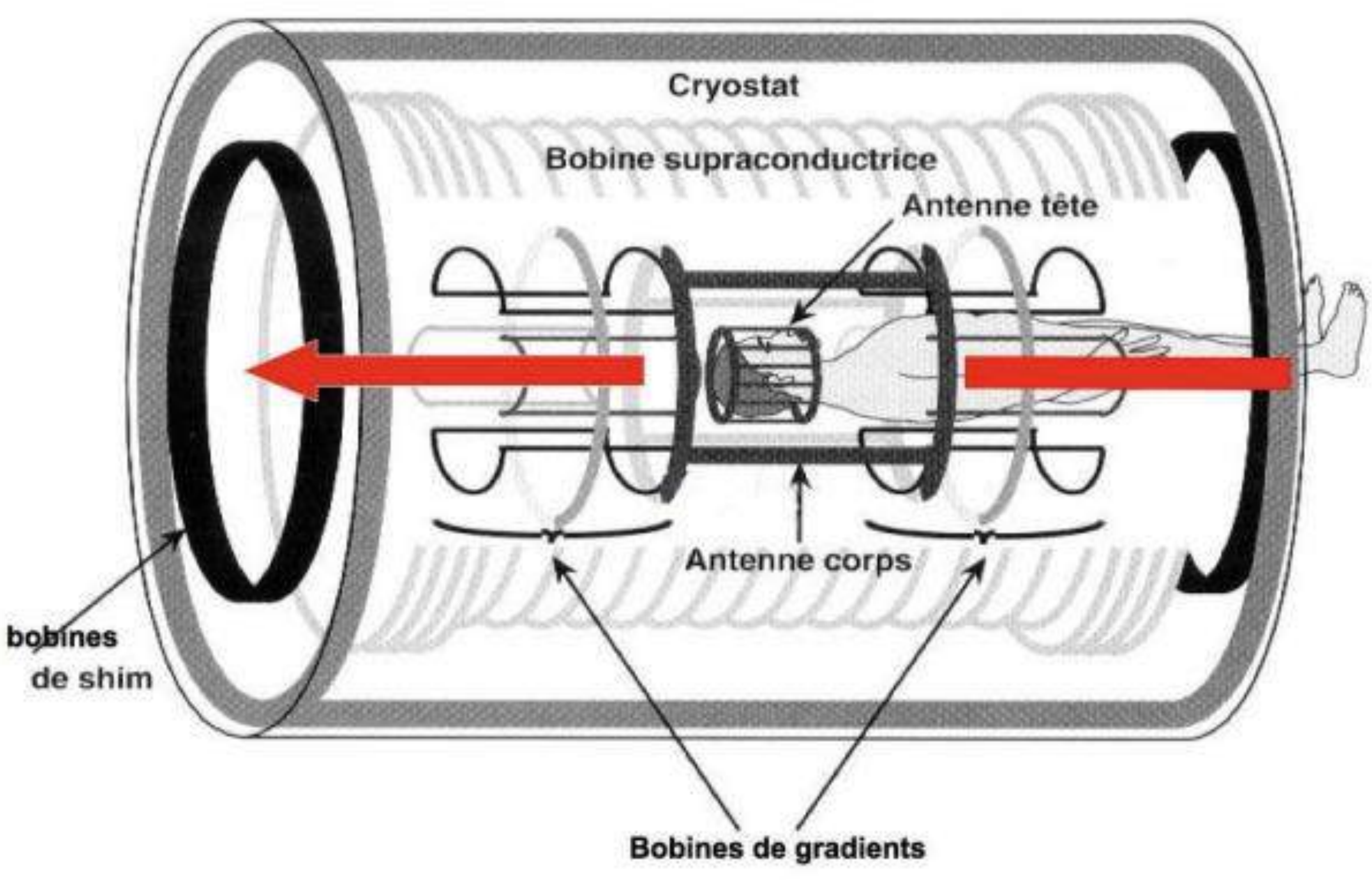
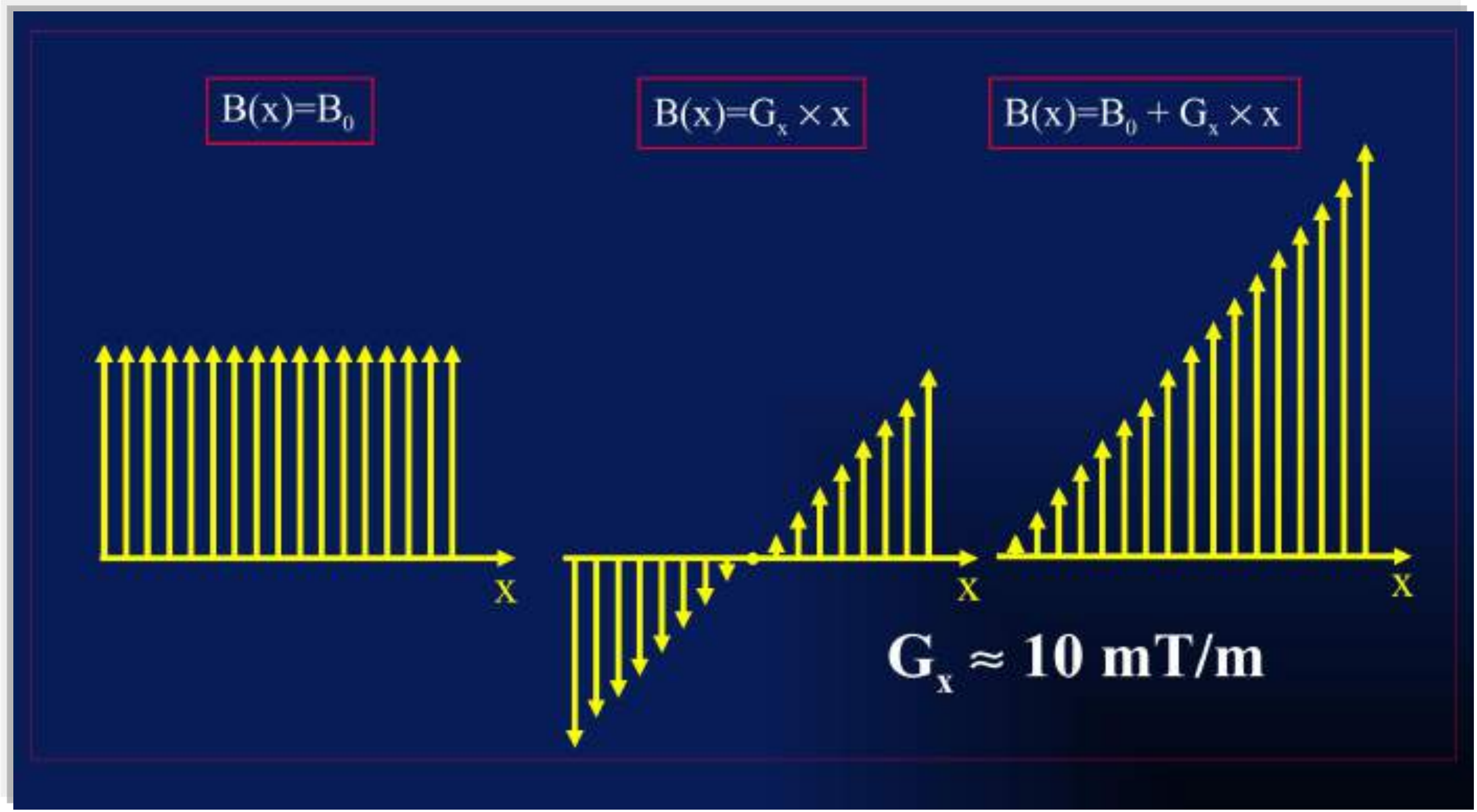
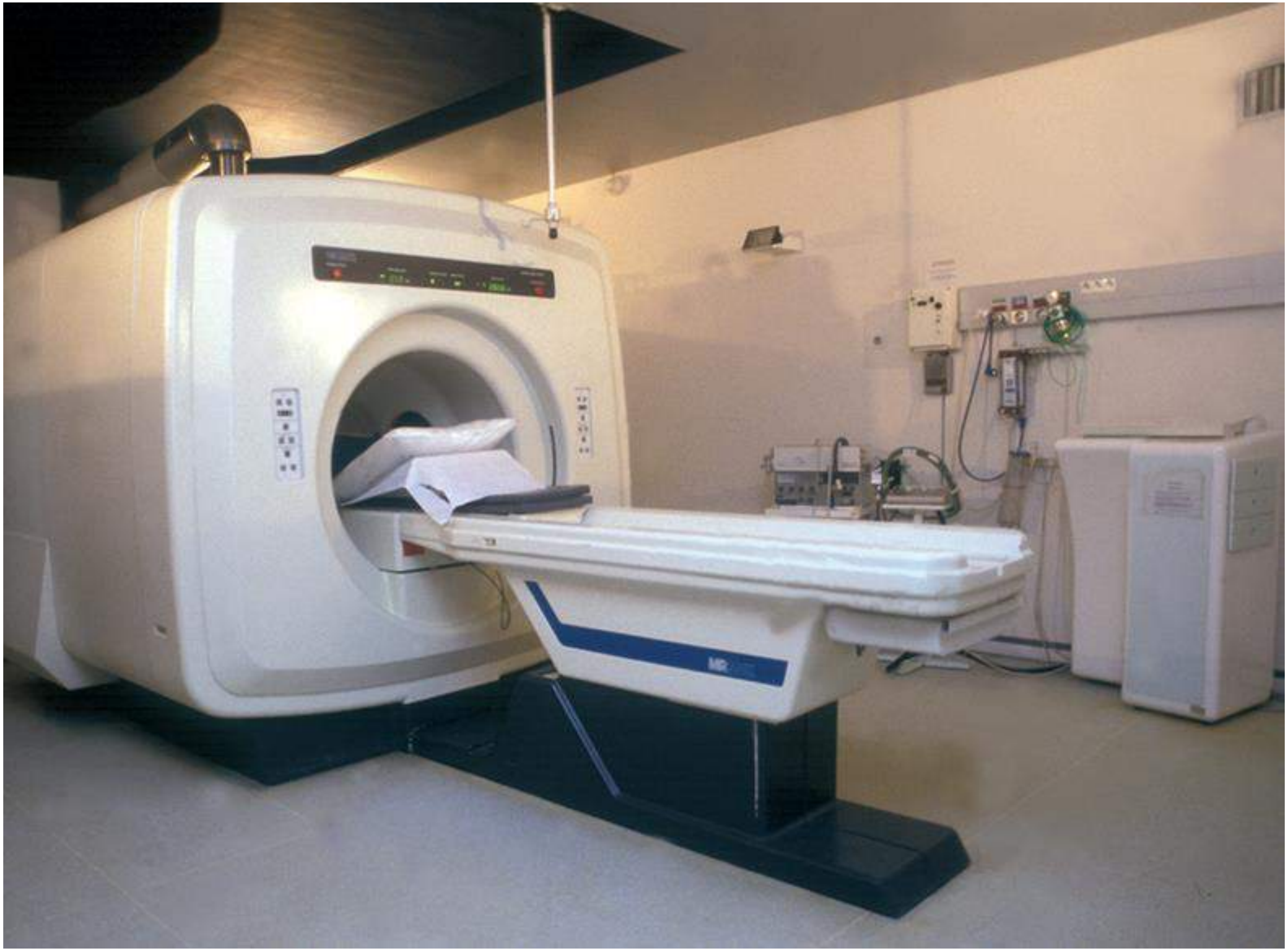
In vivo NMR spectroscopy

Magnet for IRM



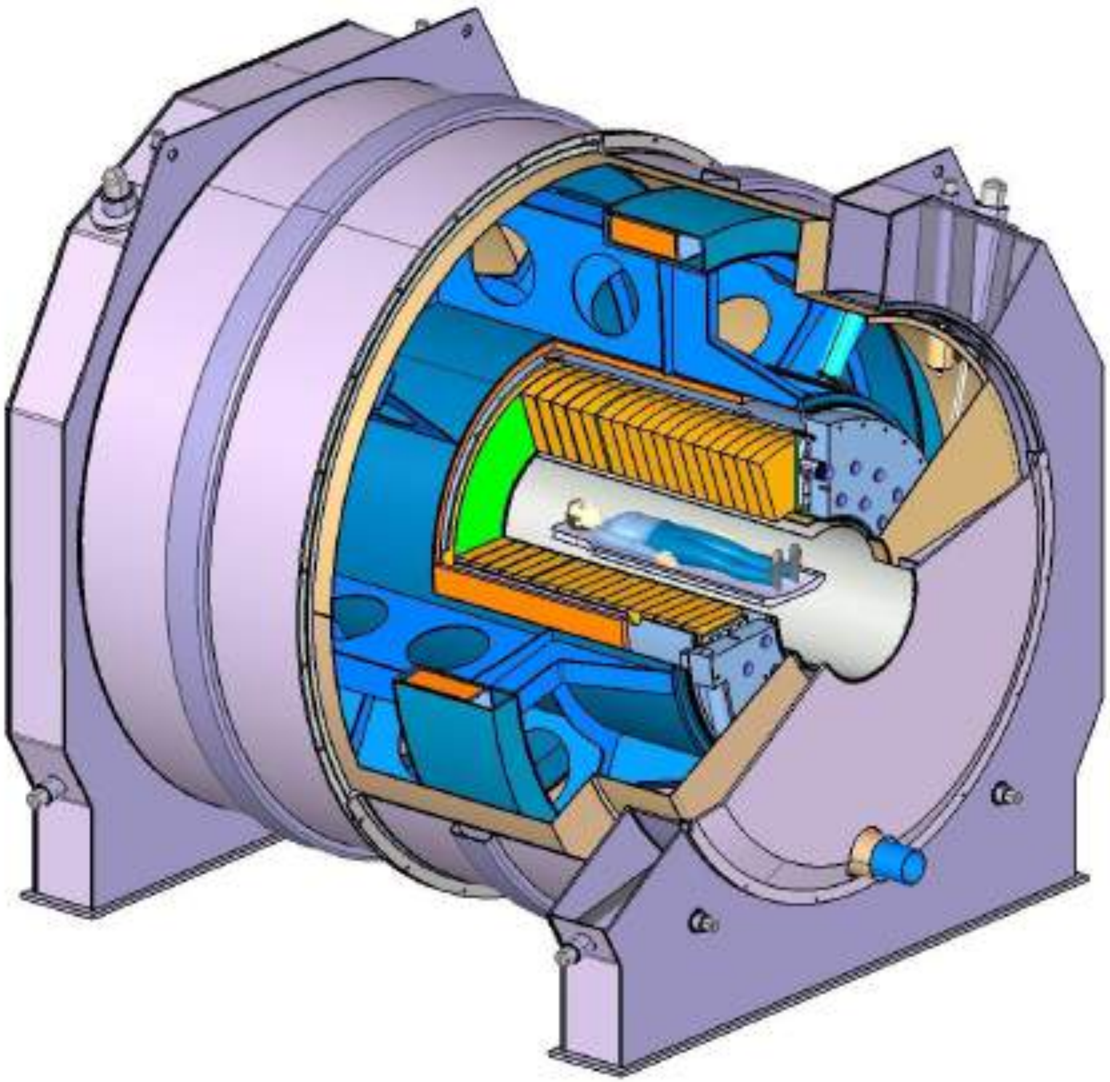
Gradient of magnetic field



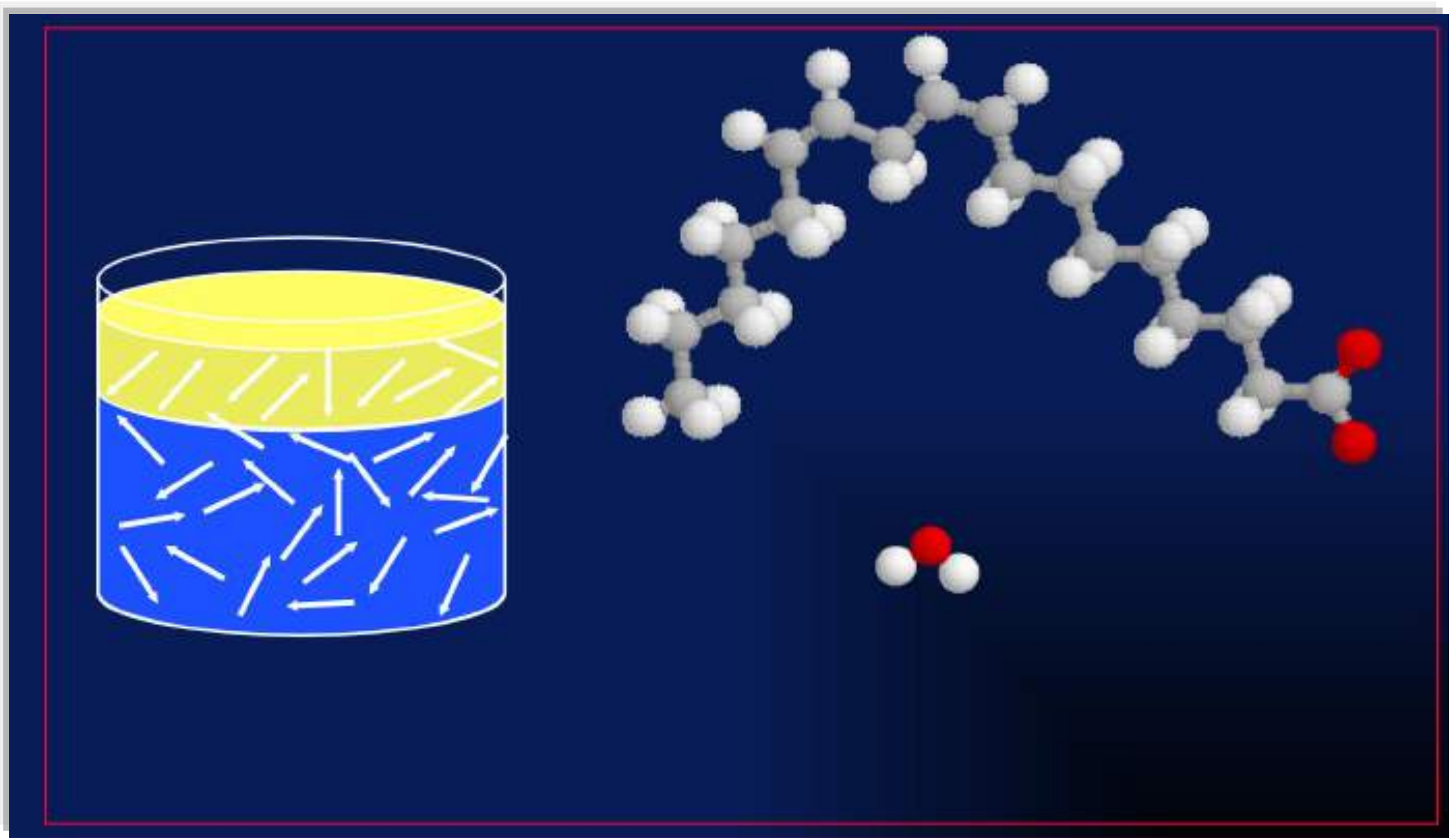


IRM 11.5 Tesla: project « *iseult* » France-Germany

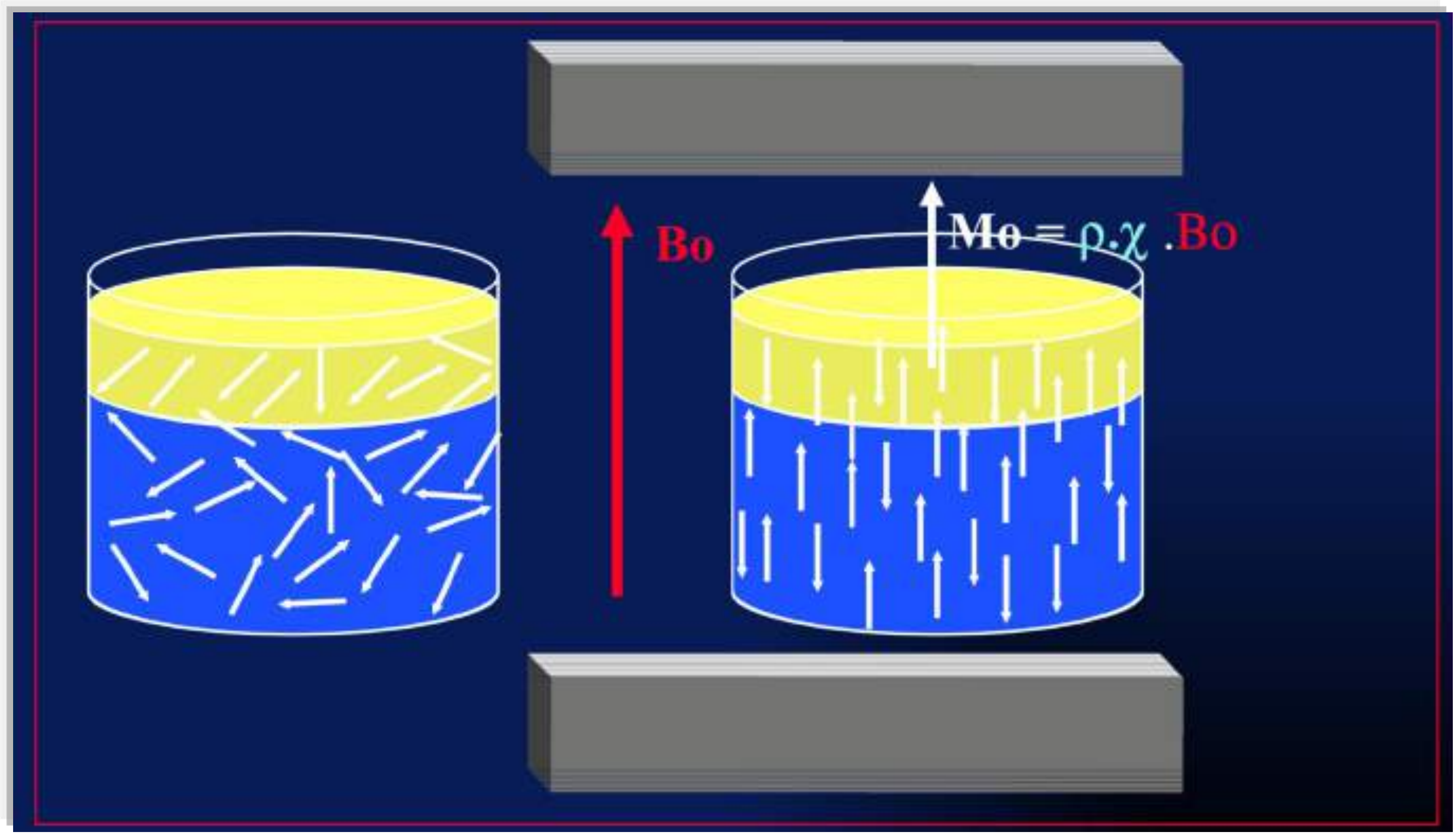
orange: superconductors coils; blue: helium enclosure and machinery
weight:45 tons



Magnetization of biological tissues

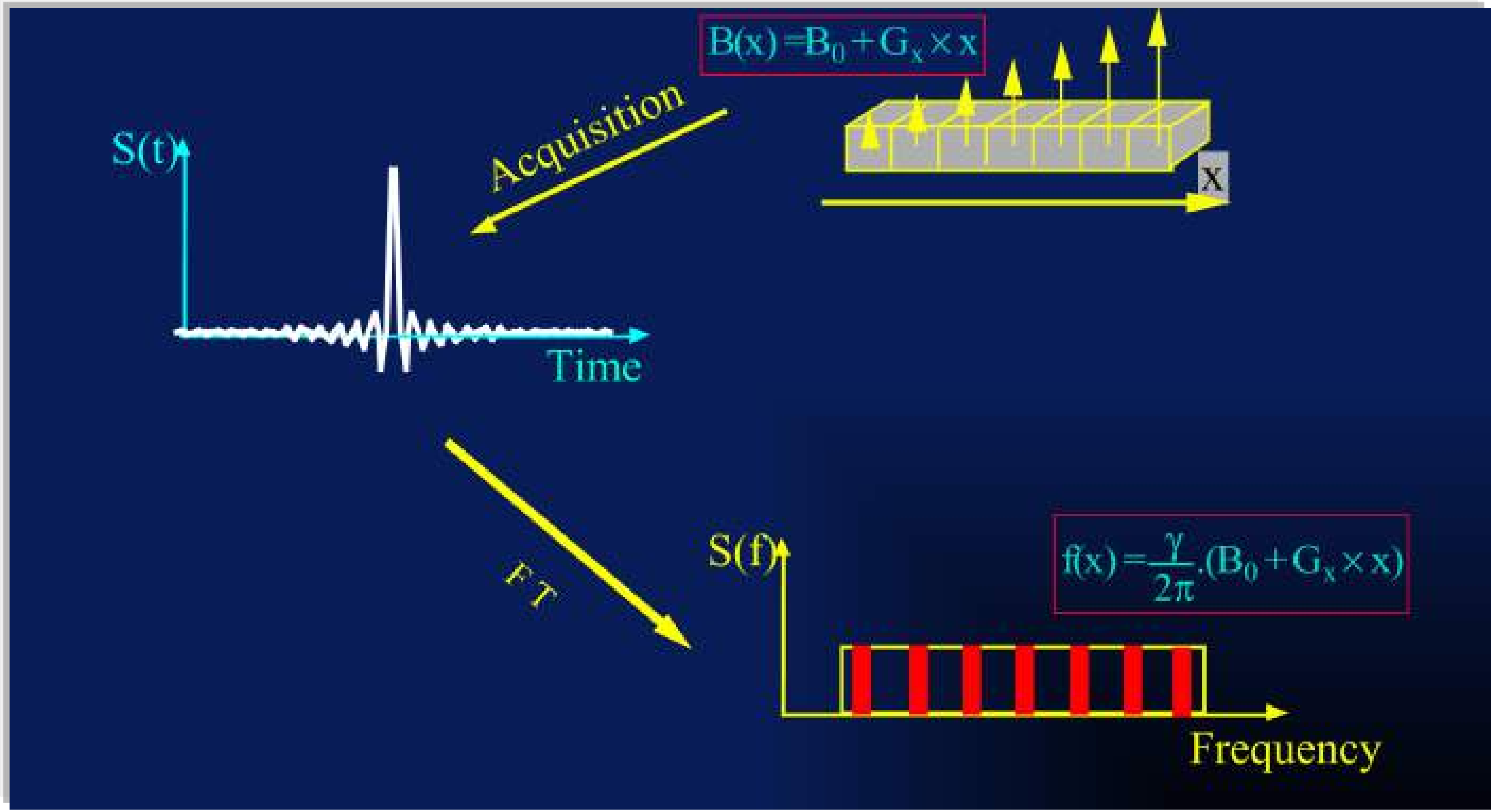


Macroscopic magnetization of biological tissues



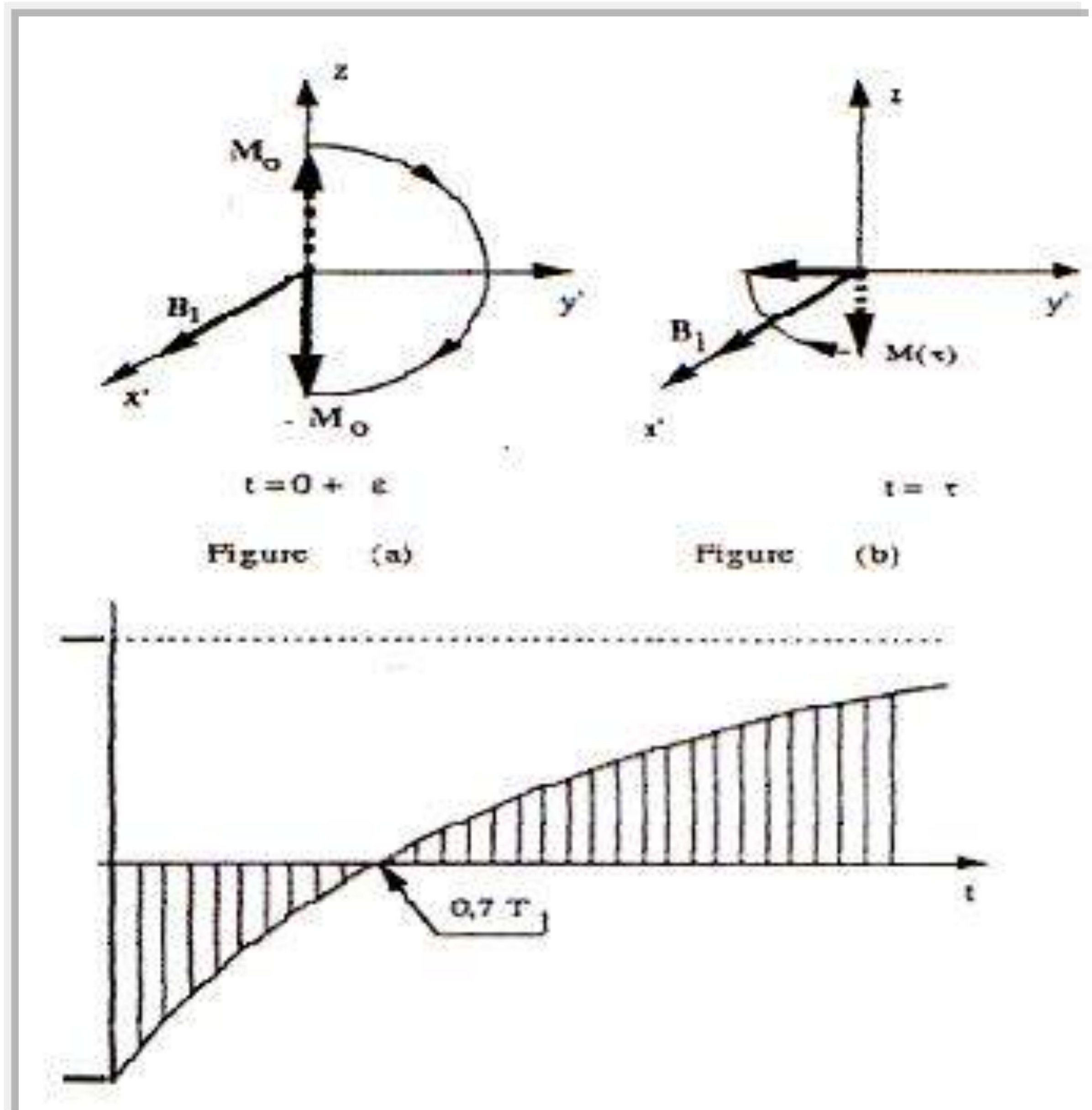
Nearly all MR image display tissue contrasts that depend on proton density PD, T1 and T2 simultaneously.
PD, T1 and T2 weighting will vary with sequence parameters, and may differ between different tissues in the same image.
To distinguish different tissues, we need to obtain contrast between them. Contrast is due to differences in the MR signal, which depend on the T1, T2 and proton density of the tissues and sequence parameters.

Encoding with frequency

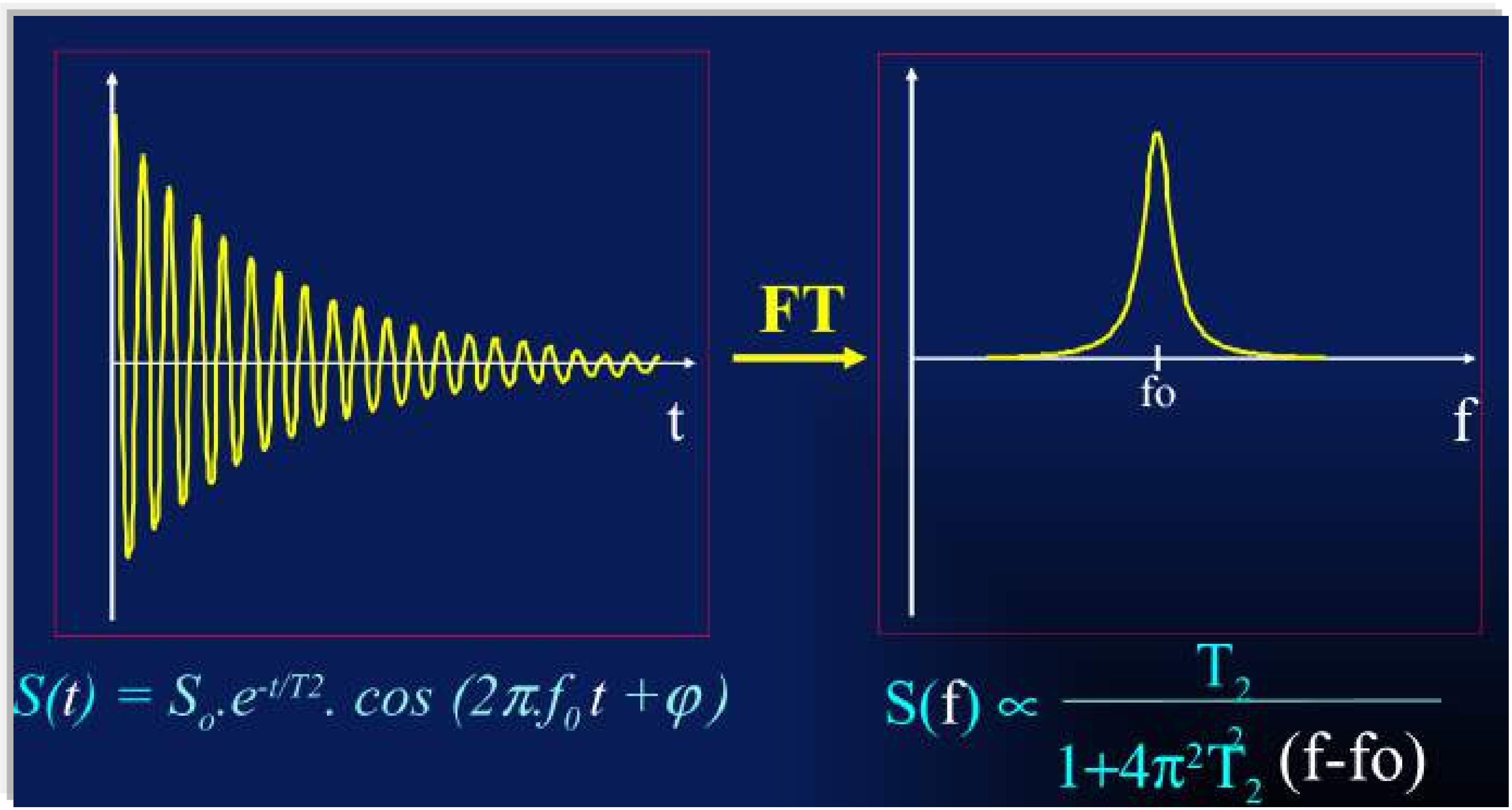


Measurement of T1 with 180°, τ, 90° sequences

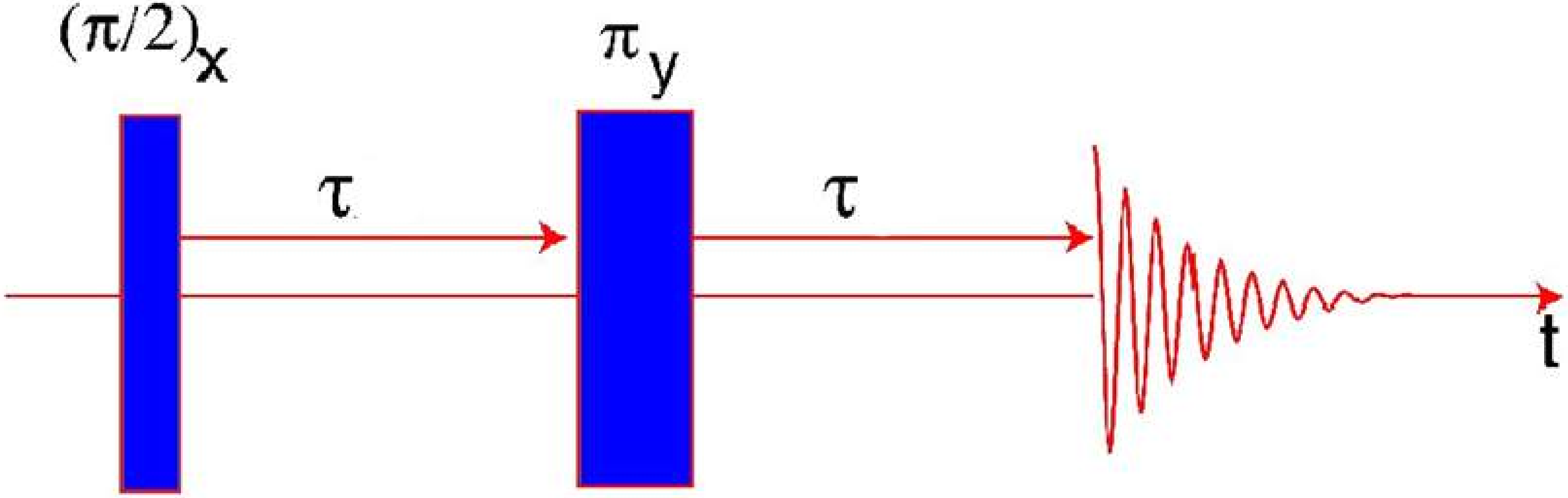
$dM_Z/dt = (M_Z - M_0)/T_1$; $M_Z = M_0 (1 - 2\exp{-t/T_1})$

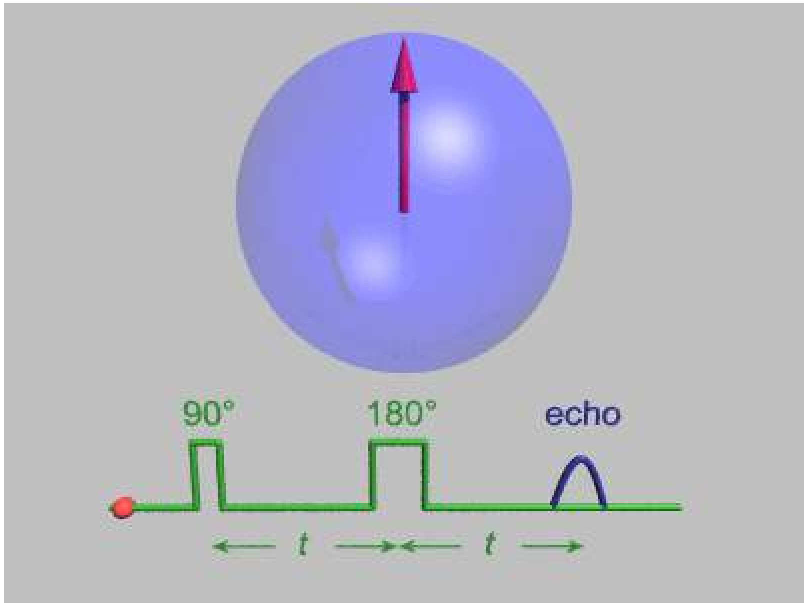


Free induction decay and Fourier transform



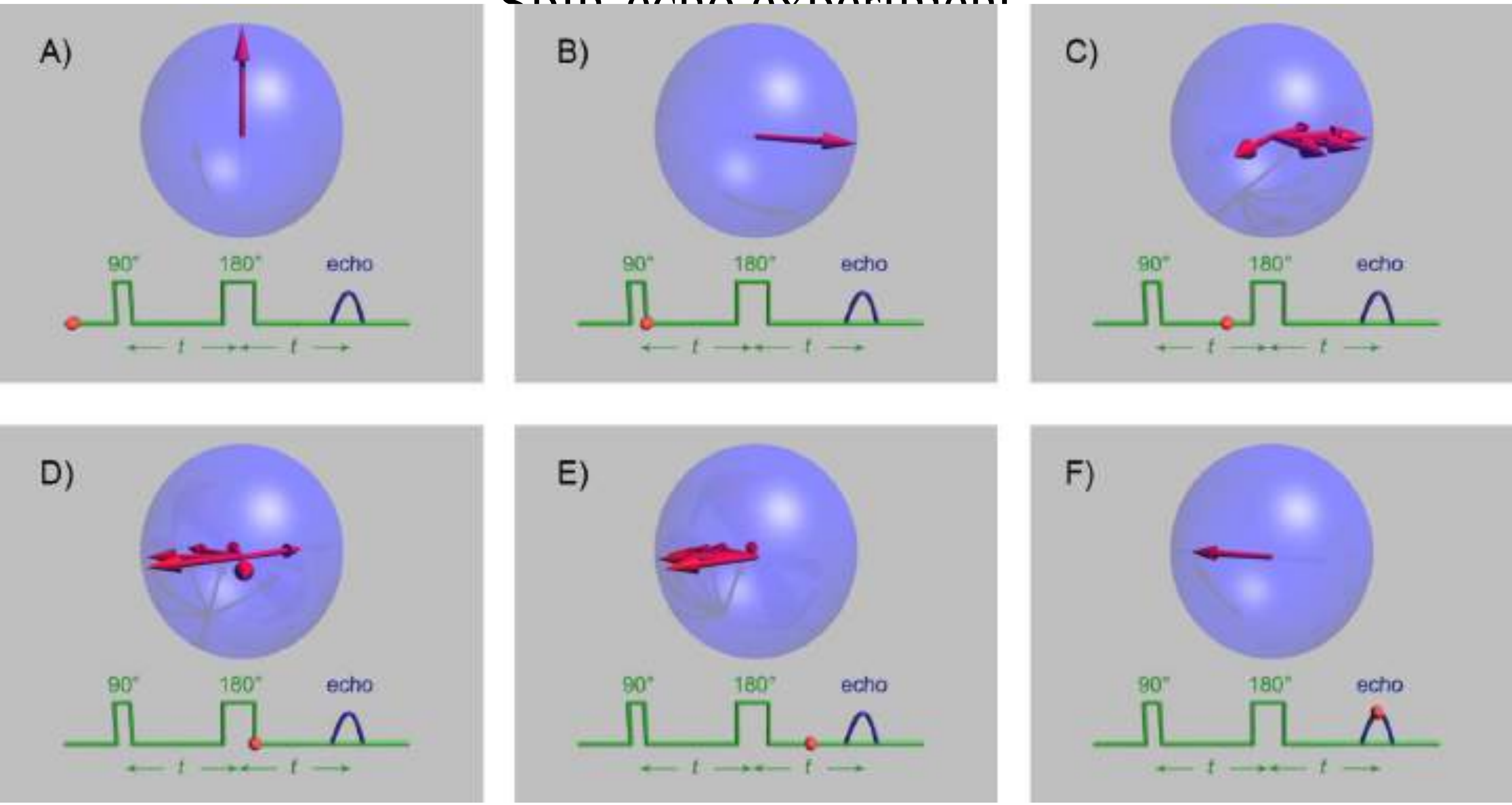
Spin-echo experiment



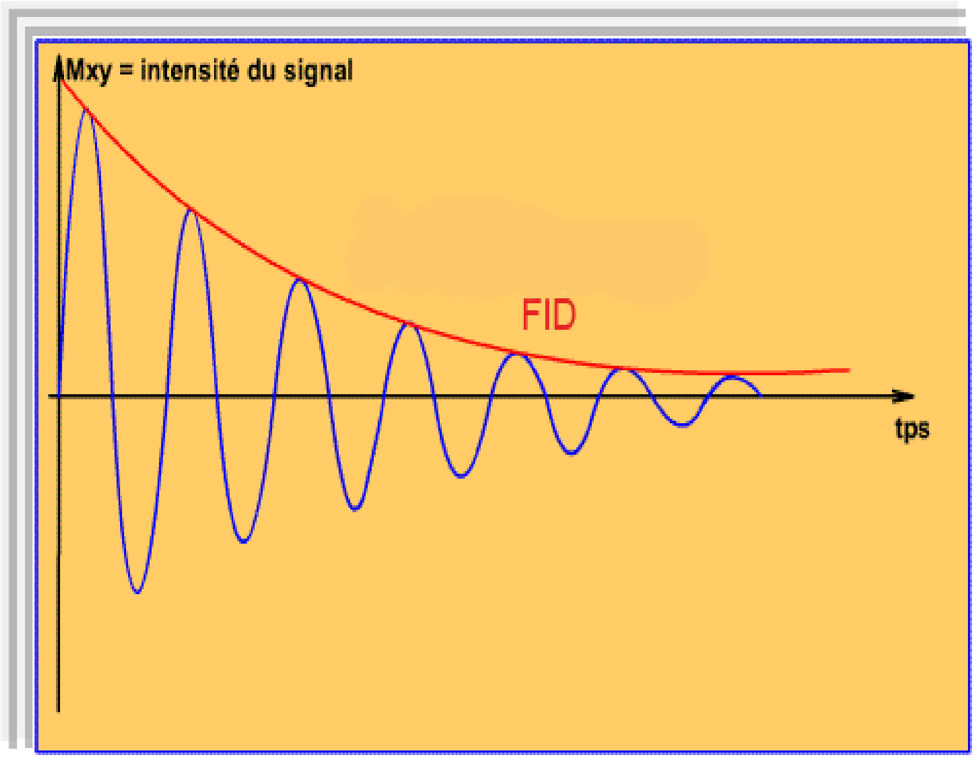


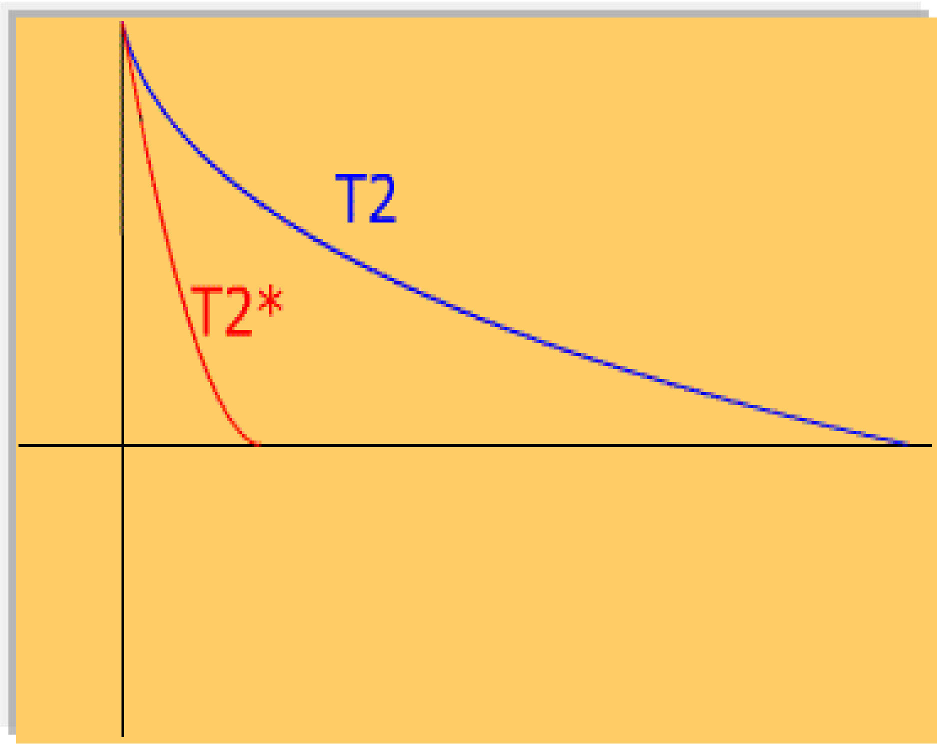
90°
180°
echo
t
t

Spin-echo experiment



The FID decreases with a time $T_2^* < T_2$ due to the static field inhomogeneities





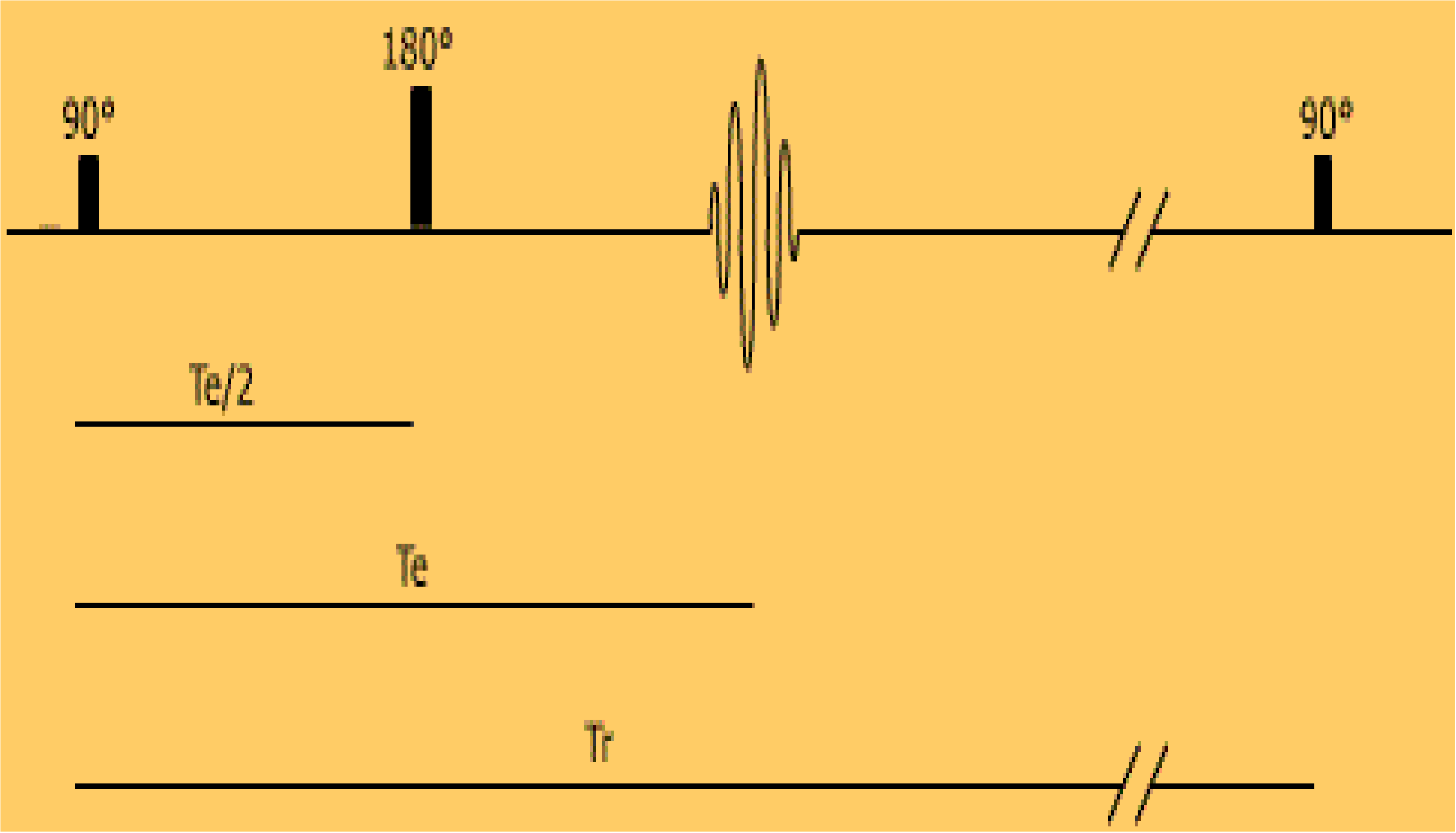
Spin-echo sequence.

TE= time between 90° pulse and signal.

small < 50ms; high > 60ms

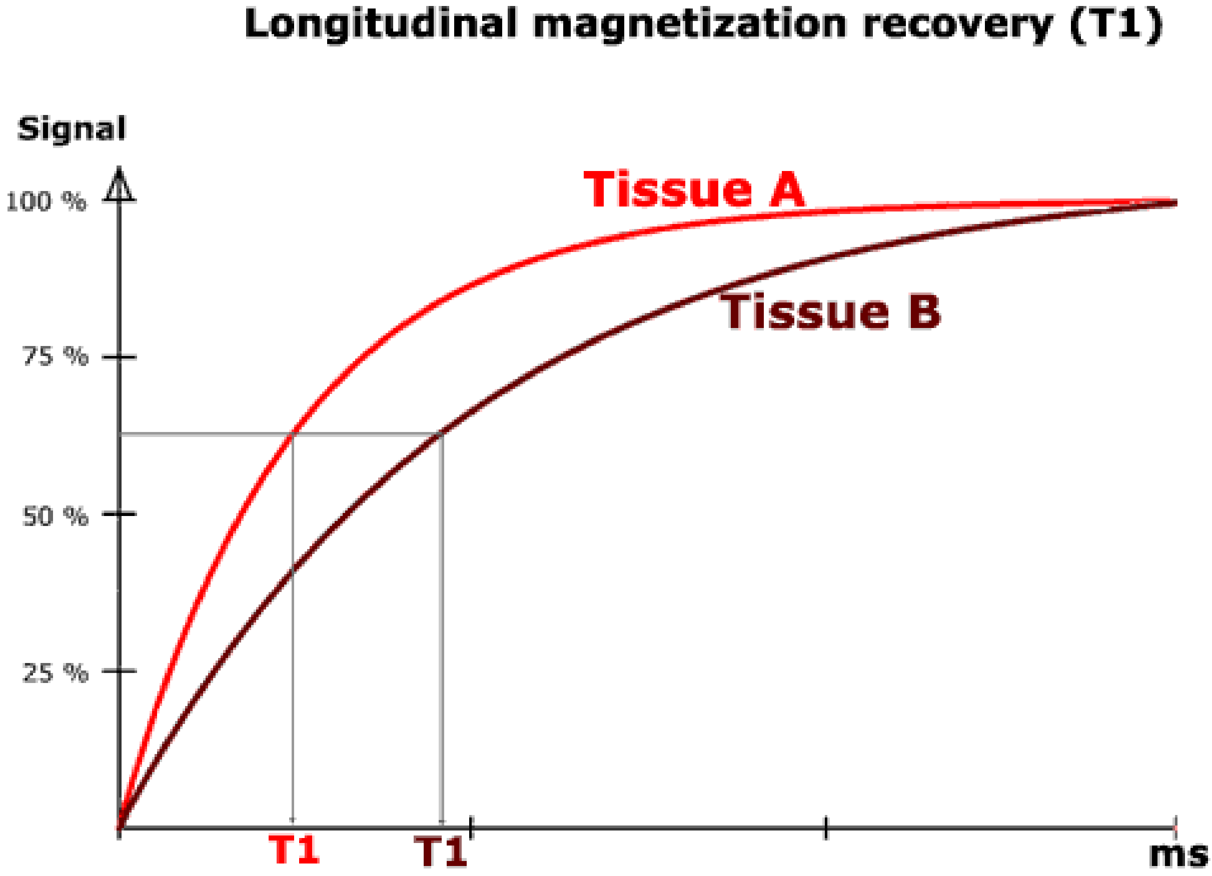
TR: Repetition time between 90° pulses.

small < 600ms; high > 1800ms



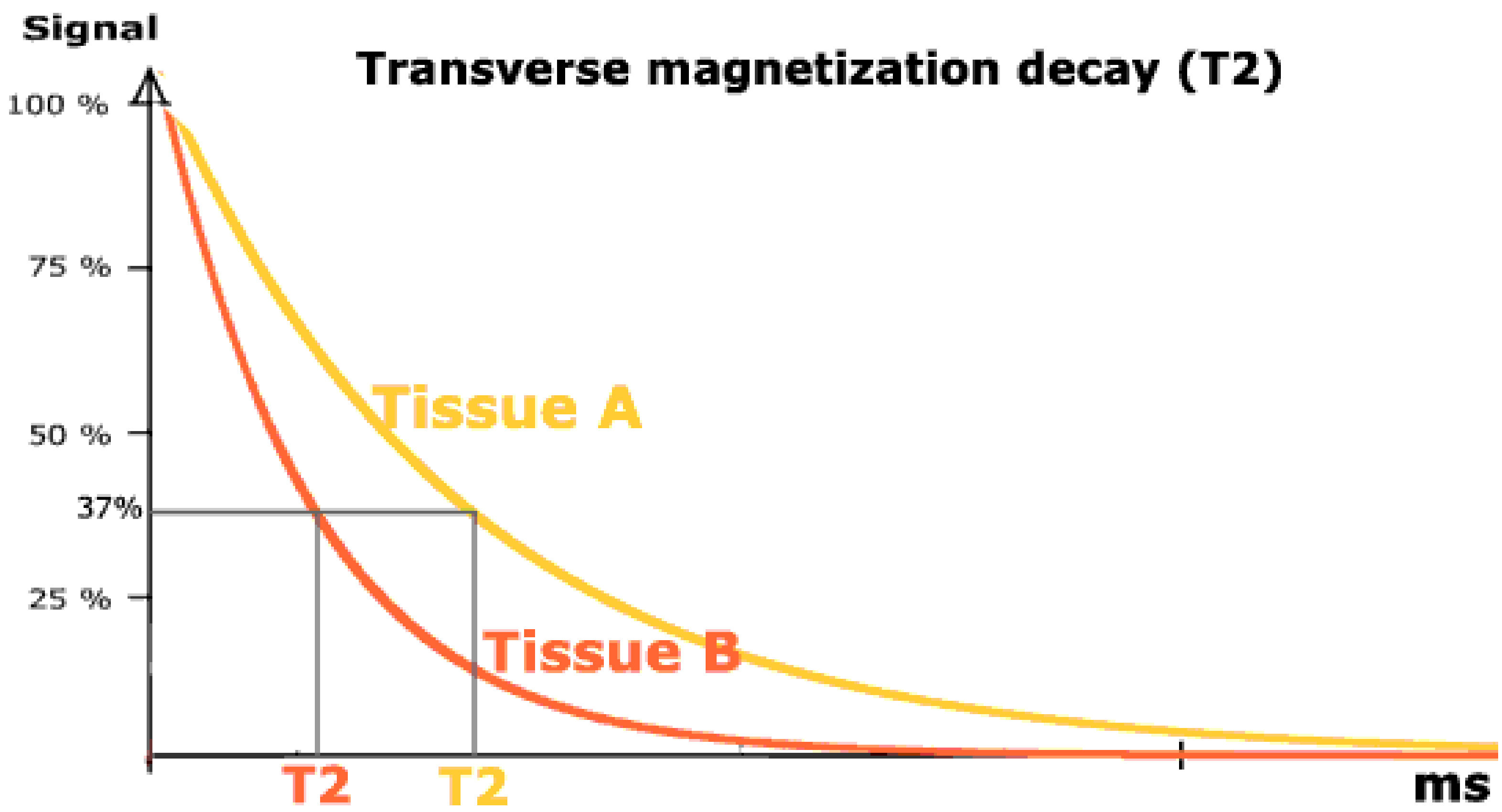
Each tissue has a specific proton density, T1 and T2 time. The NMR signal depends on these 3 factors.

After time T1, longitudinal magnetization has returned to 63 % of its final value.
T1 defines the recovery rate of longitudinal magnetization.
With a 1.5 T field strength, T1 values are about 200 to 3000 ms.



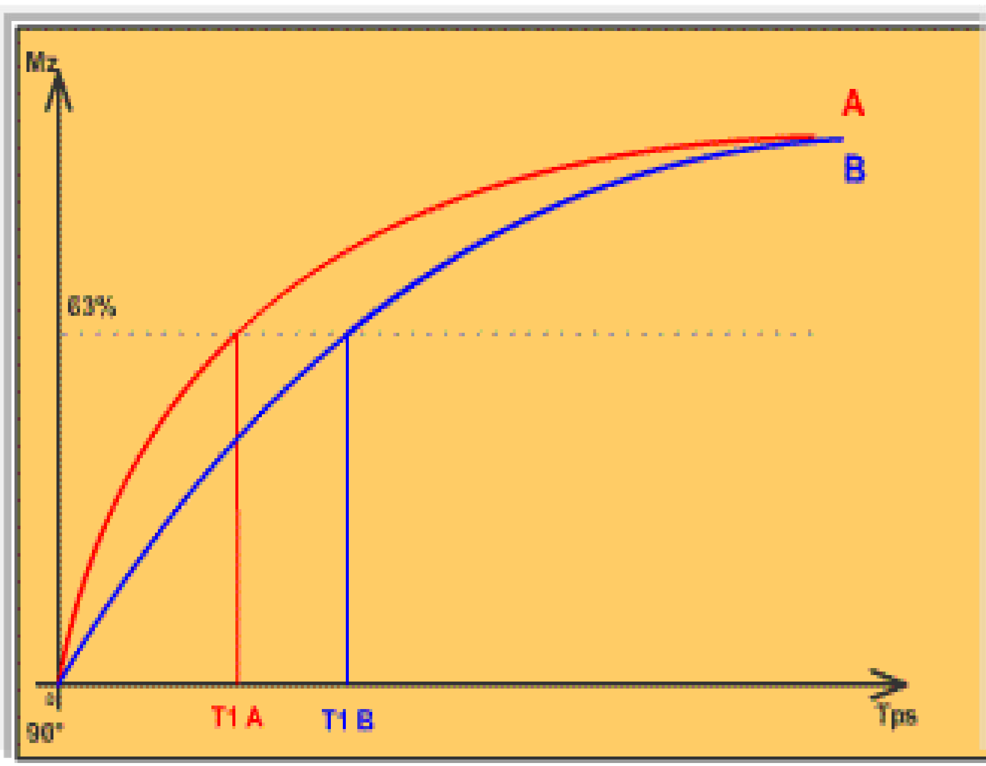
After time T2, transverse magnetization has returned to 37 % of its initial value. T2 defines the decay rate of transverse magnetization.

For example, here are transverse magnetization decay curves for 2 tissues A and B with different T2s.

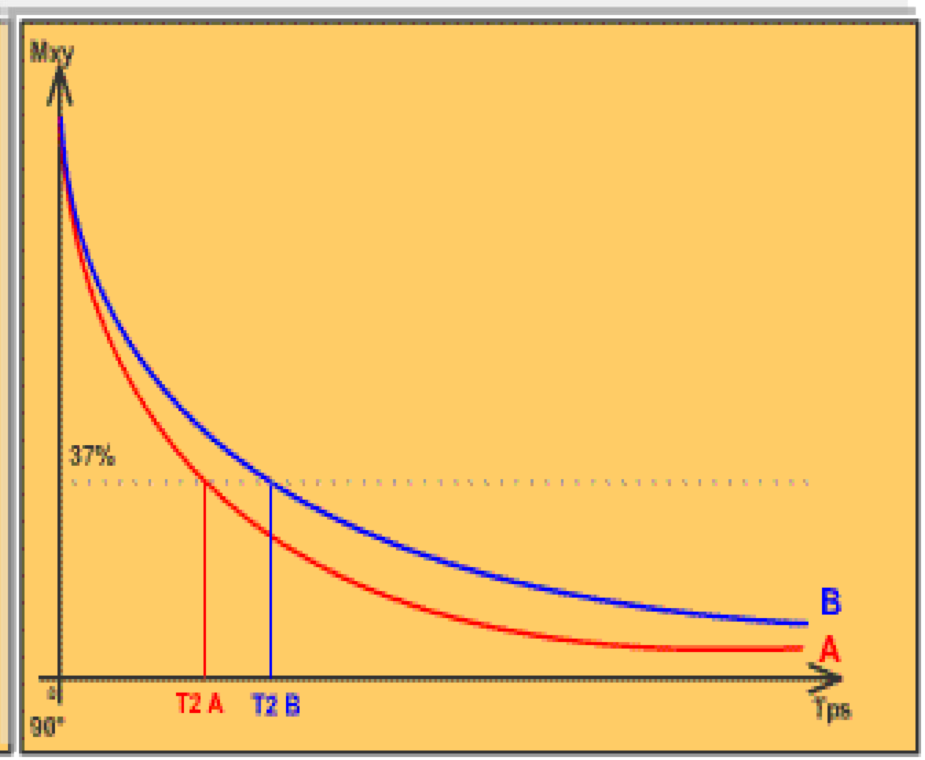


T_1 and T_2 of tissues

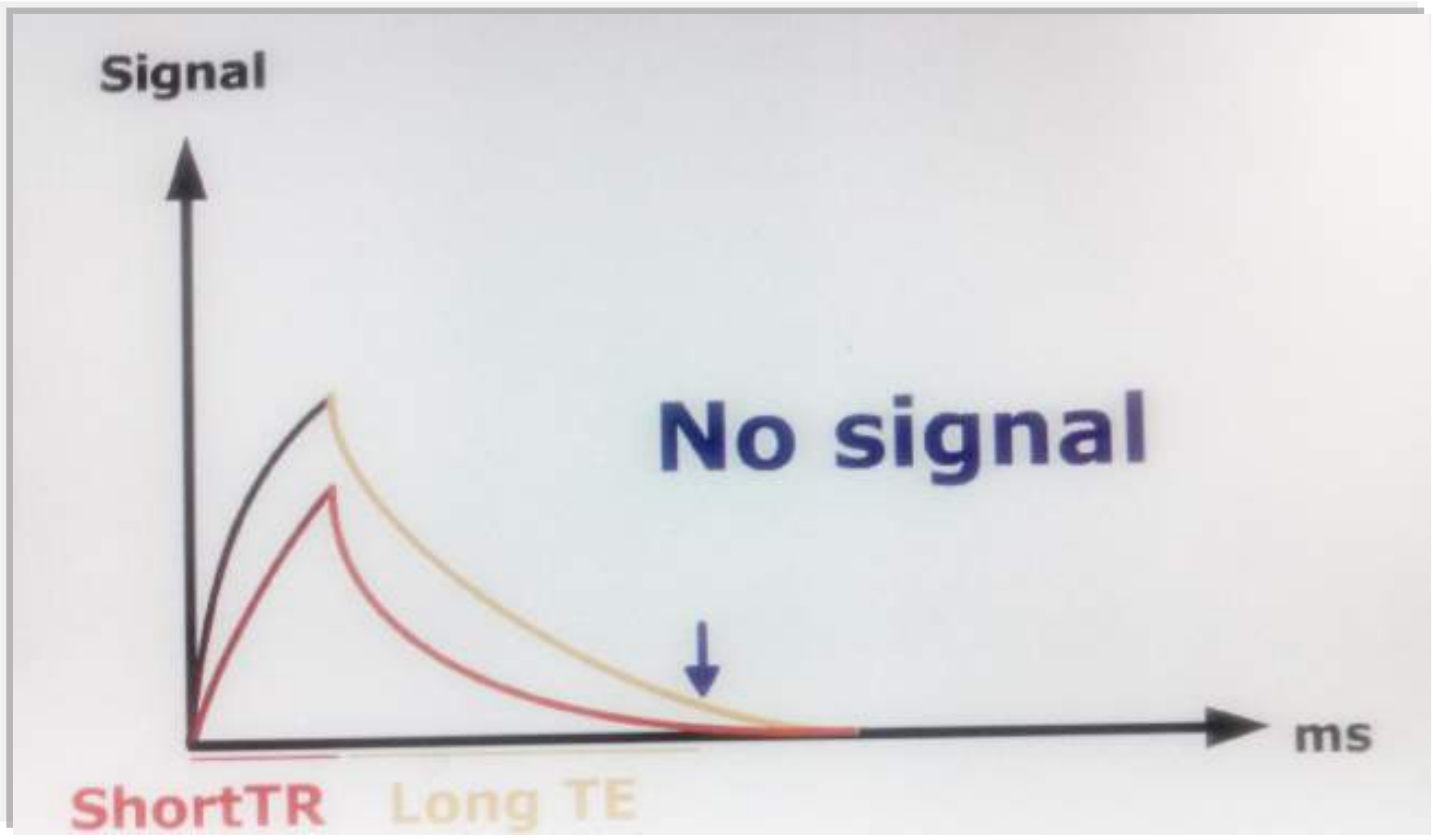
63 % of T1



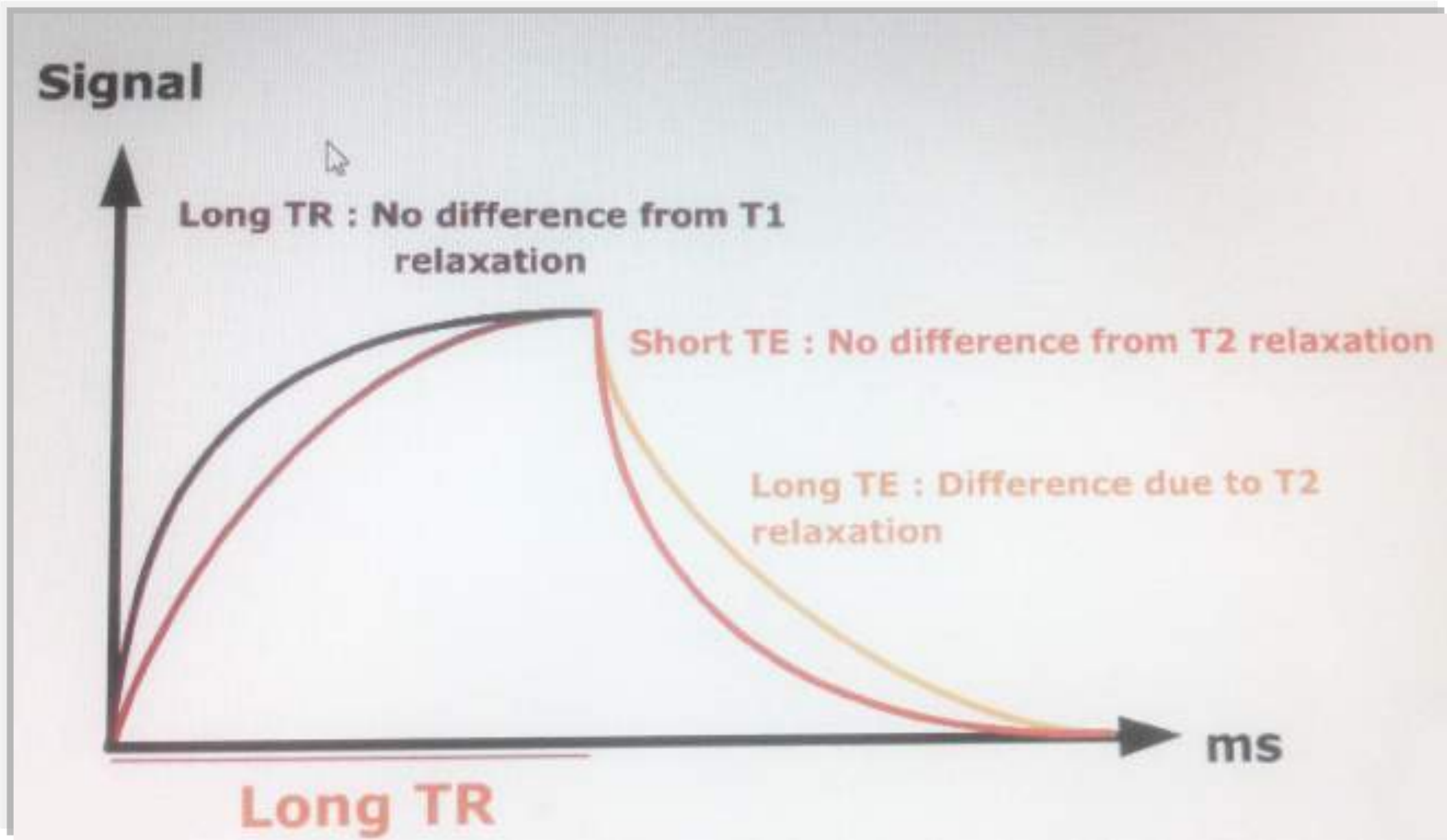
Residual : 37 %



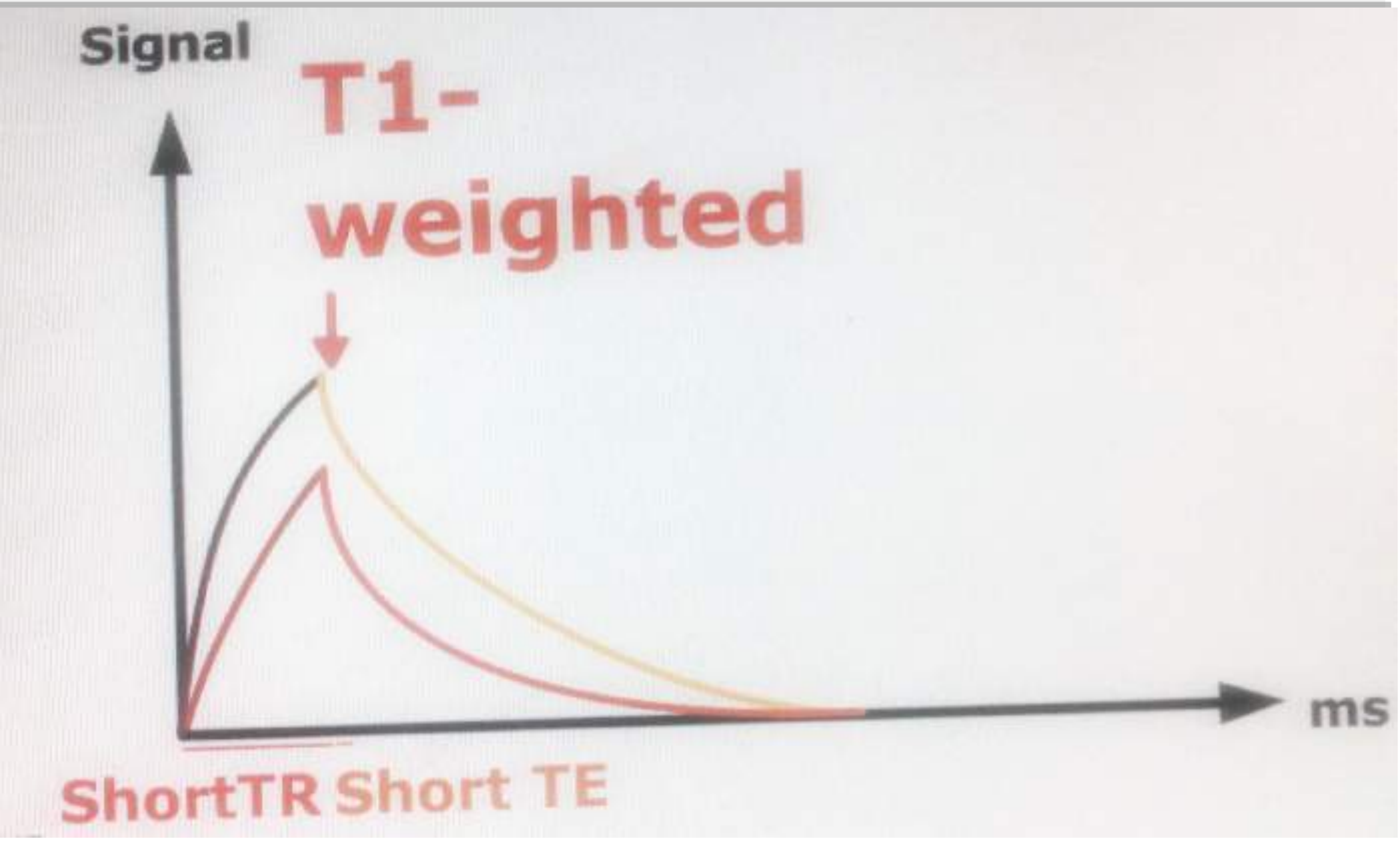
Short TR and long TE



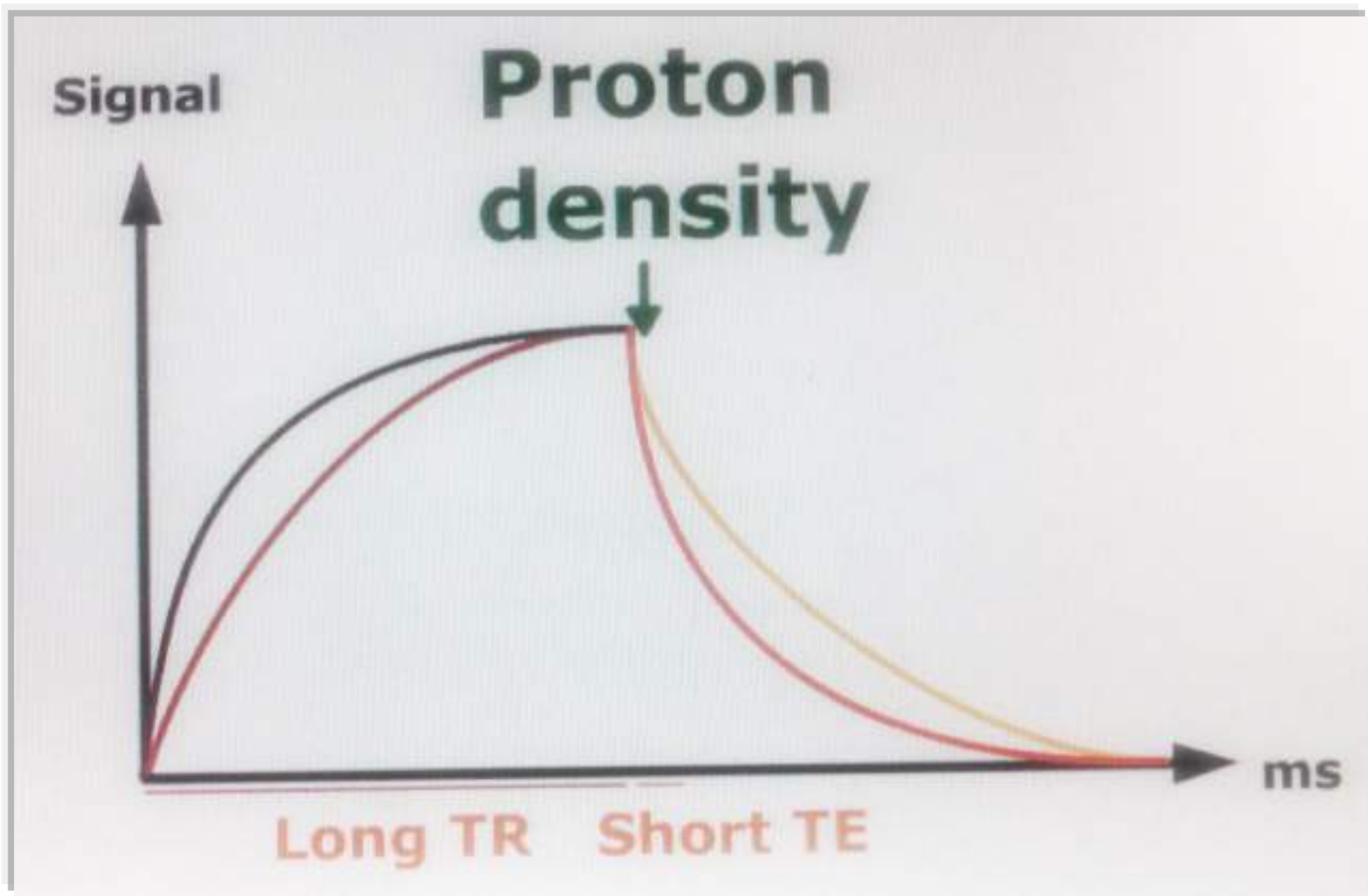
Long TR; short or long TE



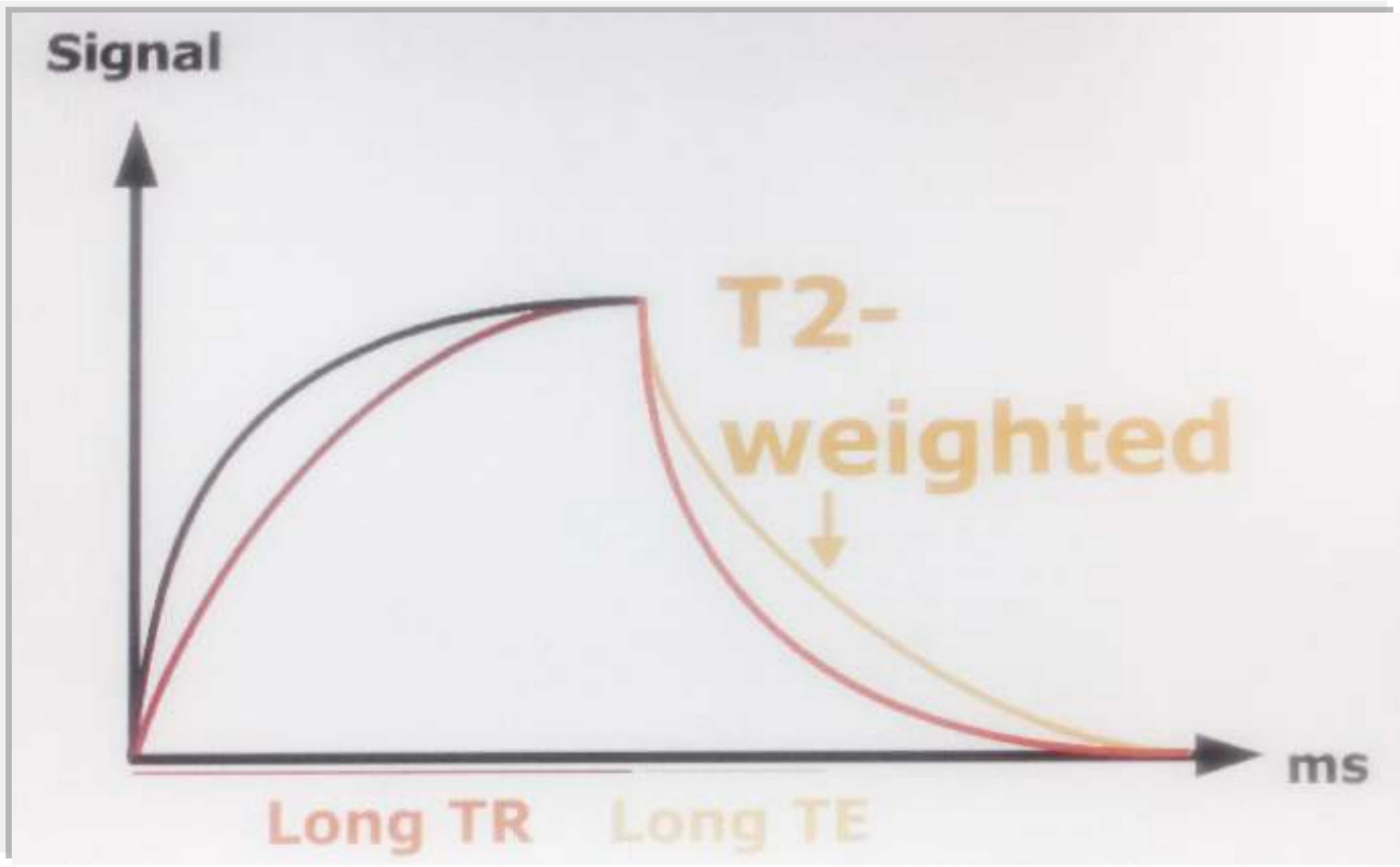
Short TR, short TE



Long TR; Short TE

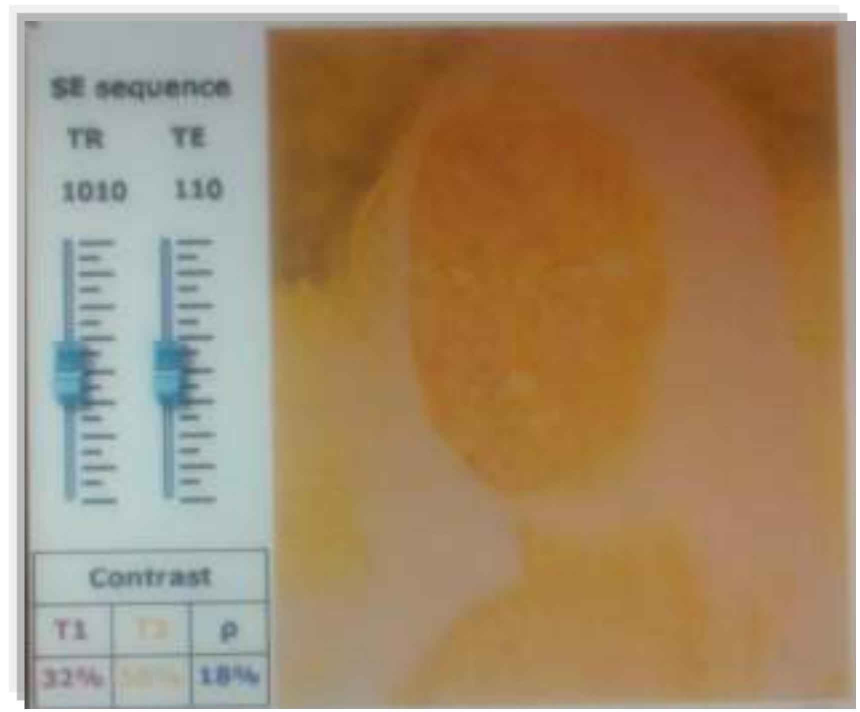


Long TR; long TE

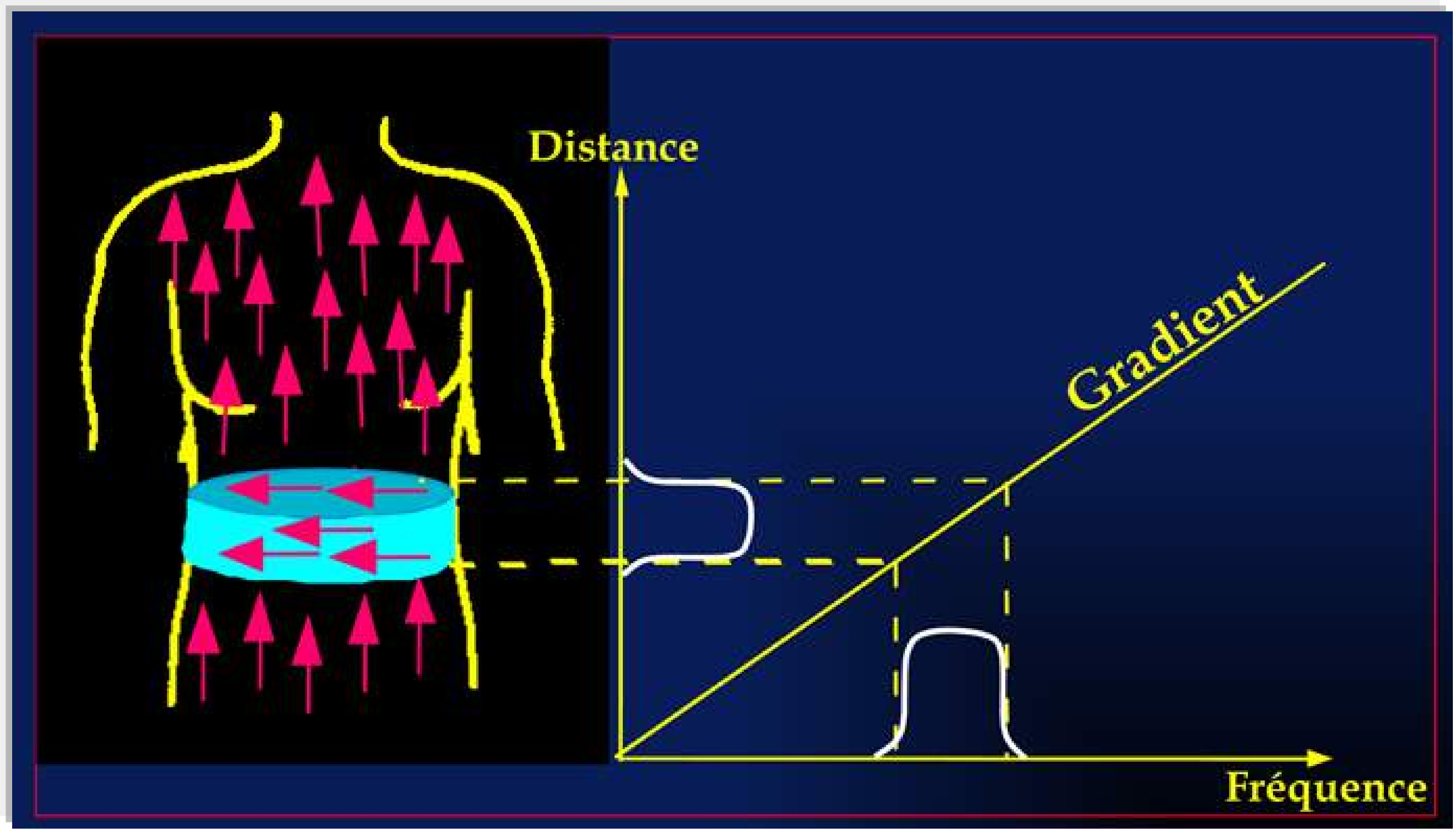



SE sequence
TR
TE
1710
110
Contrast
T1
ρ
7%
18%

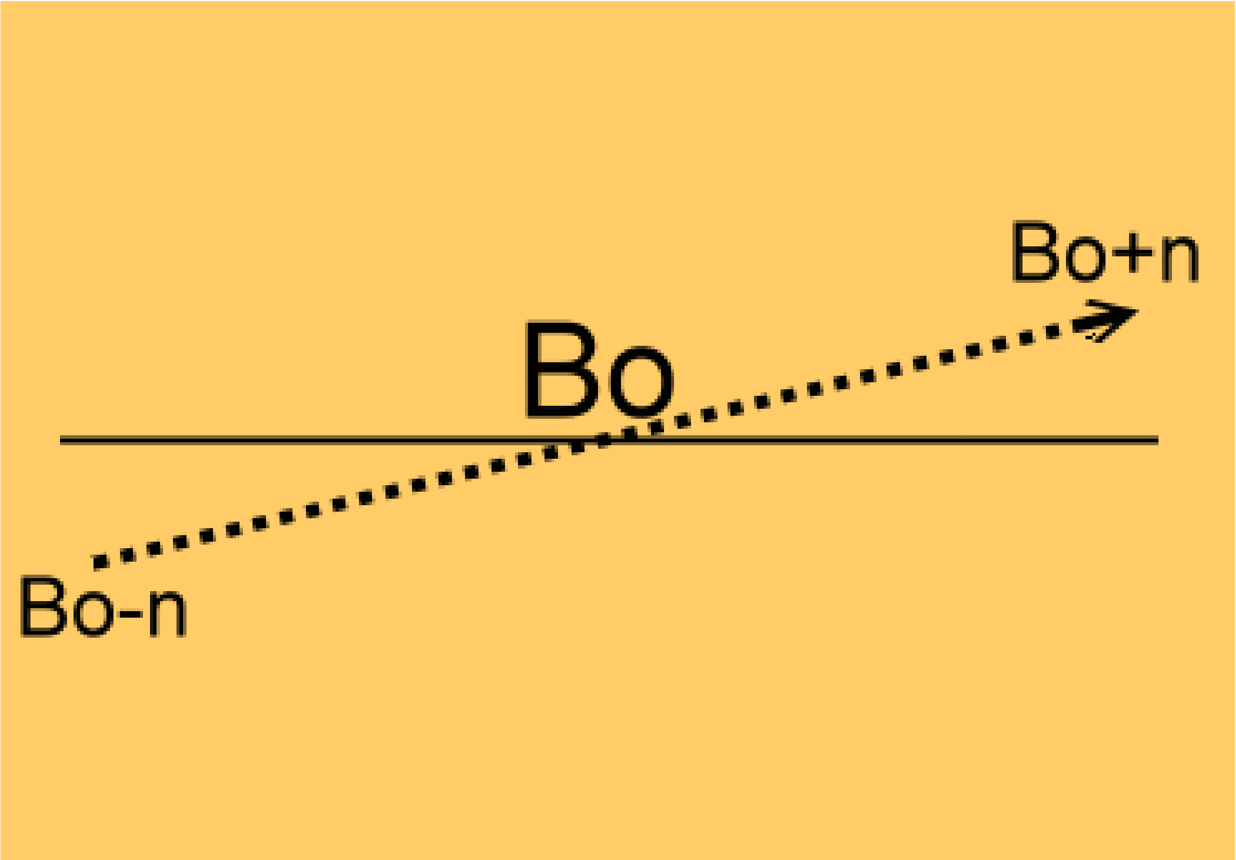

SE sequence
TR
TE
1050
200
Contrast
T1
ρ
73%
13%


SE sequence
TR
TE
1010
110
Contrast
T1
ρ
32%
18%

Selective excitation -MRI



The gradients of the magnetic field are generally linear and symmetrical



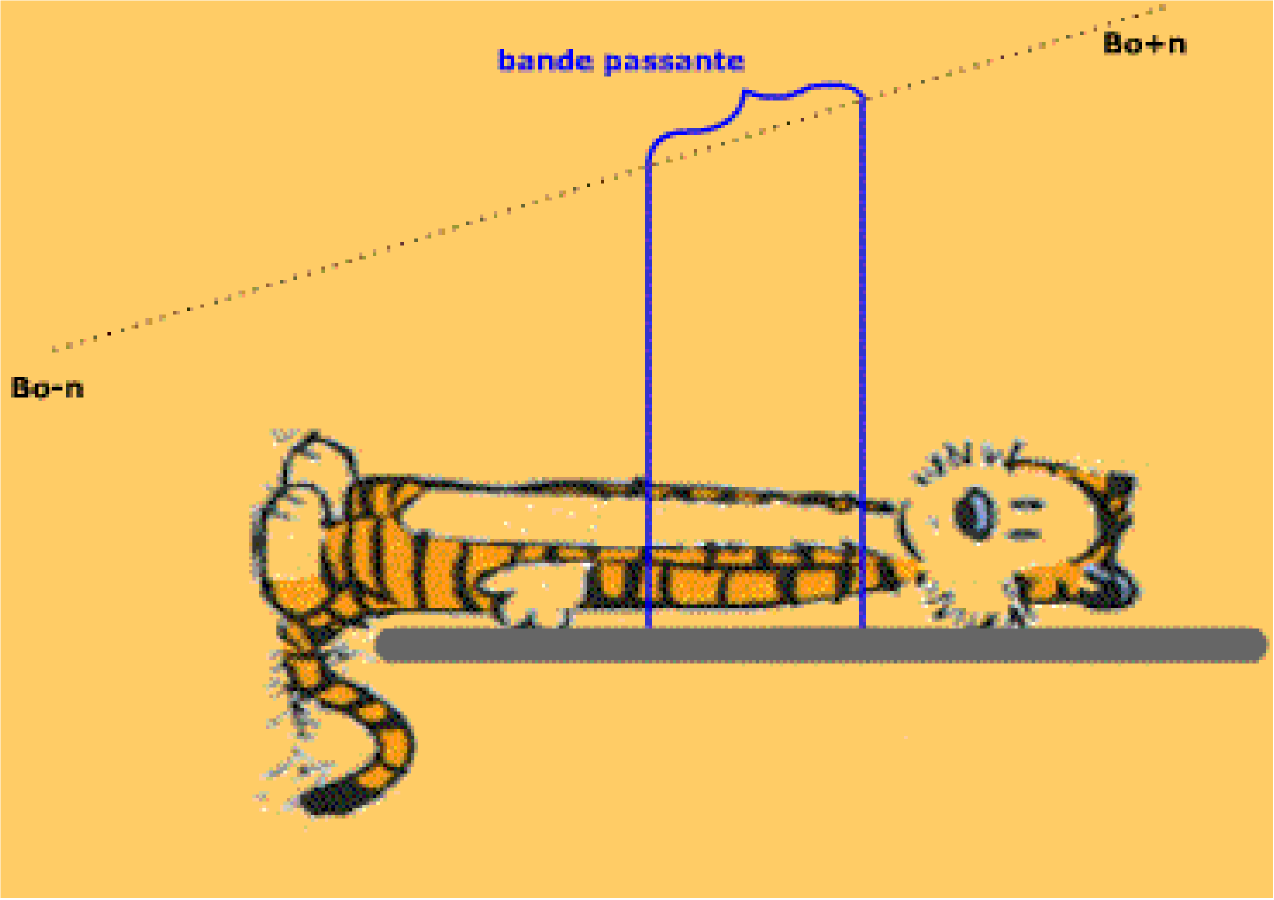
GSS: gradient of the slice selection

This gradient is applied during the Rf pulses

The thickness of the slice is determined :

-by the slope of the gradient G if the frequency band, Δν, is constant;

-by the frequency band if the slope of the gradient G is constant.



VID_20170513_174342_049.mp4

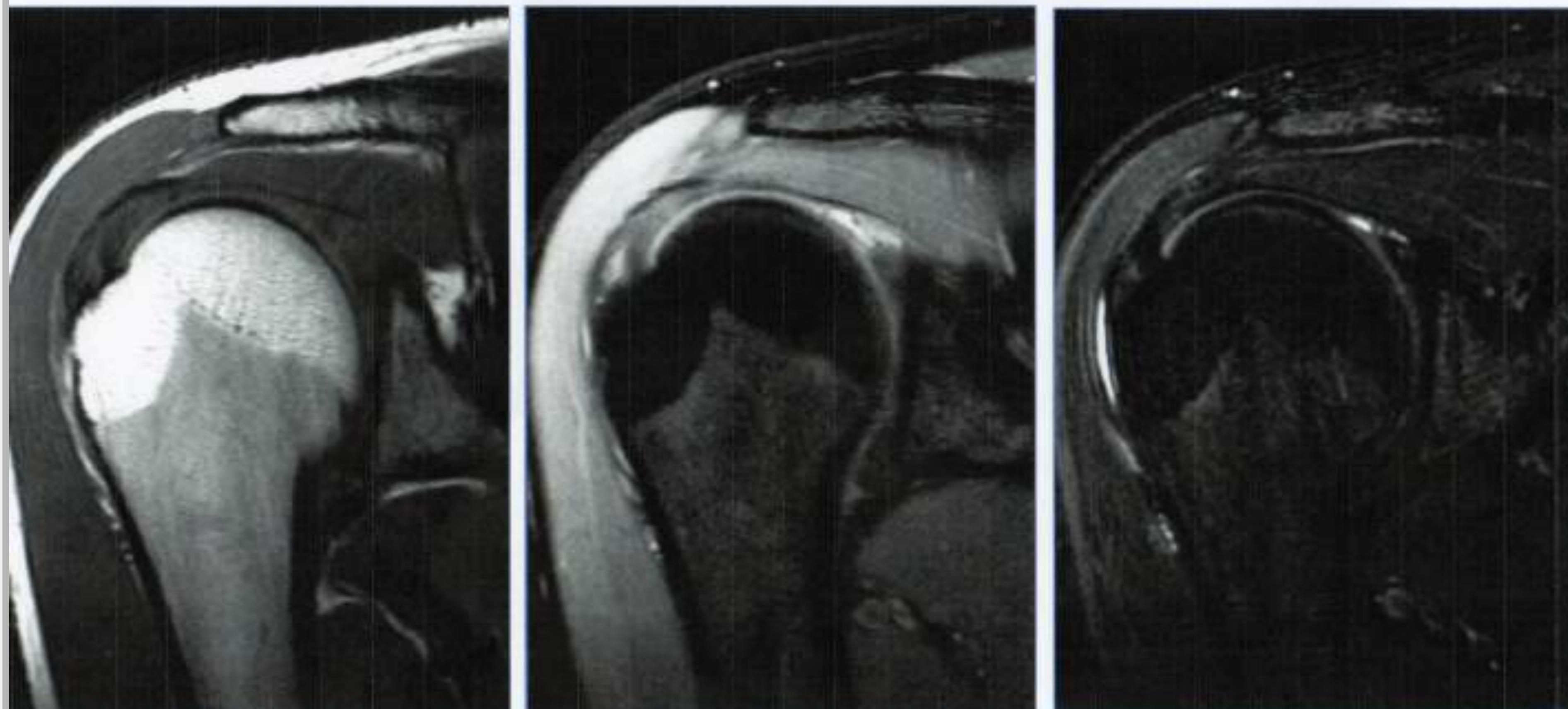
Rough order of relaxation times

Relaxation Times / Human Tissues	T_1	T_2
Cephalo-rachidian liquid	2500 ms	2000 ms
Gray matter	900 ms	90 ms
White matter **Liver**	750 ms 450 ms	80 ms 50 ms
Fat	300 ms	40 ms

Weighting T_1 and T_2

Tissue	**Weighting T_1**	**Weighting T_2**
Fat	Hyperintense (blanc)	Hyperintense (blanc)
Cortical bone	Hypointense (noir)	Hypointense (noir)
Bone marrow (adult)	Hyperintense (blanc)	Hyperintense (blanc)
Tendons /ligaments /muscles	Hypointense (noir)	Hypointense (noir)
Simple Cyst	Hypointense (noir)	Hyperintense (blanc)

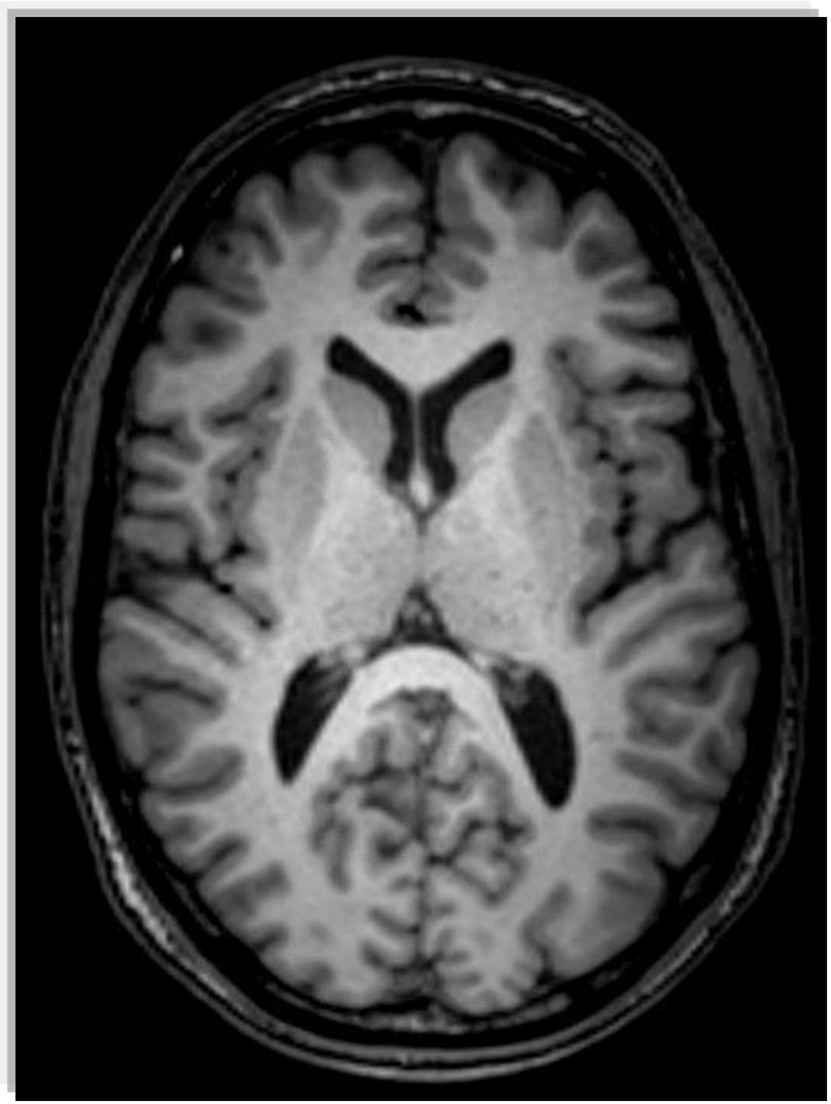
Spin-Echo Contrast Variations



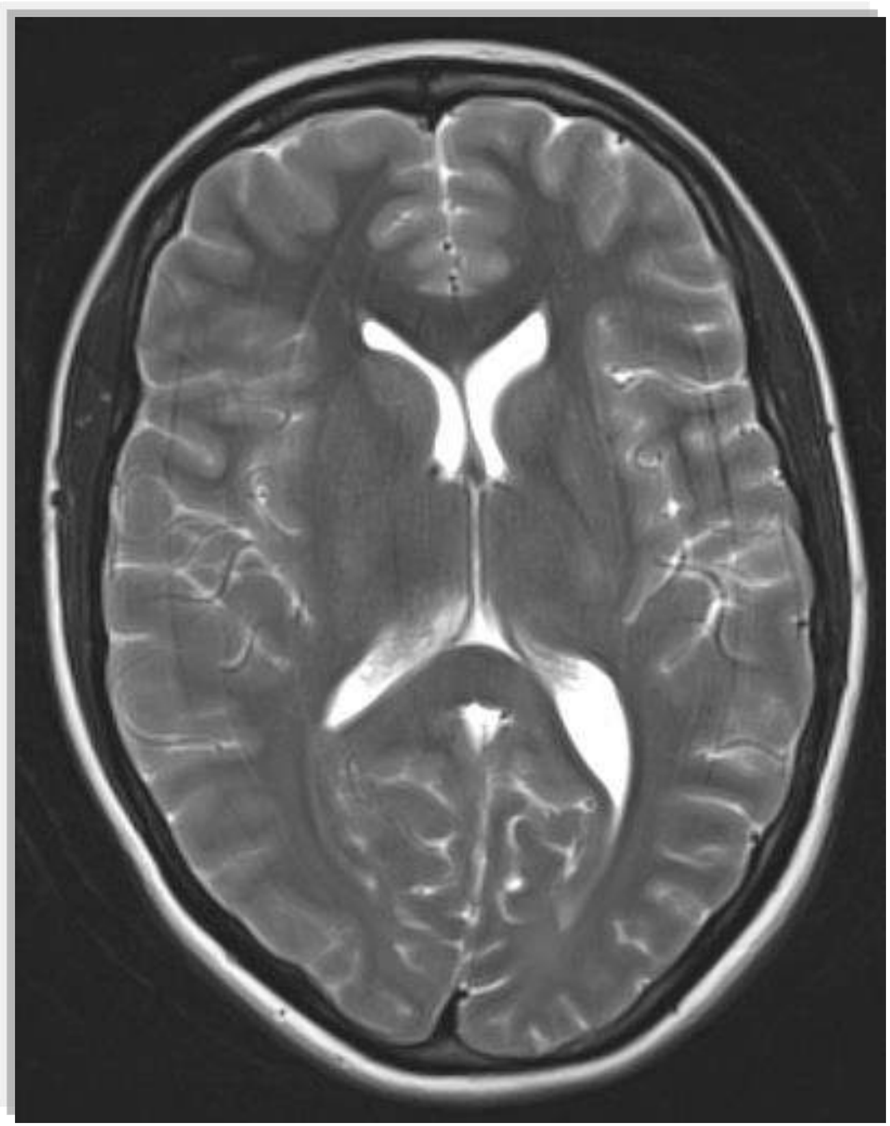
(Coronal shoulder images showing rotator cuff tear)

Normal Cranium

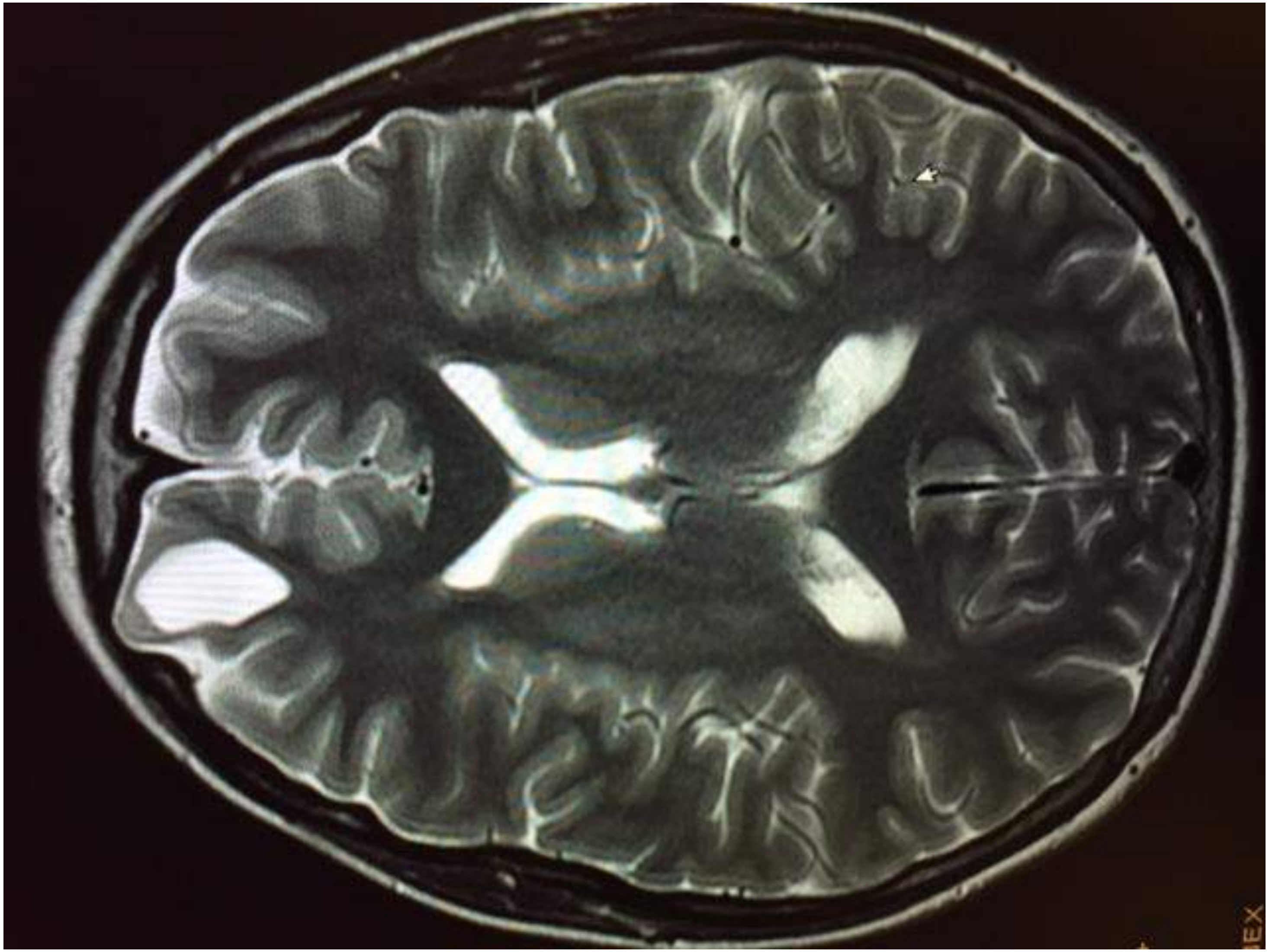
Axial section T_1

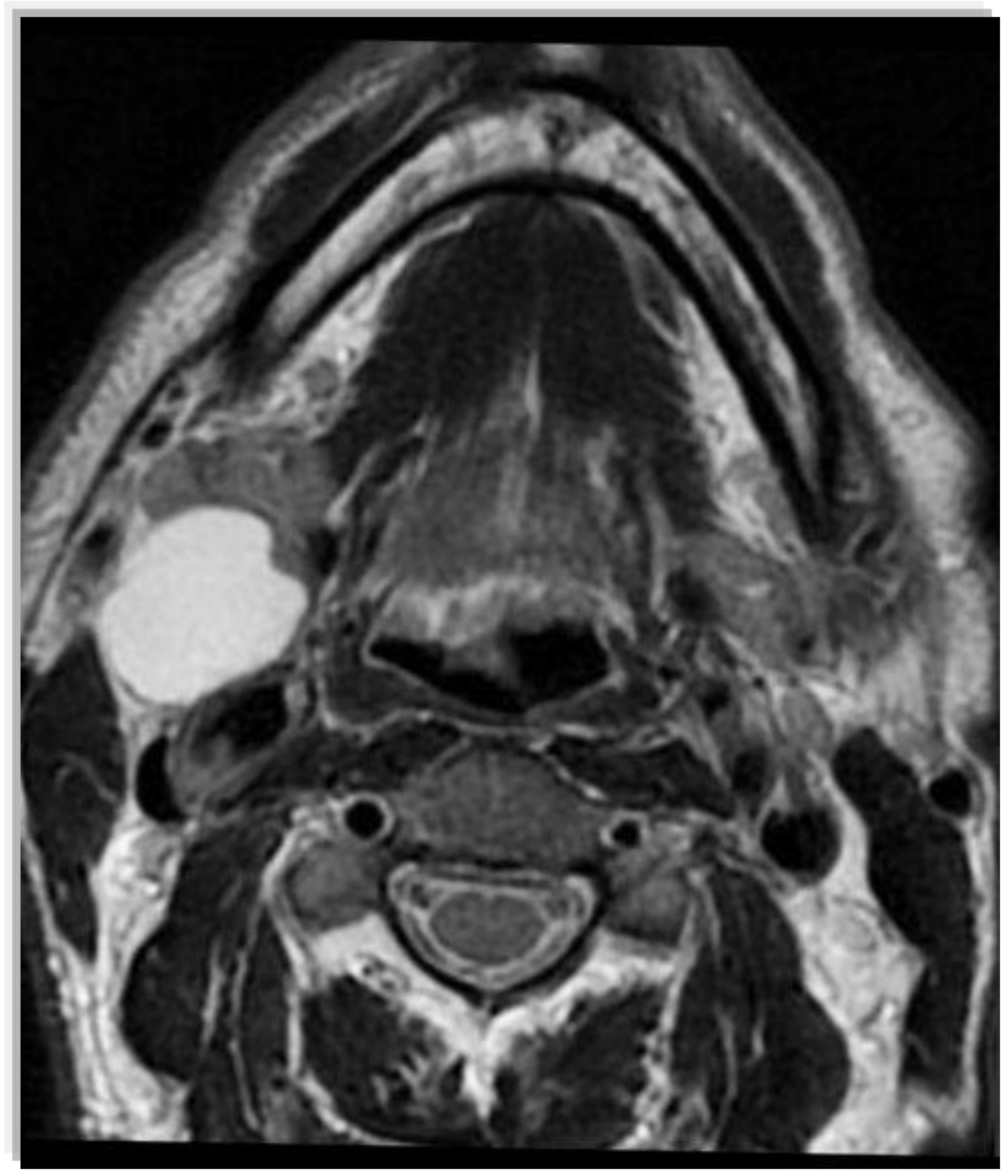


Axial section T_2

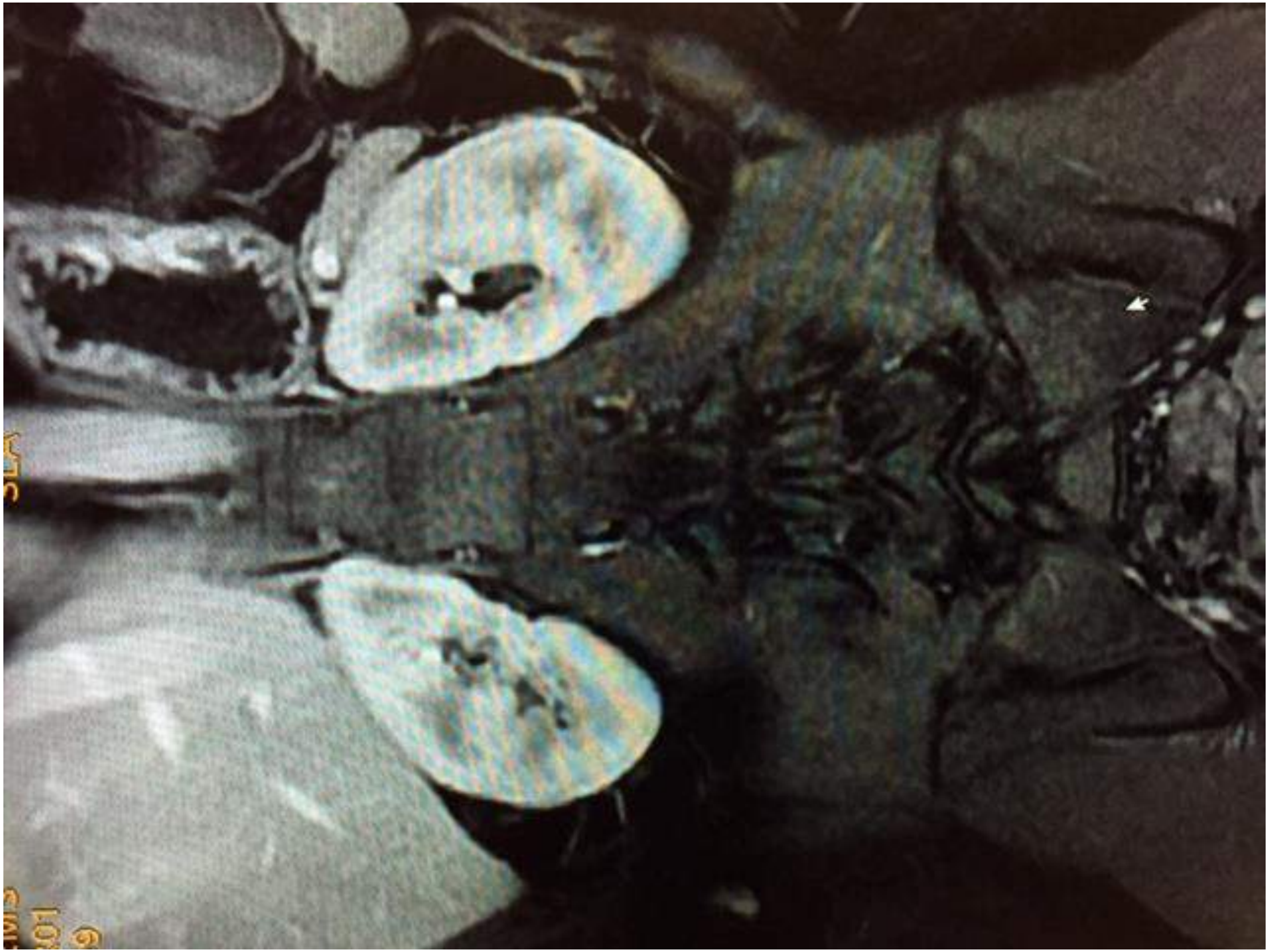


Benign cerebral tumour





Normal kidney



Normal liver; normal left kidney

Hepatic tumor: angioma

Normal womb, bladder (vesica) and rectum

Spine (vertebral column), spinal cord

Effect of a contrast agent in MRI:
Increases the difference of the signal intensity between two adjoining tissues

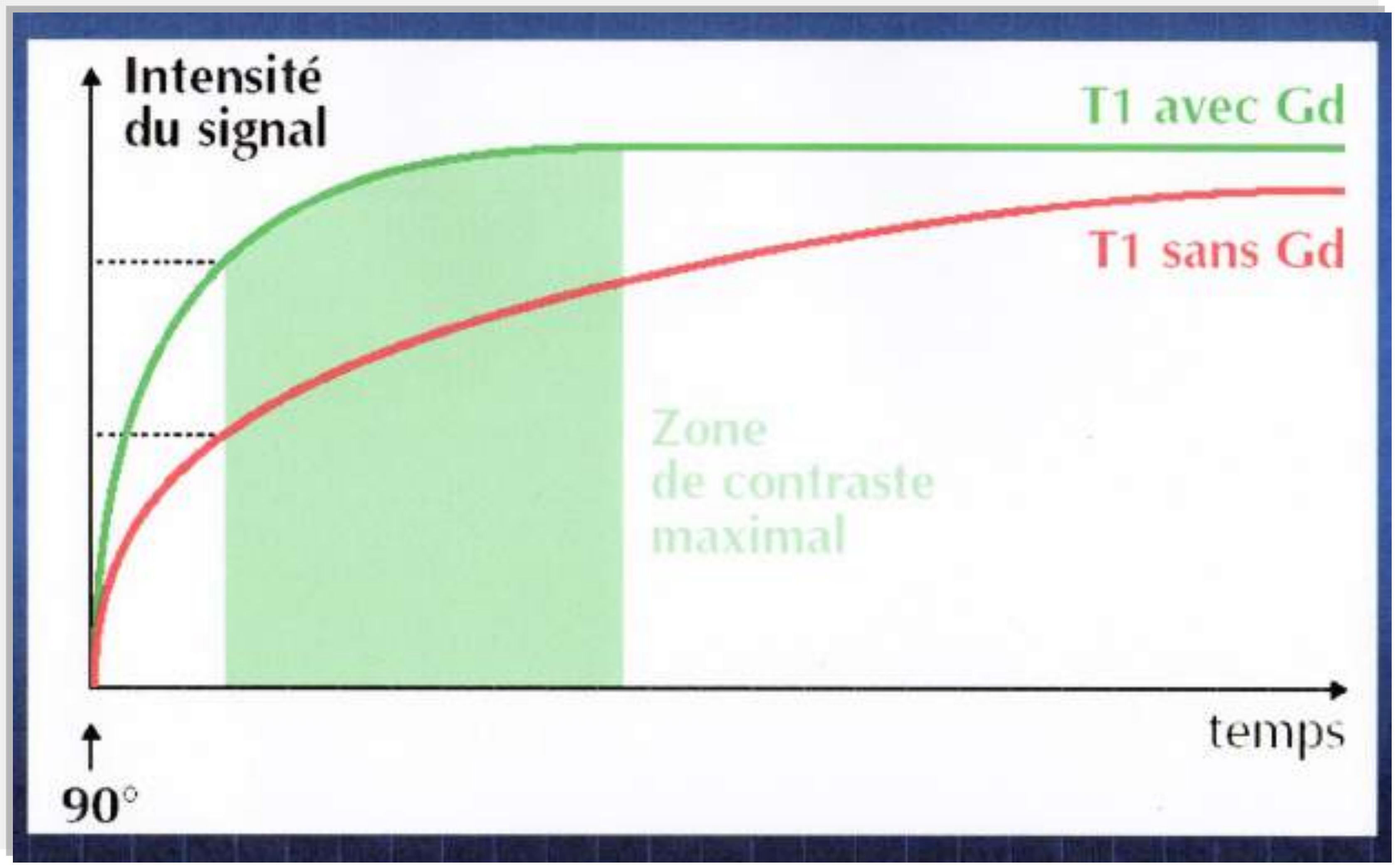
-:-:-:-:-:-:-

Contrast Mechanism in MRI

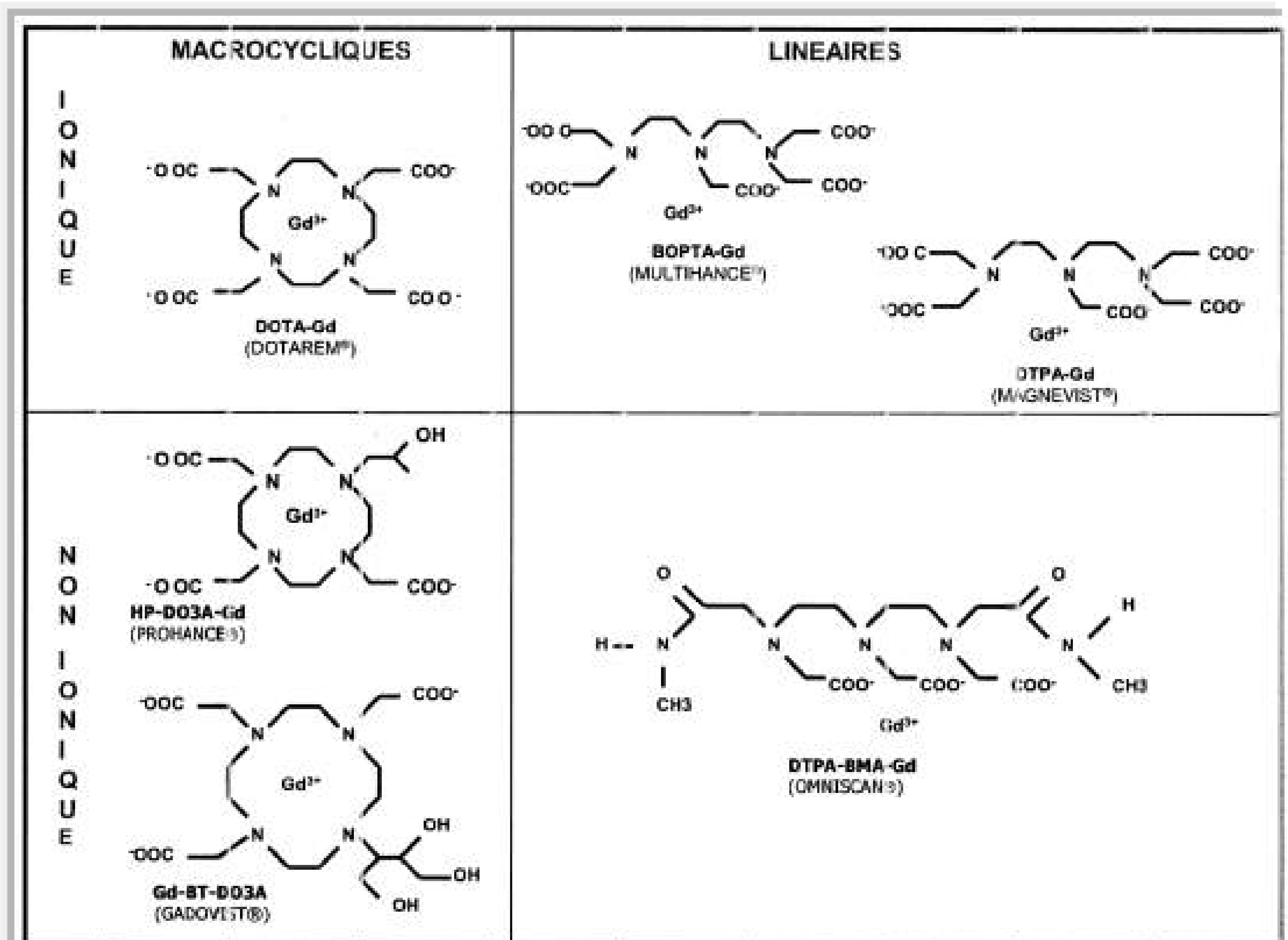
-Difference of the proton density (cannot be modified)
-Modification of T1 and T2 relaxation times
-Susceptibility effects (T2*)
-Resonance frequency shifting

Influence of Ga on T1(with,without)

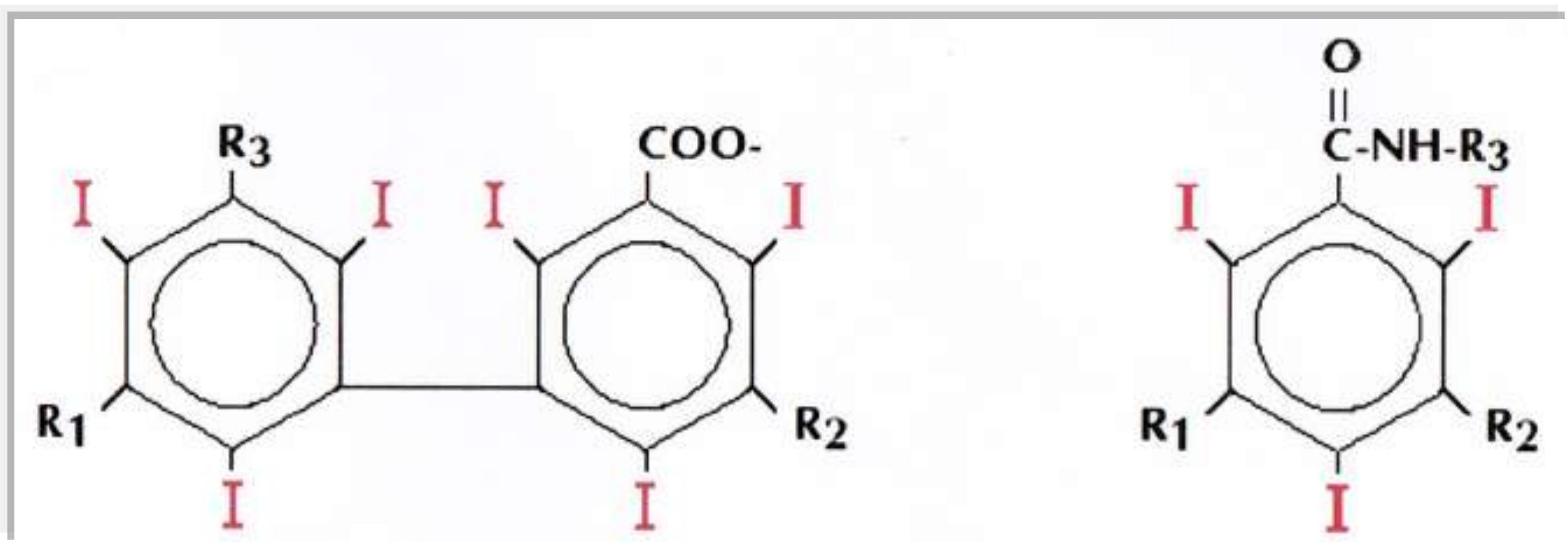
green zone: maximum contrast



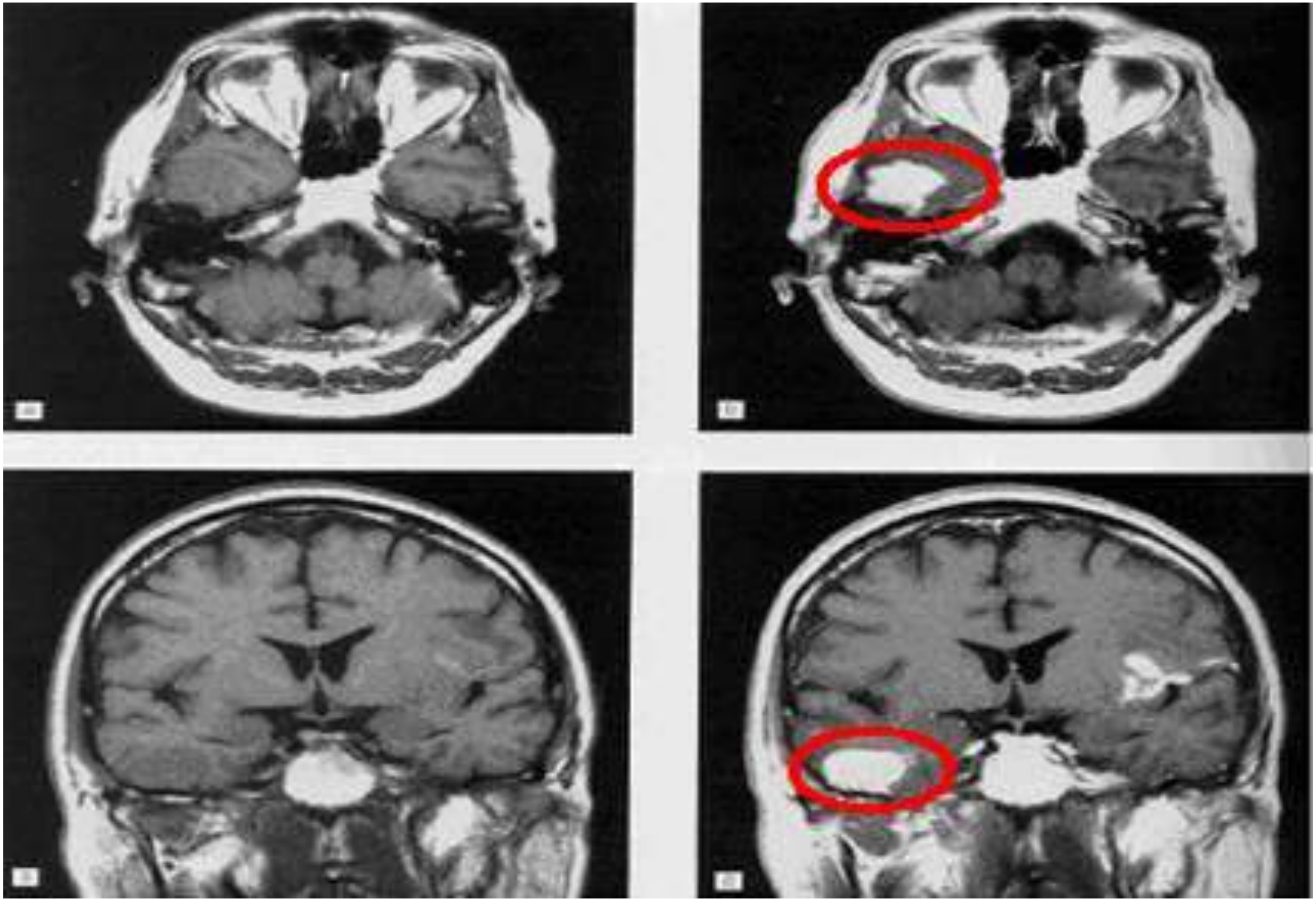
Complexes with gadolinium



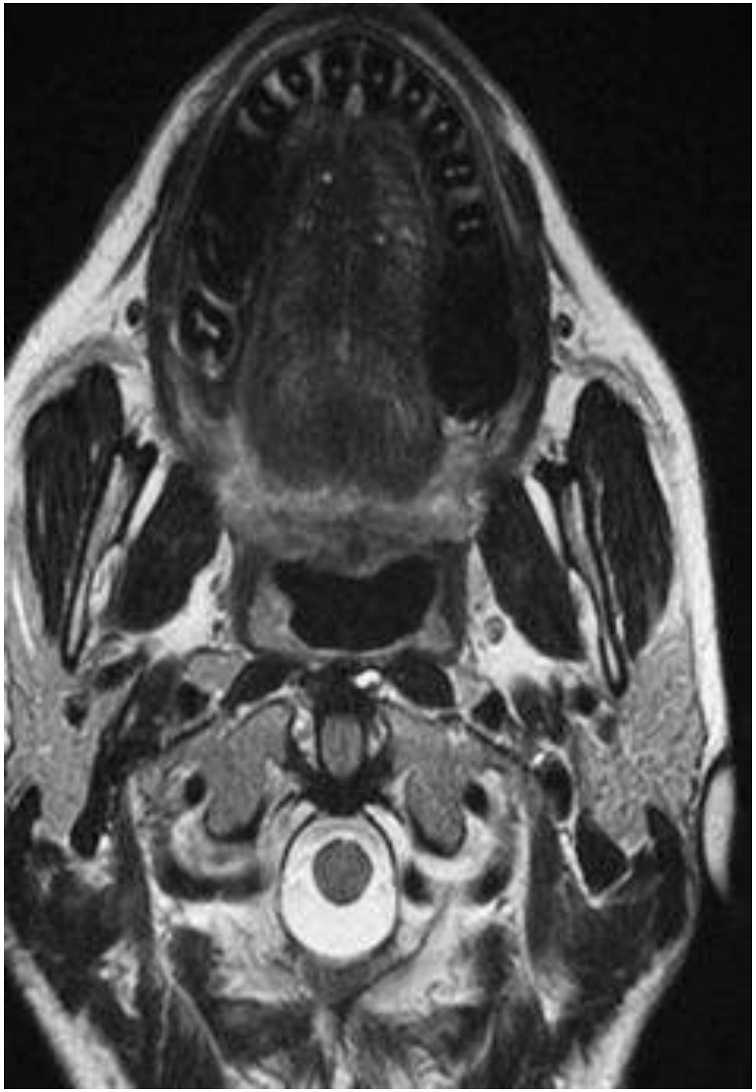
Iodide organic compounds

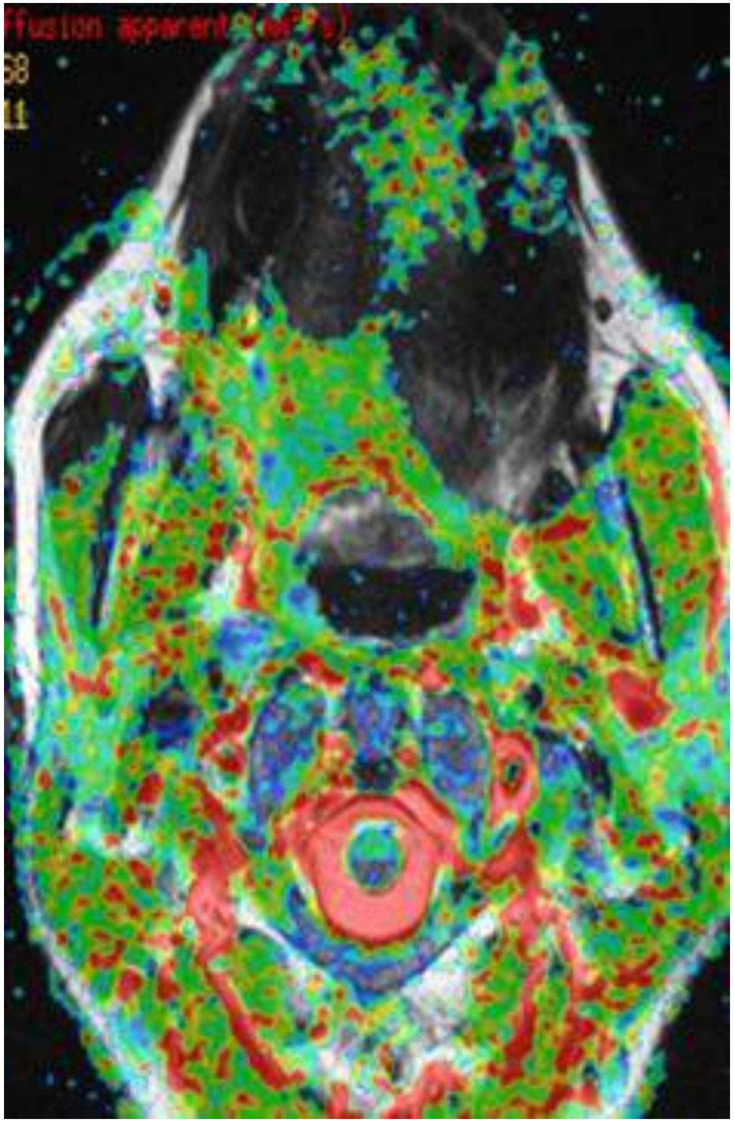


Effect of a contrast agent in MRI: increases the difference of the signal intensity between two adjoining tissues



MRI with contrast agents





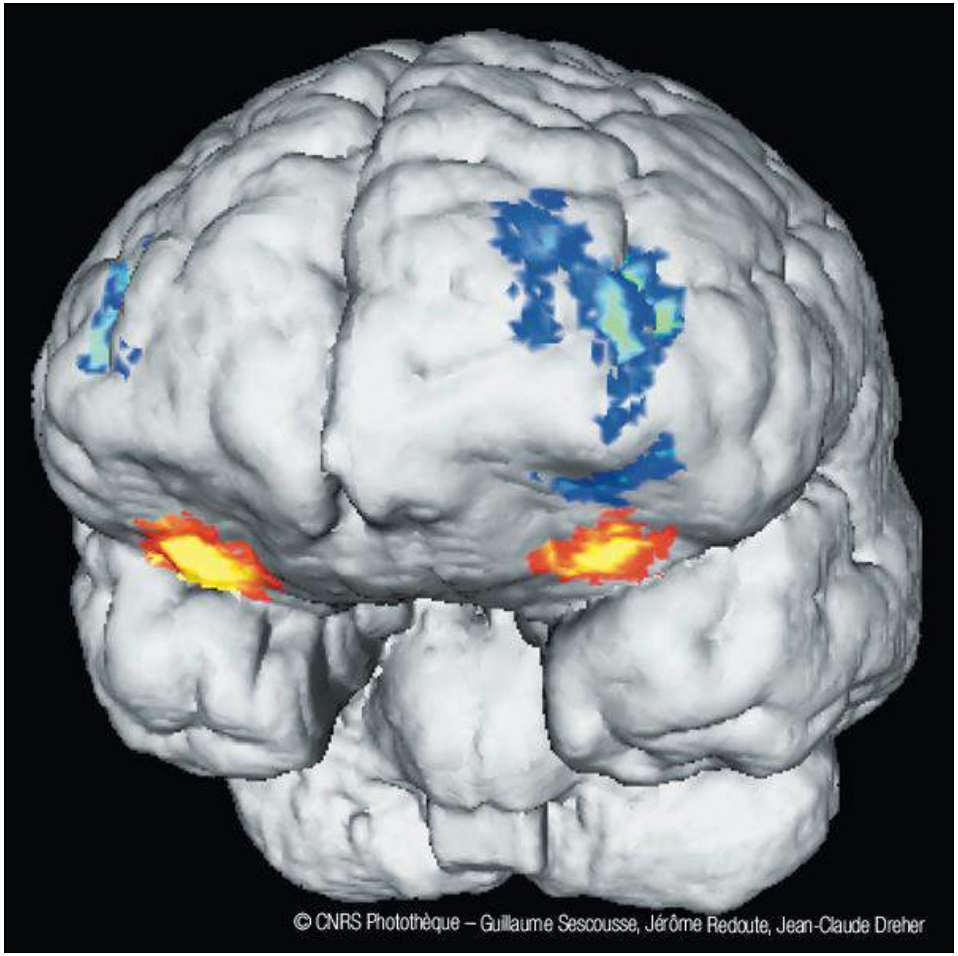
Functional MRI

Since the detection of images is very fast (< 1s) and the resolution is <1 mm, it is possible to detect the functional activity of the brain.

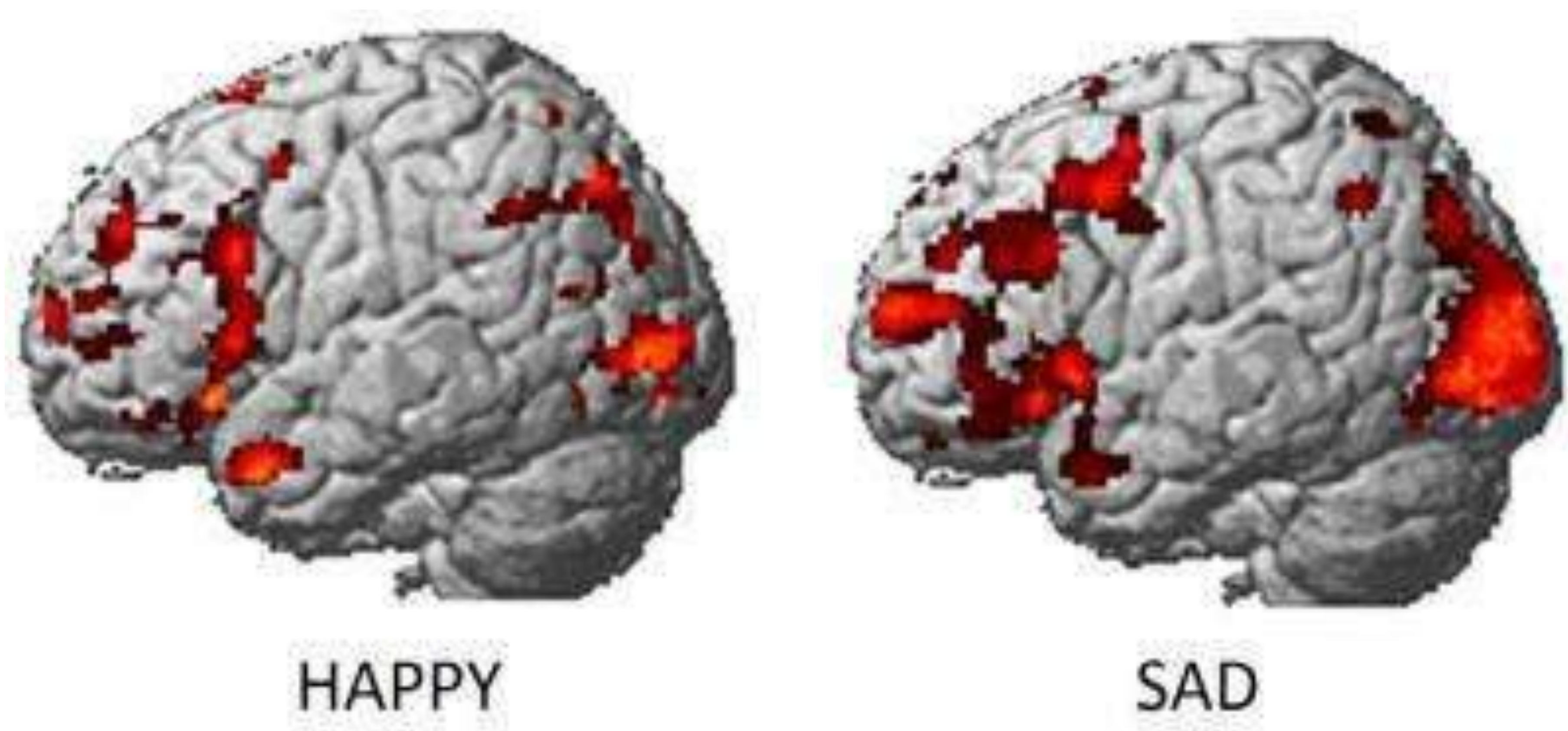
The principle consists of the exchange between the oxyhaemoglobine HbO and the desoxyhaemoglobine which increases locally in the space activated by the arrival of fresh blood.

Functional MRI.

Left: erotic images; right:saving of money



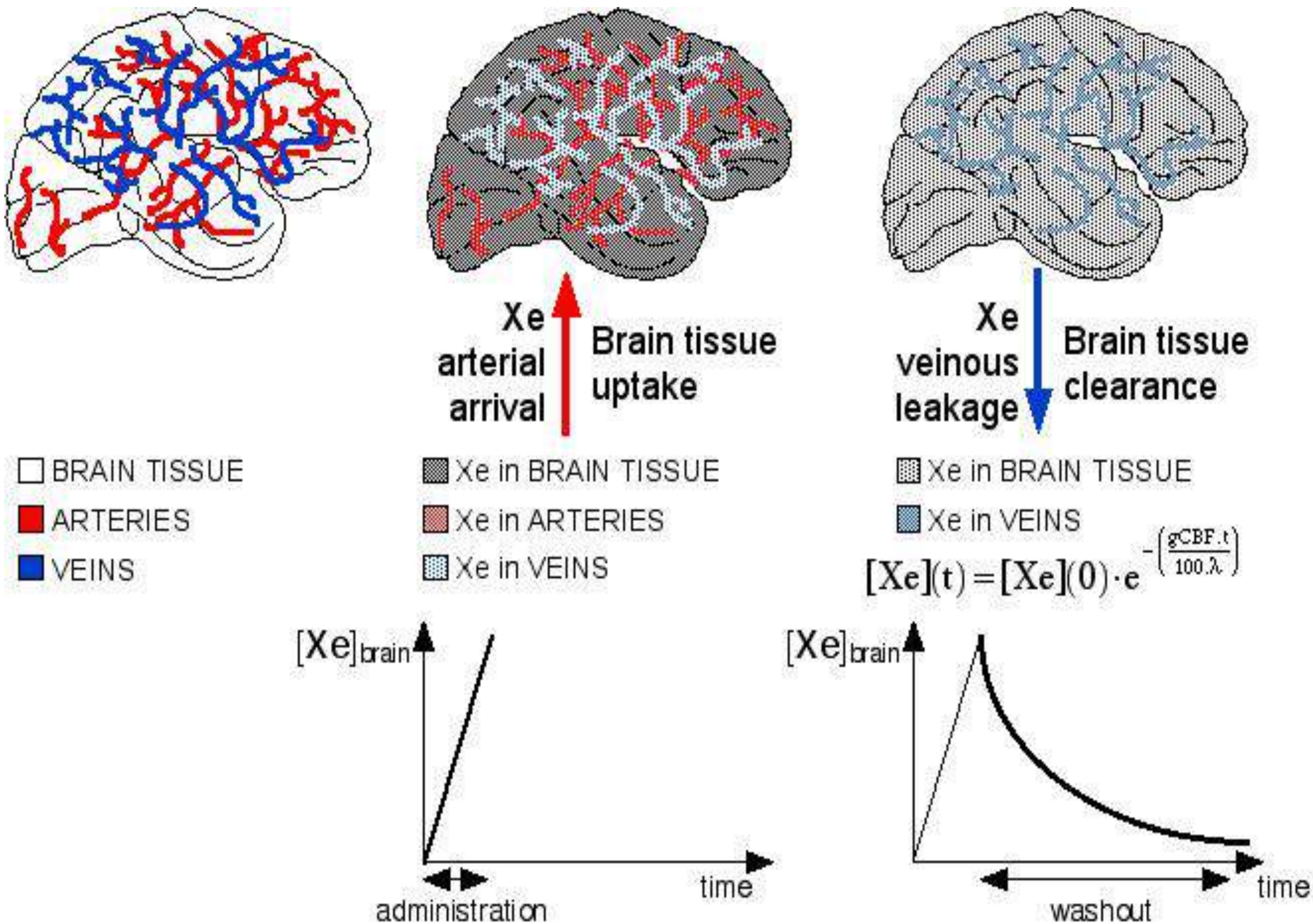
Are you happy or sad?



^{129}Xenon NMR

Cerebral Blood Flow (CBF)

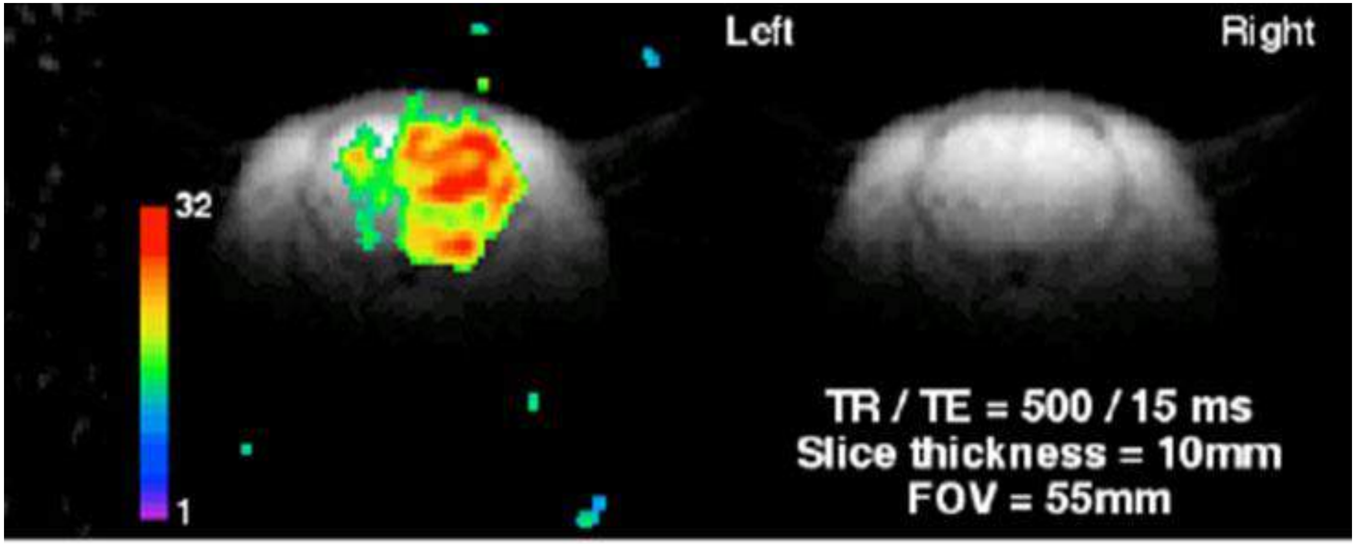
P. Choquet *et al*, Mag. Res. in Medicine, 2001, 46, 208-212 ; Methods in Enzymology, 2004, 385, 149



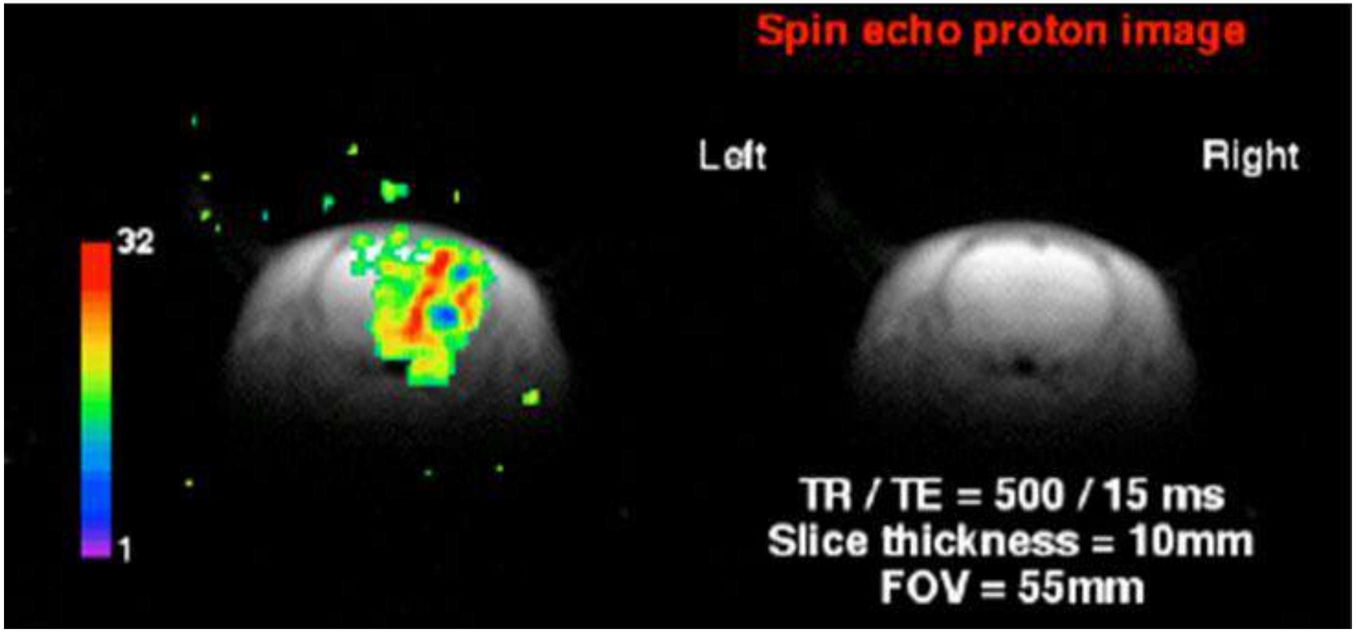
$$[Xe](t) = [Xe](0) \cdot e^{-\left(\frac{gCBF.t}{100.\lambda}\right)}$$

Injection of Xenon through the

right internal carotide artery



left internal carotide artery



MRI of stroke using HP 129 Xe

Xin Zhou…….Mitchell Albert

NMR in Biomedecine, wileyonlinelibrary.com

Imaging from a nonlesioned rat brain: homogeneous image within both brain hemispheres.

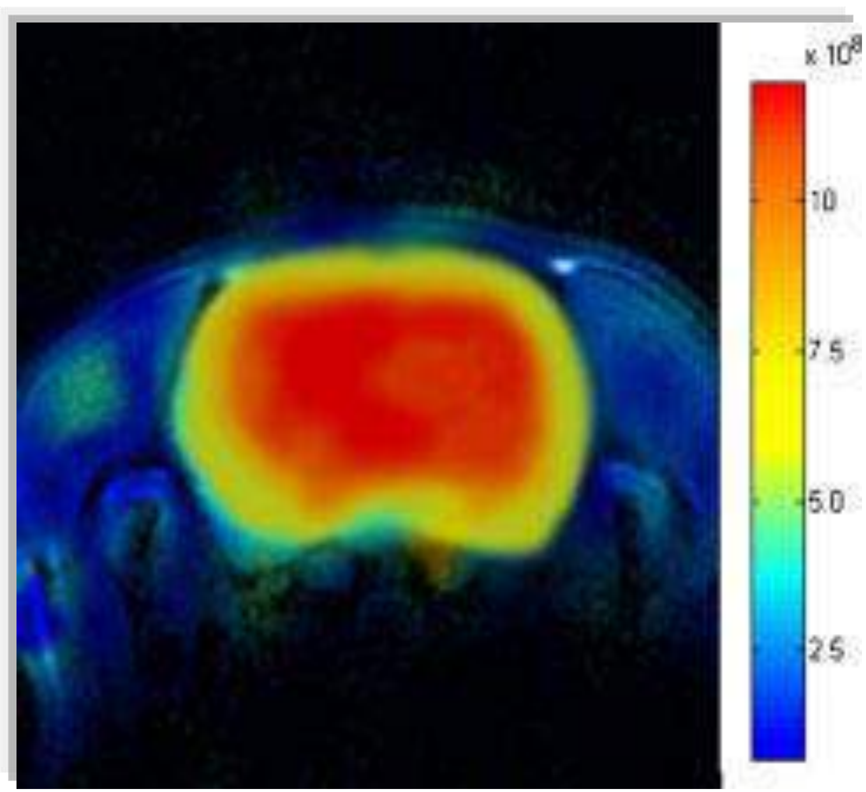
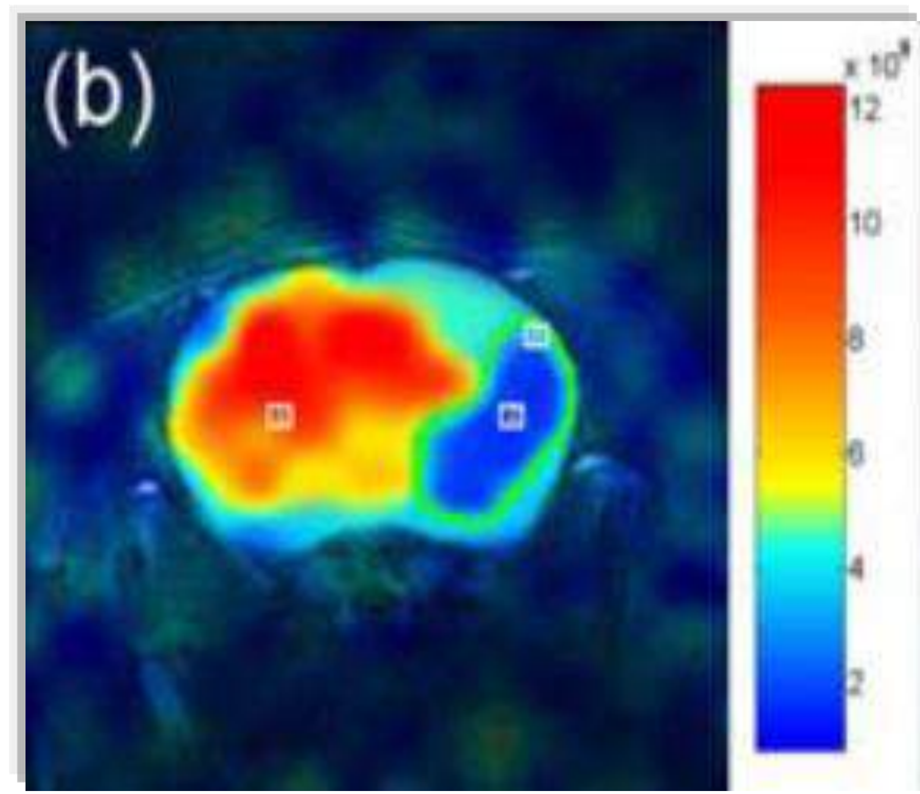


Image after right cerebral artery occlusion. There is a large signal void in the ipsilesional (right) hemisphere.



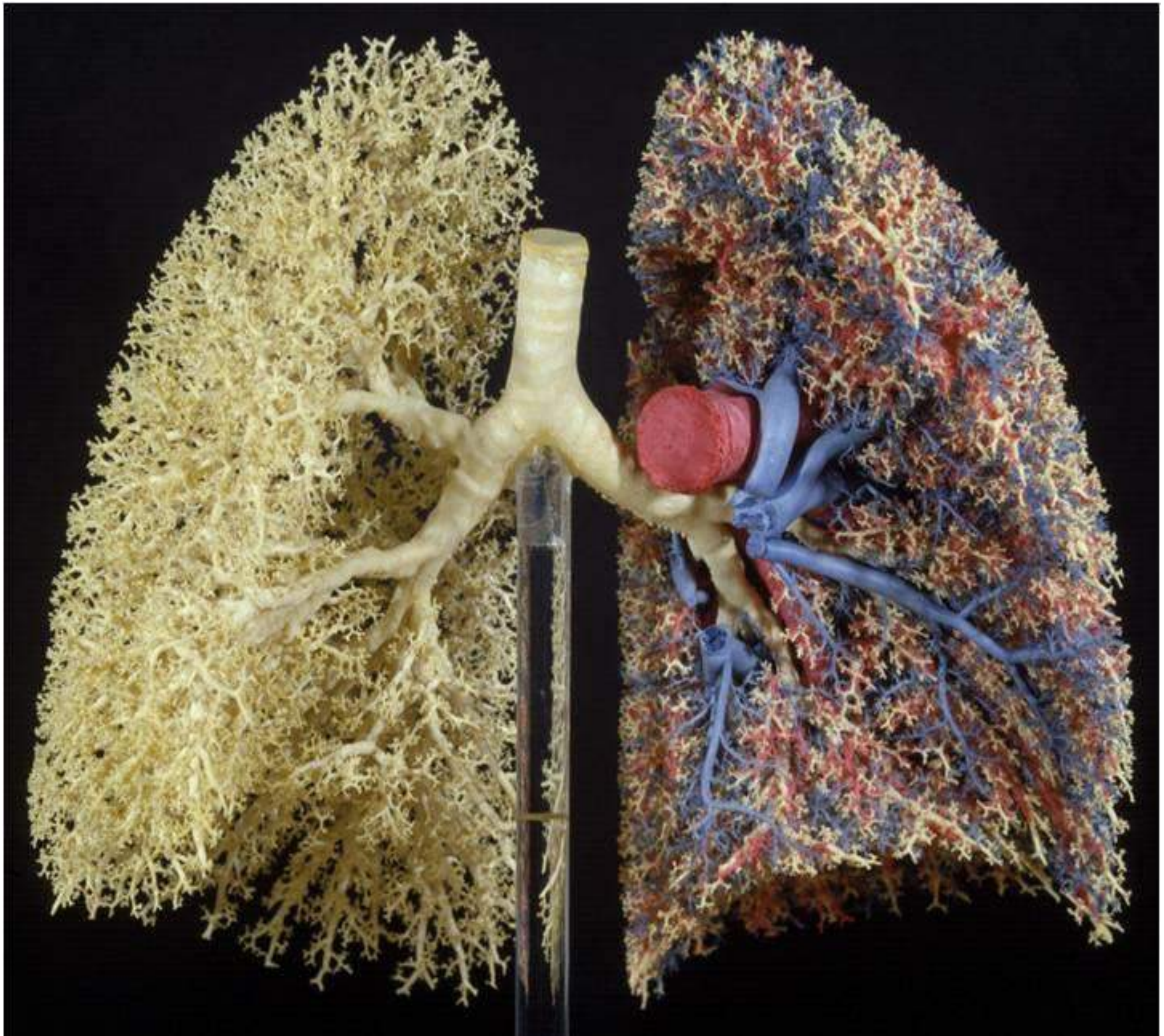
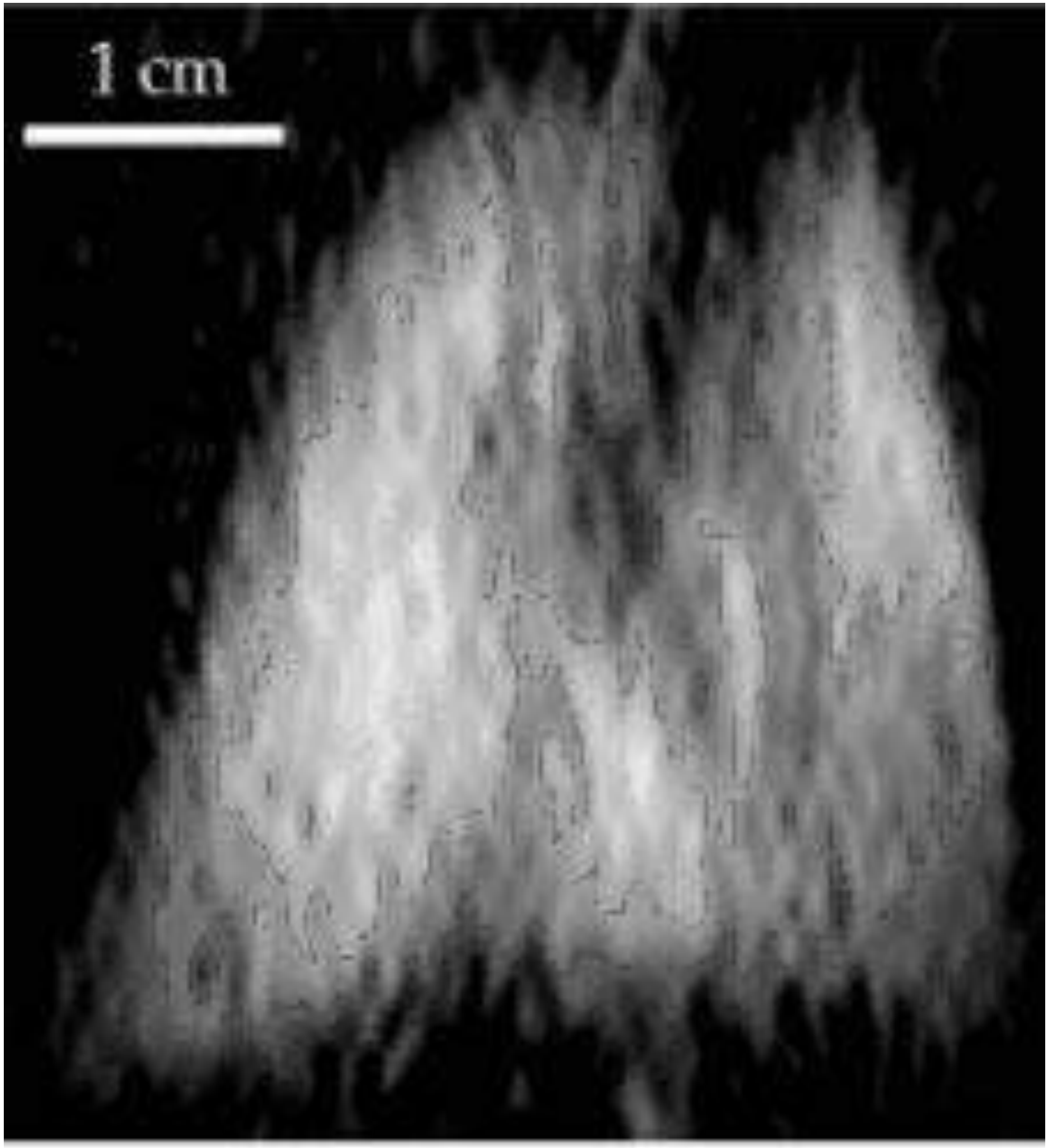


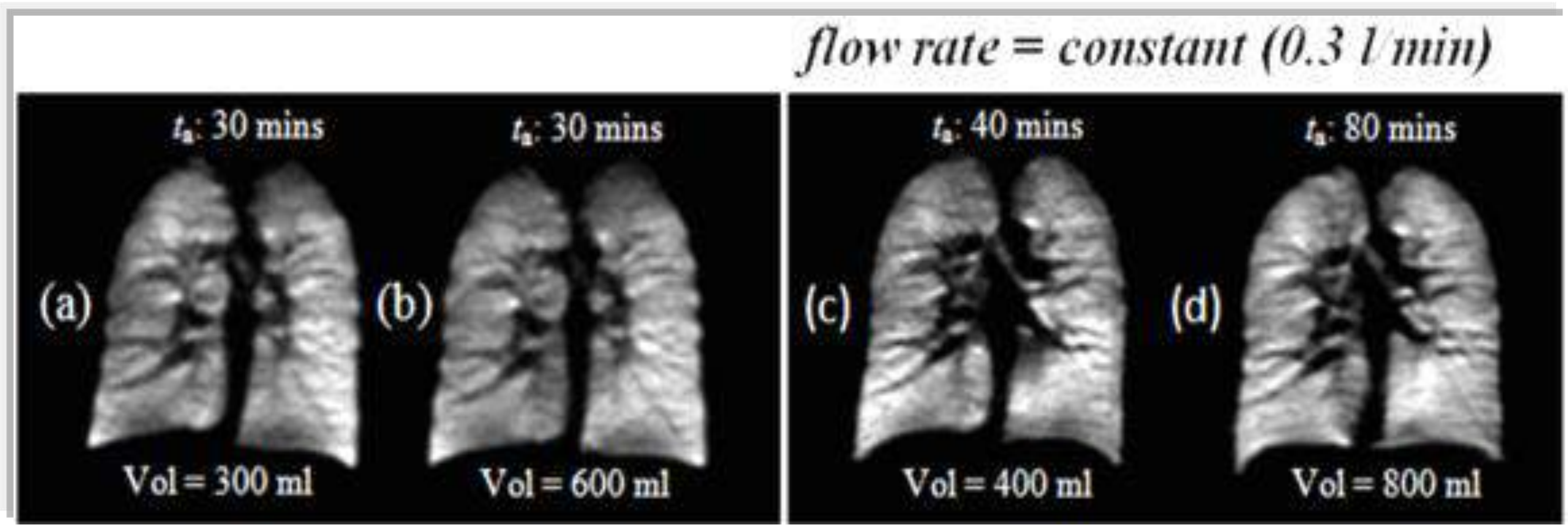
Image of a rat lung after inhalation of HP Xe

Hiroshi Sato *et al*., Mag. Res. in Medical Sciences, 2004, 3, N°1, 1-9.



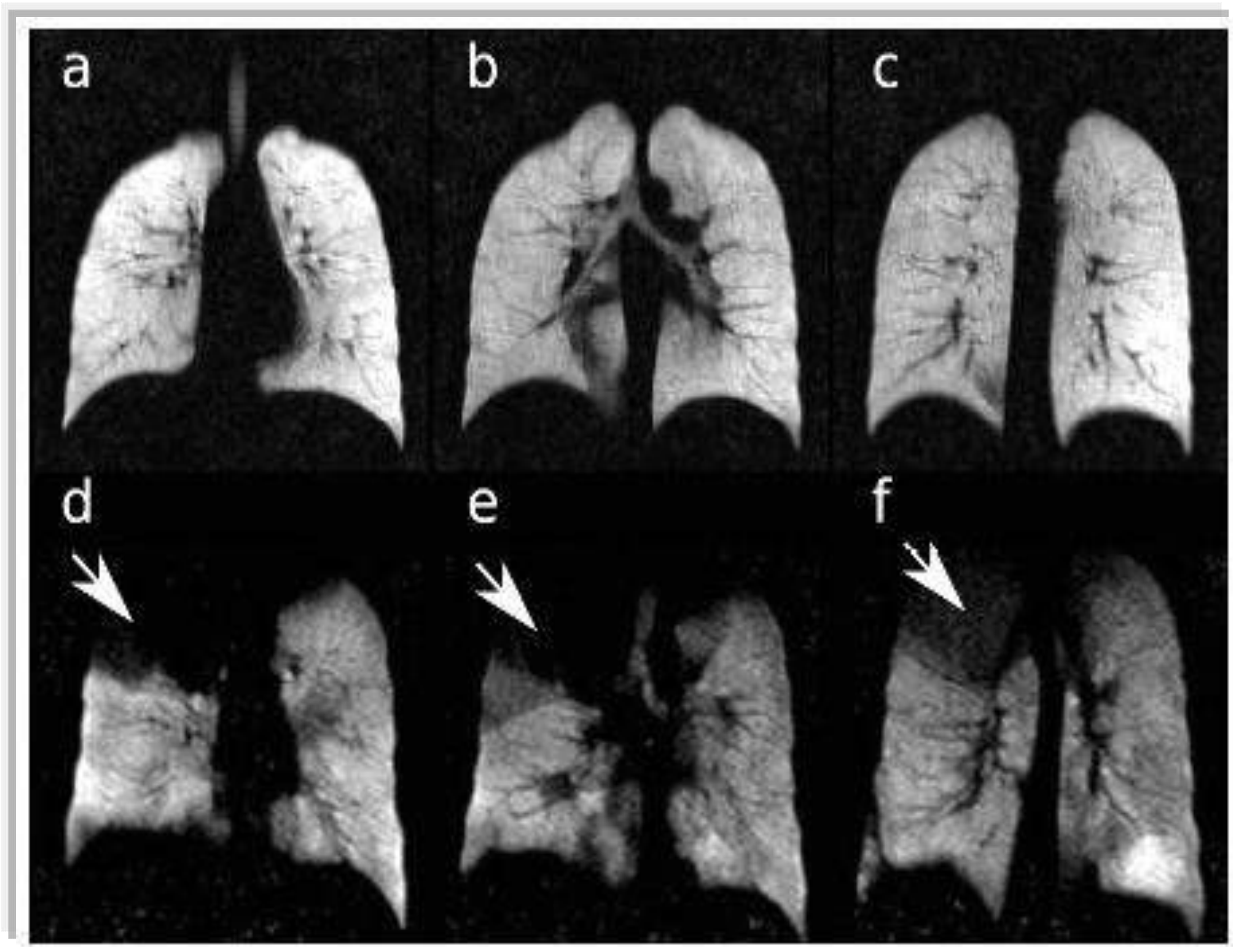
In vivo gas-phase image human lung from healthy volunteer. These images show that the increase of the Xe concentration does not increase the SNR.

G. Norquay *et al*, XEMAT 2012



Ventilation scans of volunteers: a, b, c: healthy subjects; d, e, f : chronic obstructive pulmonary disease (COPD)

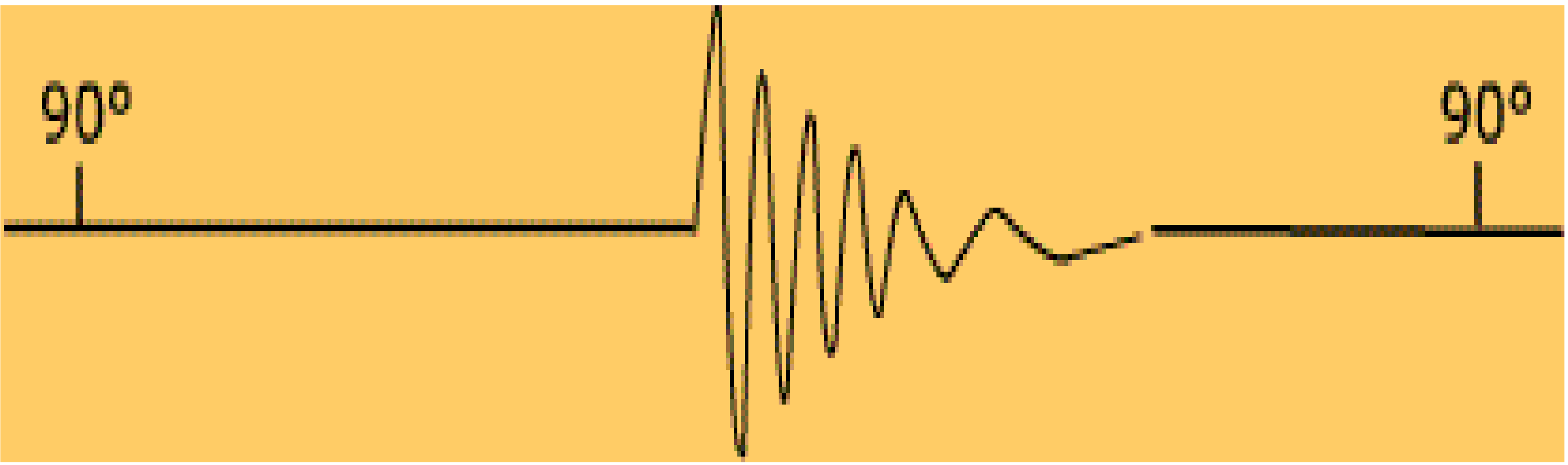
Isabel Dregely et al, XEMAT 2012



End of the part 5

VID_20170517_151507_815.mp4

Pulses 90° and signal



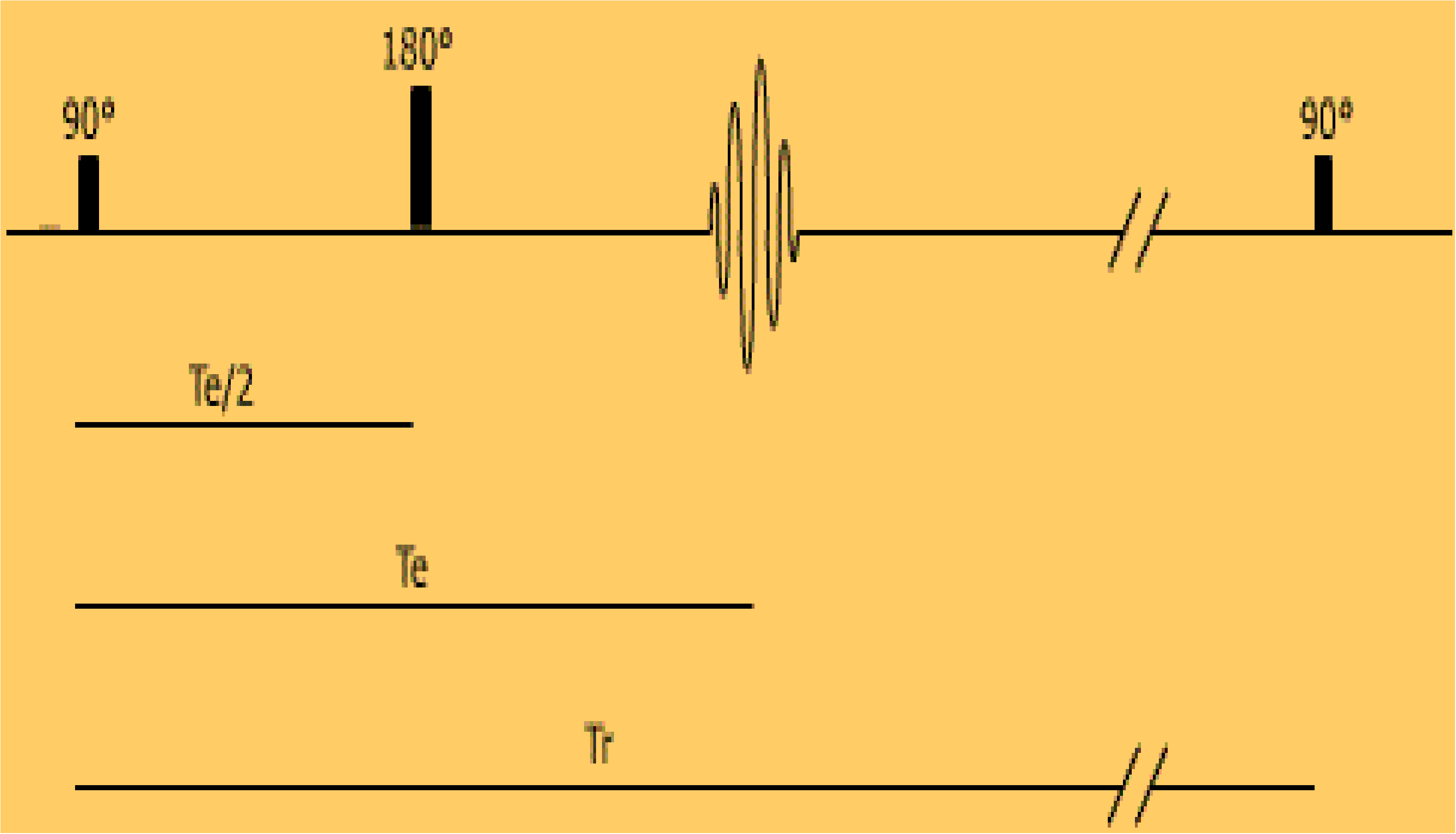
$$A \text{ (echo at } 2\tau) \propto \exp[-(2\tau/T_2) - (2\gamma^2 G^2 D\tau^3)/3]$$

Time of the experiment Te

Diffusion coefficient *D*

Spatial magnetic field gradient *G*

Spin-echo sequence



Acquiring of several projections