
$$\mathrm{MTT} = \frac{\mathrm{rCBV}}{\mathrm{rCBF}}$$

A patient with 99% stenosis of right internal carotid artery (ICA)

Consecutive axial DSC-MRIs

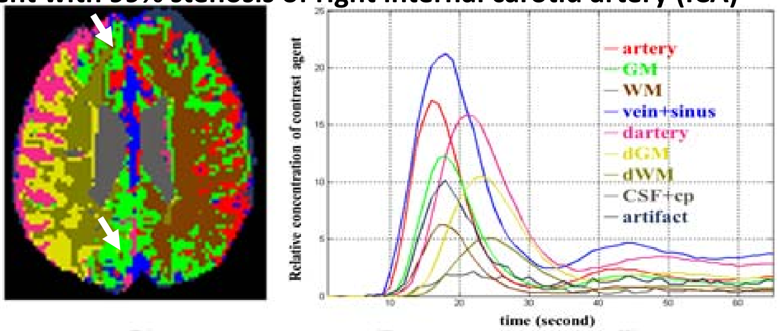


Angiograms **T2-weighted image** **Diffusion-weighted image**

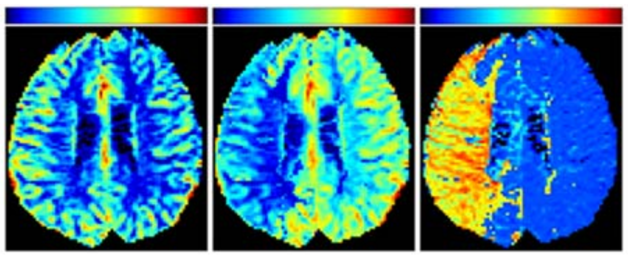


Lu el al, PLoS One, 8(7): e68986, 2013.

A patient with 99% stenosis of right internal carotid artery (ICA)



rCBV **rCBF** **MTT**



Lu el al, PLoS One, 8(7): e68986, 2013.

Table 4 The hemodynamic parameters of segmented tissue types for the patient with unilateral ICA stenosis.

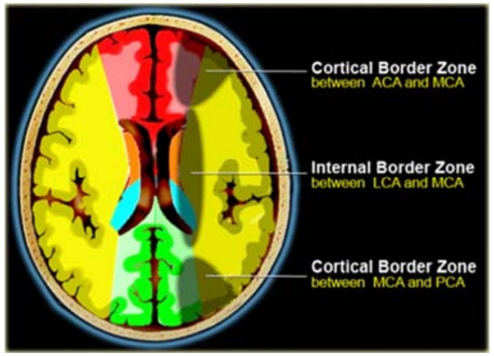
	artery	GM	WM	CSF+cp	dArtery	dGM	dWM	vein+sinus
TTP (second)	16.44±1.03	17.85±1.23	17.91±1.11	22.48±8.33	21.44±2.02	23.31±2.44	24.33±2.56	17.68±3.78
rCBV (ml·100g^{-1})	7.05±3.76	5.34±2.36	2.55±1.02	1.41±1.11	9.09±4.27	6.06±2.64	2.96±1.08	11.40±6.12
rCBF (ml·100g^{-1}·min^{-1})	74.74±42.08	54.26±21.12	27.45±9.91	11.06±8.18	57.82±24.15	39.51±15.32	19.54±6.60	96.59±55.89
MTT (second)	5.64±1.02	5.85±0.94	5.52±0.82	6.02±2.45	9.30±1.88	9.16±1.86	9.08±1.56	7.28±1.73

Infarct threshold
GM: CBF 34 ml/100g/min CBV 1.6 ml/100g
WM: CBF 20 ml/100g/min CBV 1.2 ml/100g

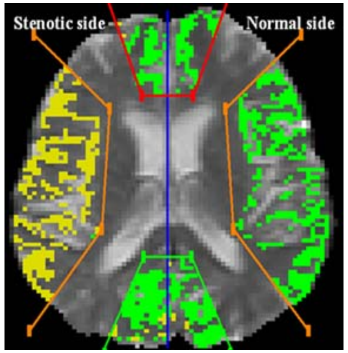
Lu el al, PLoS One, 8(7): e68986, 2013.

Do the delay/dispersion phenomena of hemodynamics caused by ICA stenosis differ between vessel territories??

Cerebral vessel territories



ACA

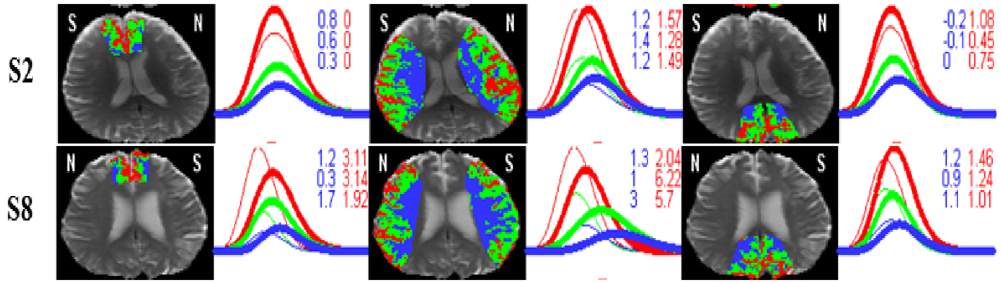


MCA

PCA

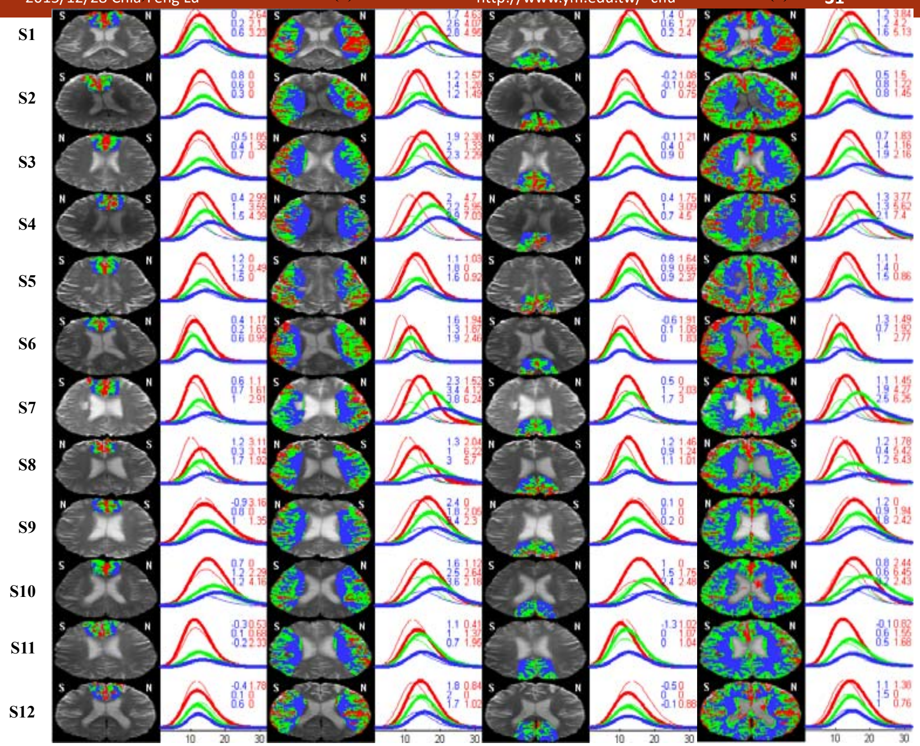
Robin Smithuis, Brain Ischemia - Vascular territories

delay/dispersion in different vessel territories



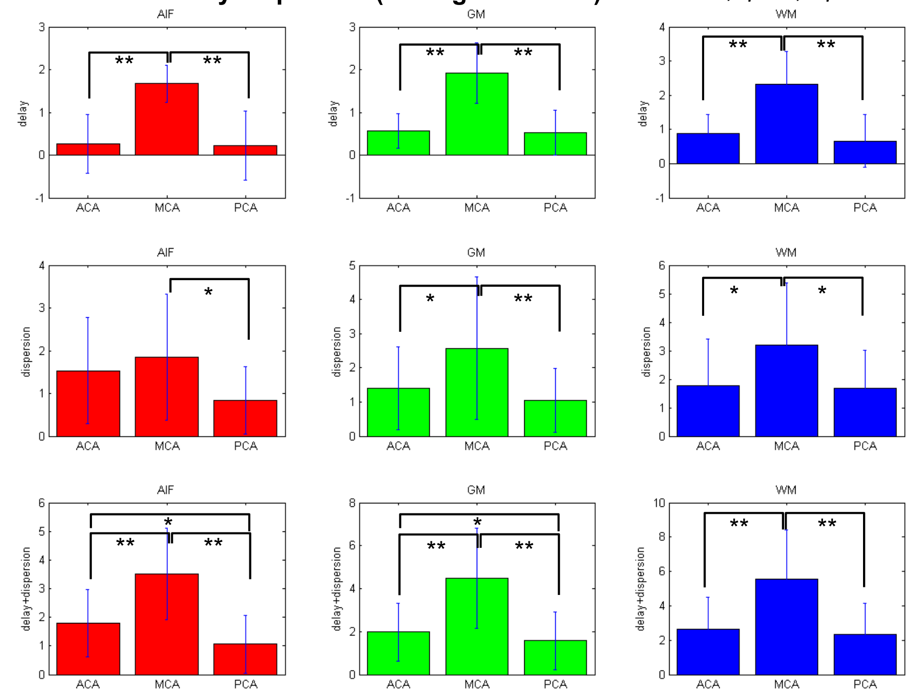
Artery delay, Artery dispersion
GM delay, GM dispersion
WM delay, WM dispersion

(unit: second)



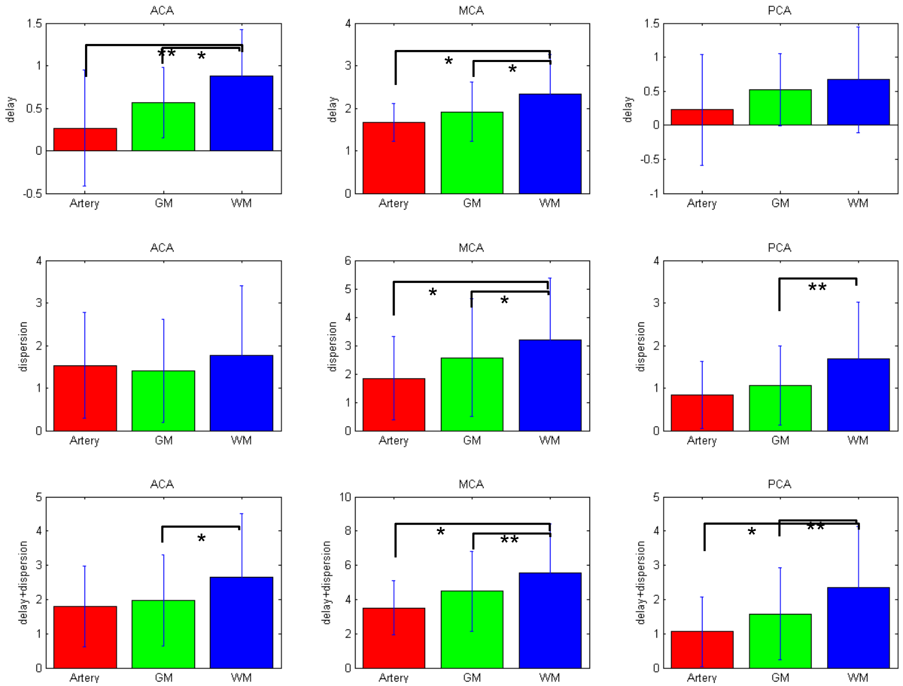
Difference of delay/dispersion (among territories)

Paired *t*-test, *:*p*<0.05, **:*p*<0.005



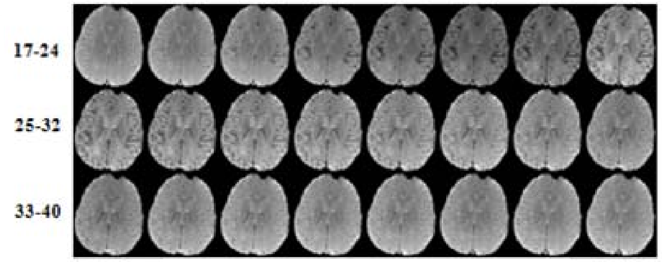
Difference of delay/dispersion (among tissues)

Paired *t*-test, *:*p*<0.05, **:*p*<0.005

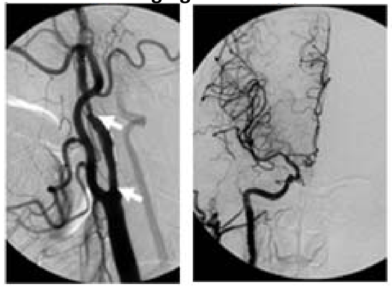


The patient with ICA stenting

Consecutive axial DSC-MRIs

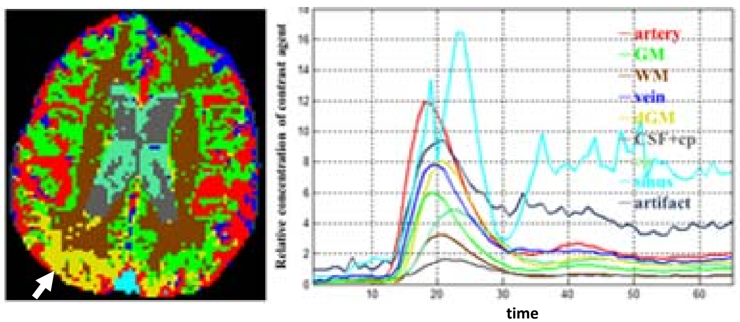


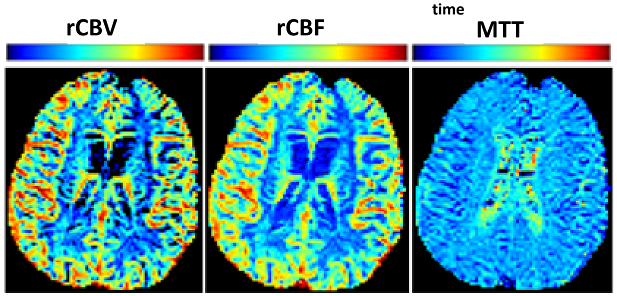
Angiograms



Lu el al, PLoS One, 8(7): e68986, 2013.

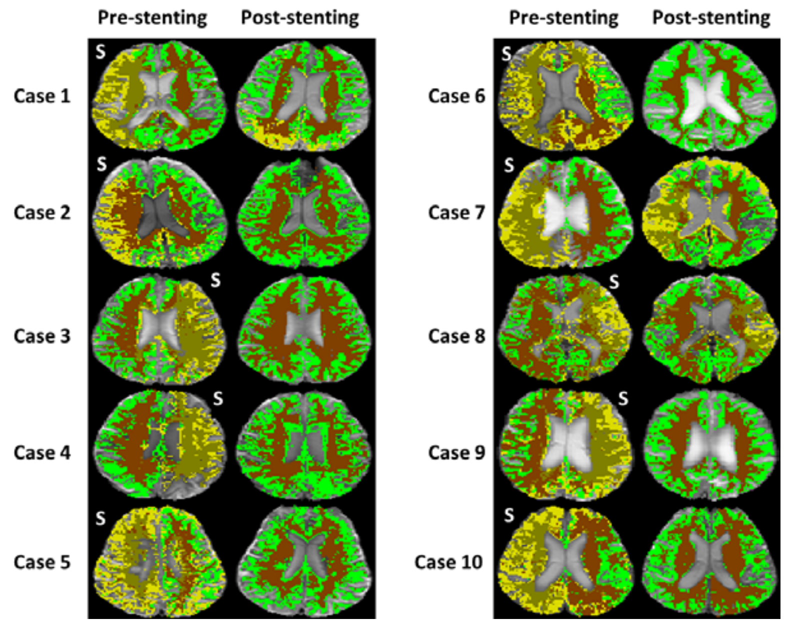
The patient with ICA stenting



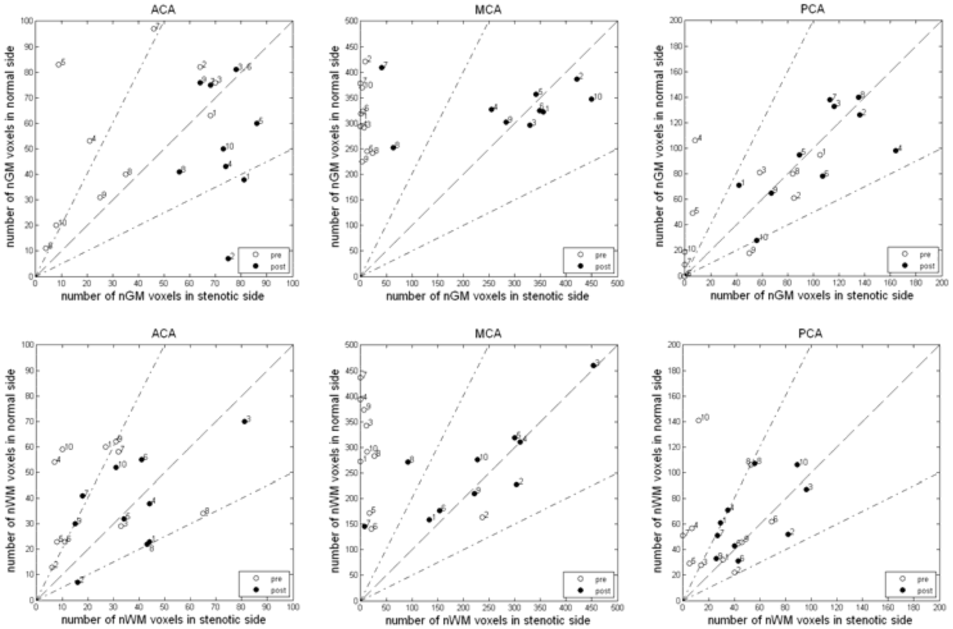


Lu el al, PLoS One, 8(7): e68986, 2013.

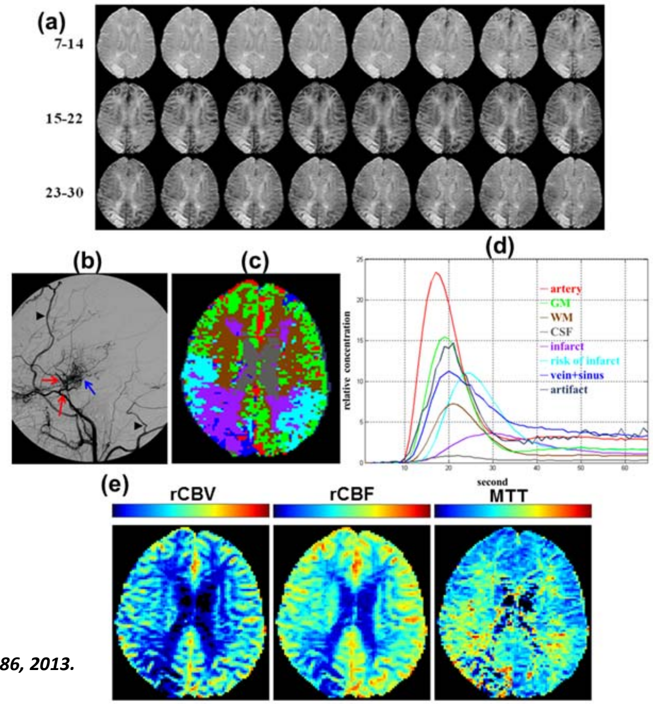
Spatial symmetry of GM/WM before and after ICA stenting



Scatter plots of spatial symmetry of GM/WM before and after ICA stenting



Moyamoya disease



Lu el al, PLoS One, 8(7): e68986, 2013.

Table 5 The hemodynamic parameters of segmented areas for the patient with moyamoya disease.

	artery	GM	WM	CSF	infarct	risk of infarct	vein+sinus
TTP (second)	17.40±1.29	19.03±1.61	21.20±2.01	21.94±9.18	29.71±6.18	24.63±2.22	22.96±5.73
rCBV (ml·100g^{-1})	7.05±2.86	4.71±2.13	2.67±1.00	0.35±0.41	1.46±0.93	4.49±1.83	5.61±3.64
rCBF (ml·100g^{-1}·min^{-1})	63.93±28.64	43.59±18.61	20.18±7.58	3.28±2.41	9.95±5.37	29.98±12.68	35.36±29.05
MTT (second)	6.70±1.00	6.45±1.05	7.90±1.37	6.78±3.30	8.50±2.63	9.04±1.78	10.46±4.12

Lu el al, PLoS One, 8(7): e68986, 2013.

THE END

Thanks for your attention :)

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