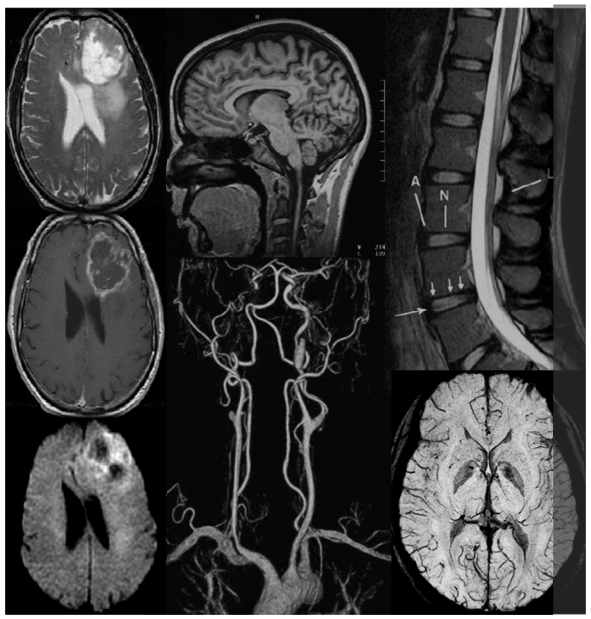
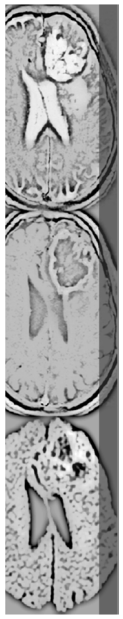


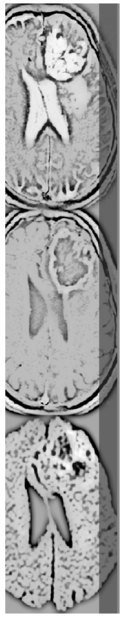
Magnetic Resonance in Medicine
Perfusion-Weighted Imaging (DSC & DCE)

Chia-Feng Lu (盧家鋒), Ph.D.
Department of Biomedical Imaging and Radiological Sciences, NYCU
alvin4016@nycu.edu.tw



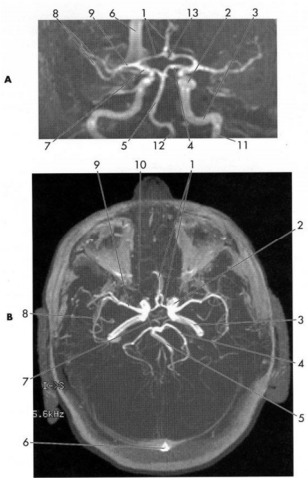
Content http://cflu.lab.nycu.edu.tw/

- **Dynamic Susceptibility Contrast (DSC) 動態磁化率對比影像**
- **Dynamic Contrast Enhancement (DCE) 動態對比增強影像**

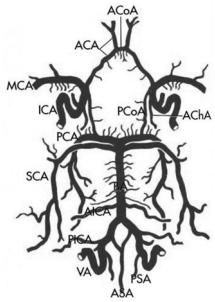


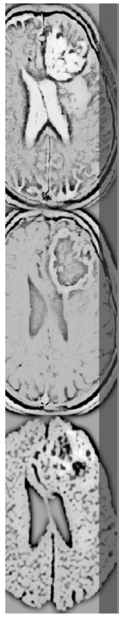
TOF MRA

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.

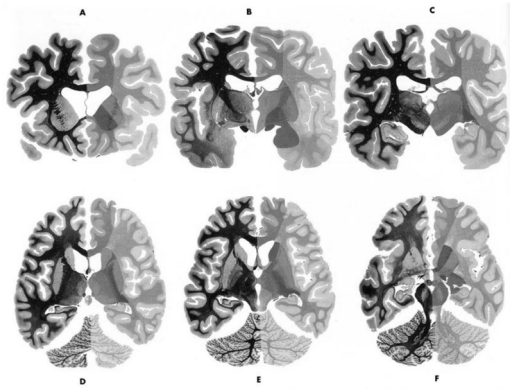


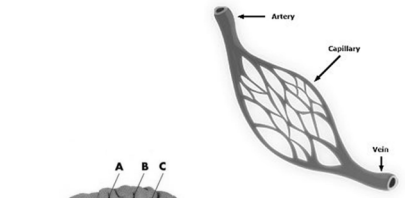
Circle of Willis

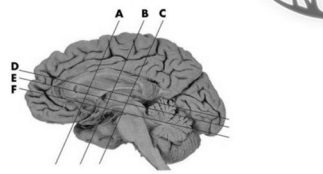




Vascular Territories





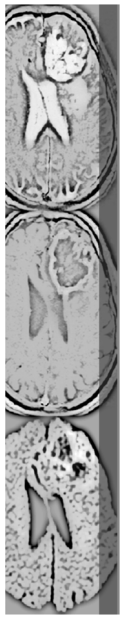


Area supplied by:

- Anterior cerebral a.
- Middle cerebral a.
- Anterior choroidal a.
- Posterior cerebral a.
- Superior cerebellar a.
- Anterior inferior cerebellar a.
- Posterior inferior cerebellar a.

- Anterior cerebral and anterior communicating aa. (perforating branches)
- Middle cerebral a. (perforating branches)
- Posterior cerebral and posterior communicating aa. (perforating branches)

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



Perfusion imaging

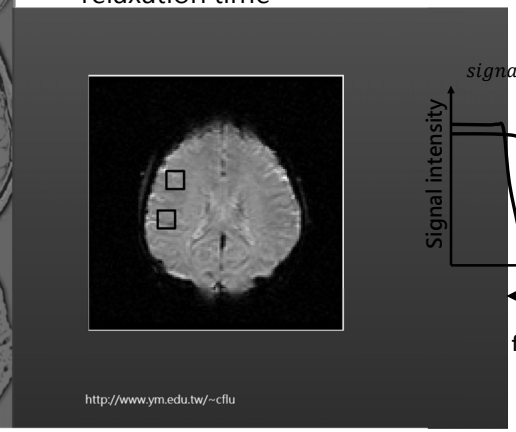
- The information on the capillary microcirculation of tissue
- Three major techniques
  - Dynamic susceptibility contrast (DSC) MRI
  - Dynamic contrast enhancement (DCE) MRI
  - Arterial spin labeling (ASL) MRI

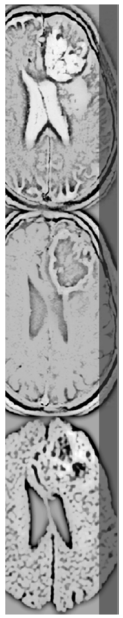
Dynamic Susceptibility Contrast, DSC

動態磁化率對比影像

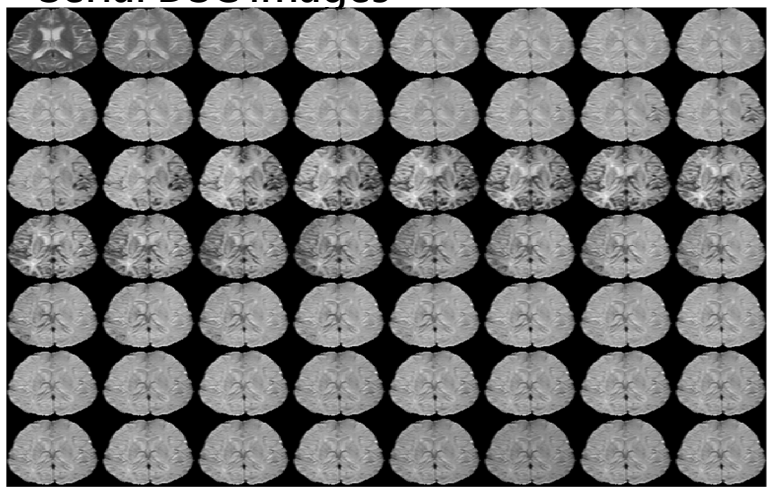
DSC MRI

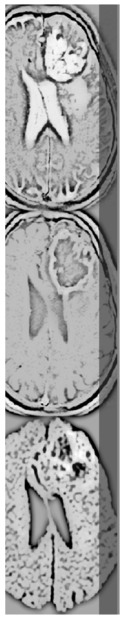
- **bolus tracking** of Gd-DTPA contrast agent, reduce T2 and T2* relaxation time





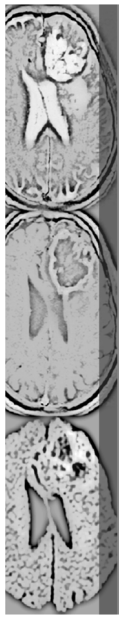
Serial DSC images





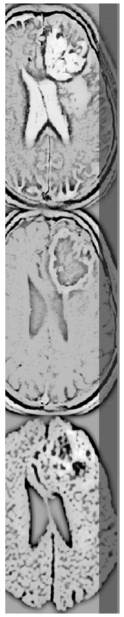
Imaging Parameters

- A multi-slice gradient-echo echo-planar imaging
- Transverse (axial) imaging
- TR/TE= 1000/60 ms
- FOV= 240 x 240 mm^2, matrix =128 x 128,
- slice thickness/gap = 5/5 mm
- 70 images per slice location with a one second temporal resolution (TR=1000 ms).



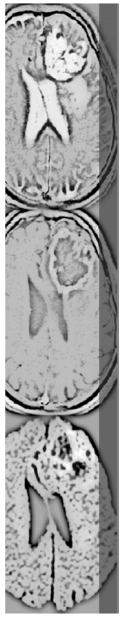
Contrast Agent Administration

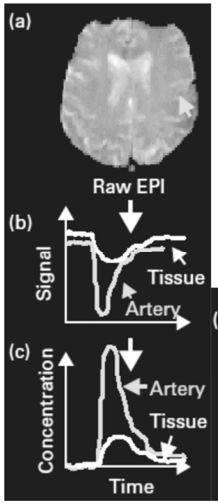
- Twenty ml of Gd-DTPA-BMA (Omniscan™) followed by 20 ml of normal saline were delivered administratively using a power injector at a flow rate of 3–4 ml/s in the antecubital vein.



DSC MRI

- T2-weigthed SE-EPI: specific to the micro-vascular compartment
- T2*-weighted GRE-EPI: also take into account larger vessels

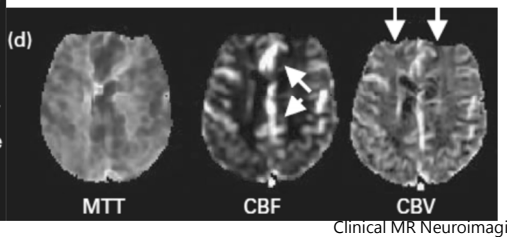




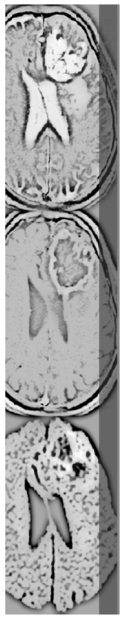
DSC Processing

An approximate linear relationship exists between tissue contrast agent concentration and change in T2 relaxation rate

- $\Delta R_2(t) \propto C_t(t), \quad C_t(t) = -\frac{k}{TE} \cdot log\left(\frac{S(t)}{S(t_0)}\right)$



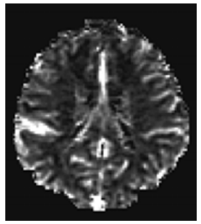
Clinical MR Neuroimaging, Cambridge, 2005.



Hemodynamic maps

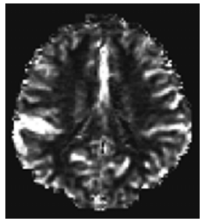
Relative Cerebral blood volume (rCBV)

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



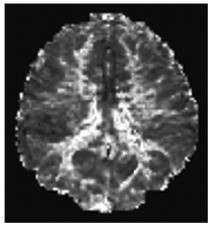
Relative Cerebral blood flow (rCBF)

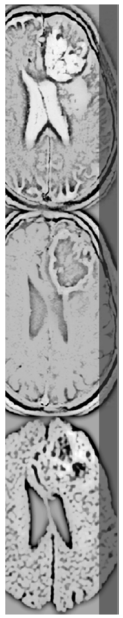
$$C_t(t) = rCBF \cdot C_a(t) \otimes R(t)$$



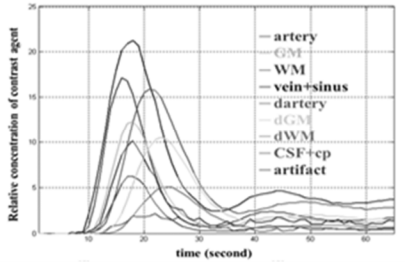
Mean transit time (MTT)

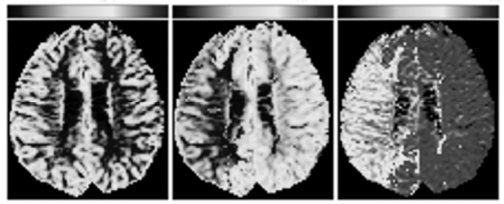
$$MTT = \frac{rCBV}{rCBF}$$





Tissue Classification using DSC



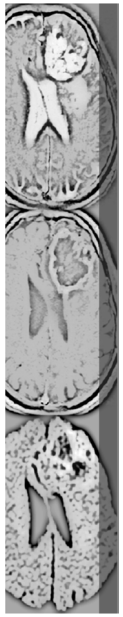


99% stenosis of right internal carotid artery

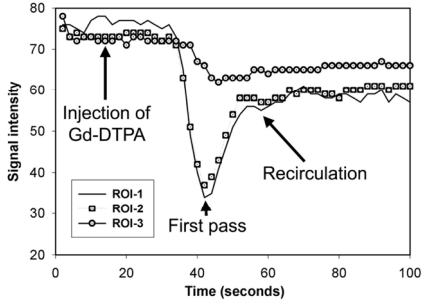
- *Wu et al,* Magnetic Resonance in Medicine, 57:181-191, 2007.
- *Lu el al,* PLoS One, 8(7): e68986, 2013.

Dynamic Contrast Enhancement, DCE

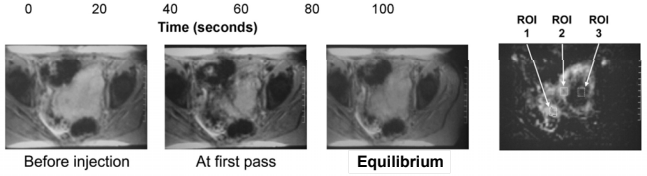
動態對比增強影像



T2* DSC-MRI of Mixed Mullerian Tumor

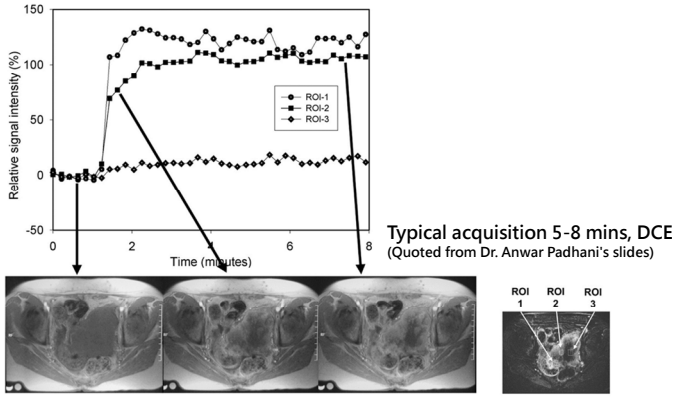


Typical acquisition 1-2 mins, DSC
(Quoted from Dr. Anwar Padhani's slides)



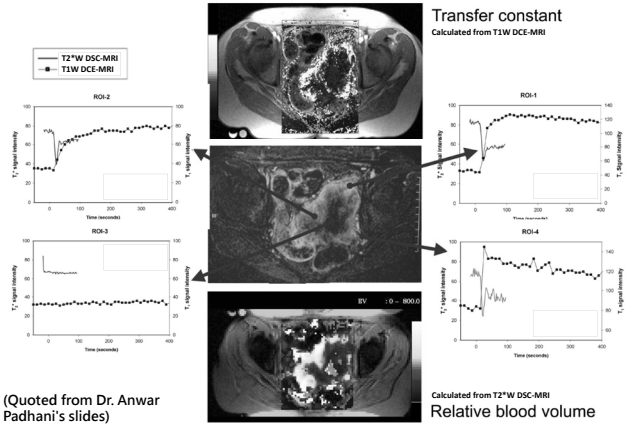
Before injection | At first pass | **Equilibrium**

T1W DCE-MRI of Mixed Mullerian Tumor



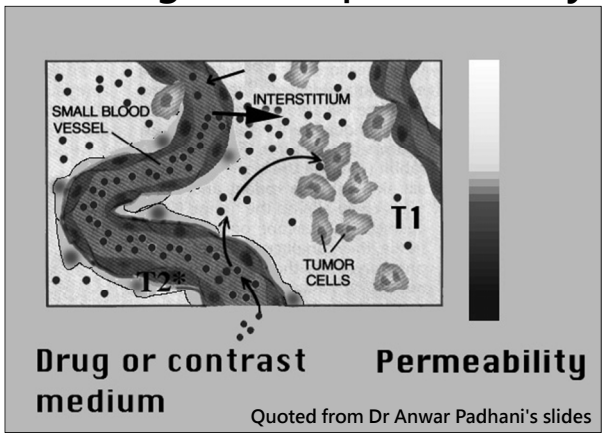
Typical acquisition 5-8 mins, DCE
(Quoted from Dr. Anwar Padhani's slides)

T2* versus T1W Perfusion MRI



(Quoted from Dr. Anwar Padhani's slides)

Contrast agent and permeability



Signal Enhanced by Contrast Agent

T_1 is reduced from its native value T_{10} by the presence of a concentration C of Gd:

$$\frac{1}{T_1} = \frac{1}{T_{10}} + r_1 C$$

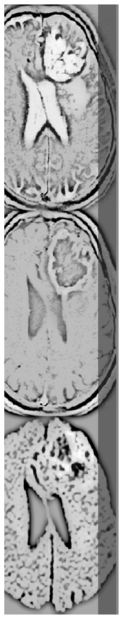
r1 is the relaxivity, and usually an in-vitro value of 4.5 s^{-1} mM^{-1} is used.
Often it is more convenient to use the relaxation rate:

$$R_1 = R_{10} + r_1 C$$

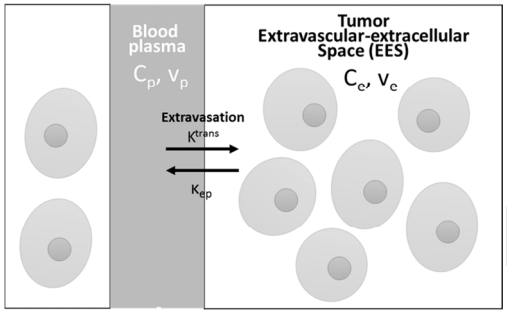
The signal S from a spoiled gradient echo sequence (i.e. FLASH) is:

$$S = S_0 \frac{(1 - e^{-TR/T_1})\sin\theta}{1 - e^{-TR/T_1}\cos\theta}$$

where S_0 is the relaxed signal (TR>>T1, =90º), and θ is the FA. S_0 can be found from the measured pre-Gd signal (before injection of CA).



Pharmacokinetic modelling
(Toft's two-compartment model)

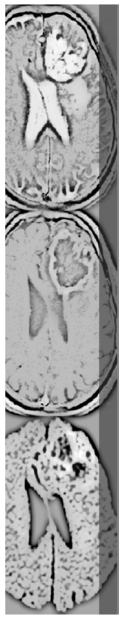


The flow of Gd across the endothelium into the EES is

$$v_e \frac{dC_e(t)}{dt} = K^{trans}(C_p(t) - C_e(t))$$

The total tissue concentration is:

$$C_t(t) = v_p C_p(t) + K^{trans} \int_0^t C_p(\tau) e^{-k_{ep}(t-\tau)} d\tau$$



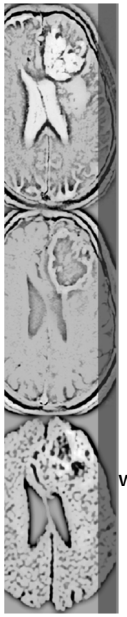
Parameters in DCE modelling

Table 2: Fixed and free parameters in DCE modelling.

Quantity	symbol	units	type
flip angle[a]	*FA*	degrees	fixed
haematocrit	*Hct*	%	fixed (42%)
onset time	*t_onset*	s	free
rate constant[b]	k_{ep}	min^{-1}	free
transfer constant	K^{trans}	min^{-1}	free
T_1 relaxivity	r_1	$s^{-1}\ mM^{-1}$	fixed ($4.5\ s^{-1}\ mM^{-1}$)
T_1 of blood	T_{10}^{blood}	s	fixed (1.4 s)
T_1 of tissue	T_{10}	s	fixed
TR	*TR*	s	fixed
fractional volume of EES[c]	v_e	$0<v_e<100\%$	free
fractional volume of blood plasma in tissue	v_p	$0<v_p<100\%$	free

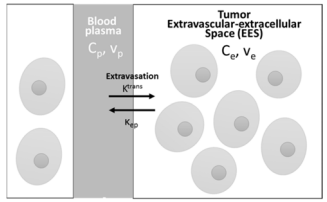
The **haematocrit** (Hct), also known by several other names, is the volume percentage (vol%) of red blood cells in blood, measured as part of a blood test.

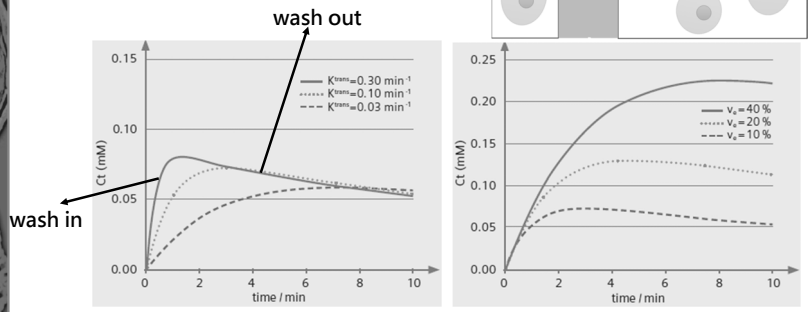
Paul s. Tofts, T1-weighted DCE Imaging Concepts: Modelling, Acquisition and Analysis, 2010.

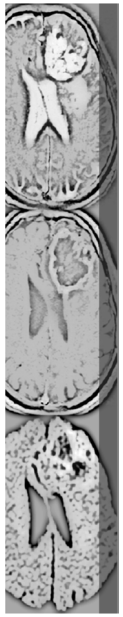


Effects of K^{trans} and v_e

- Increasing K^{trans}, with fixed v_e = 10%.
- Increasing v_e, with fixed K^{trans} = 0.1 min^{-1}.

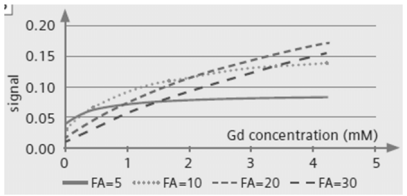


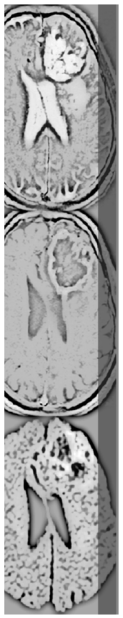




Imaging Parameters

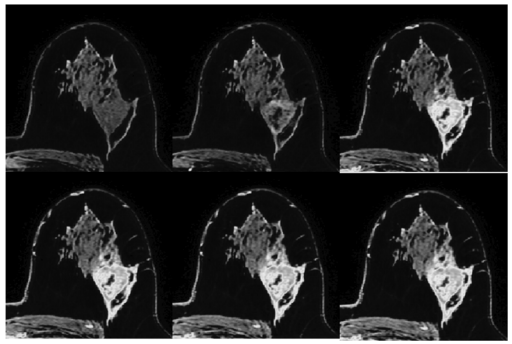
- Repeated 3D T1-weigthed images
- Transverse (both sides) or sagittal (unilateral) imaging
- TR= 2~20 s (if blood curve of arterial input function is demanded, use TR of 3s or less; It can be 60 sec for breast DCE imaging)
- Imaging duration: 5~8 minutes
- Flip angle 5~30°
  - FA↓, signal↑ at low concentration
  - FA↑, wider dynamic range

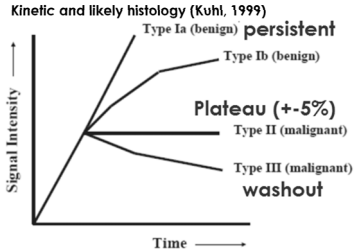


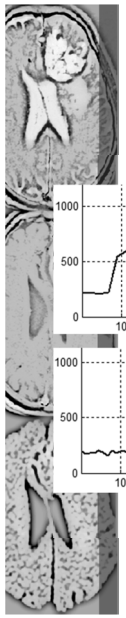


Breast DCE imaging

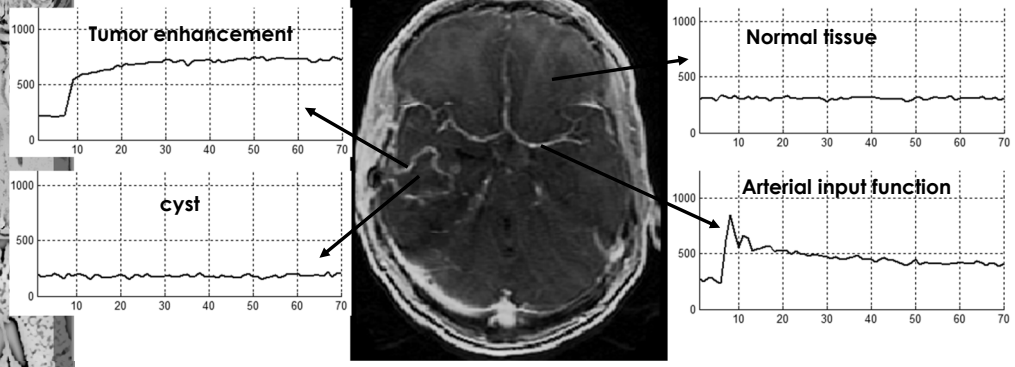
- Differentiate the tumor malignancy by DCE profile.







Cerebral DCE imaging



Grade II, oligoastrocytoma

TR=5s

THE END

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