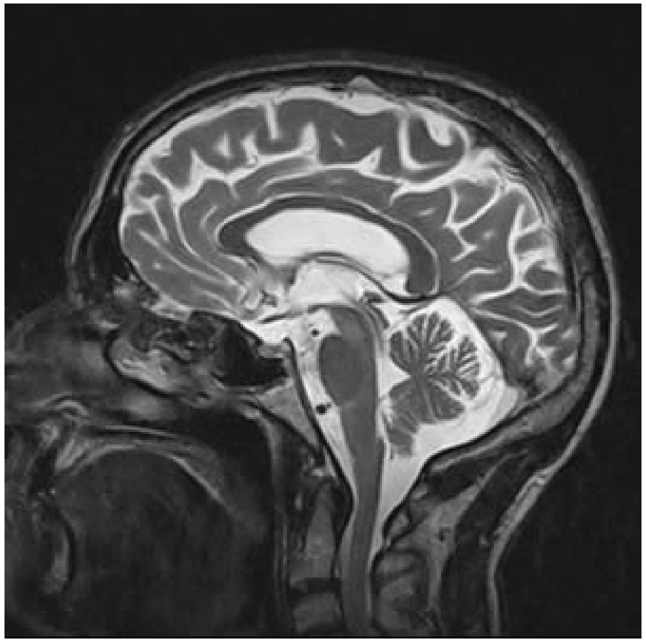
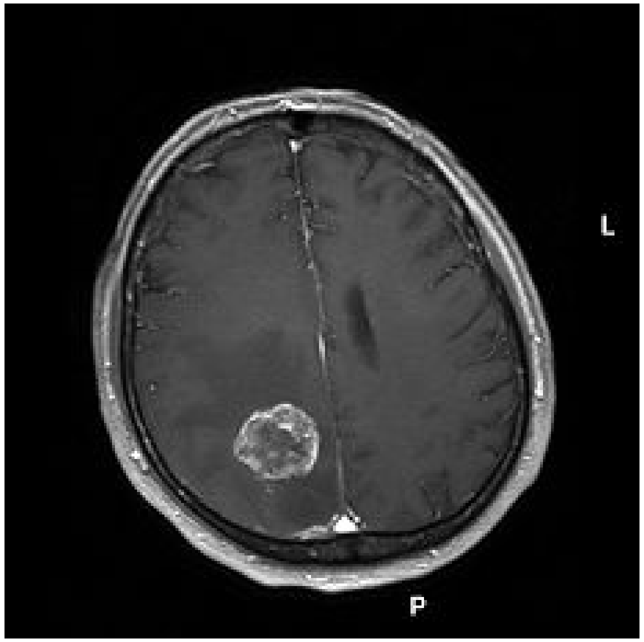
Medical Imaging
Magnetic Resonance Imaging, Medical Applications
(Outline of Lecture 4)

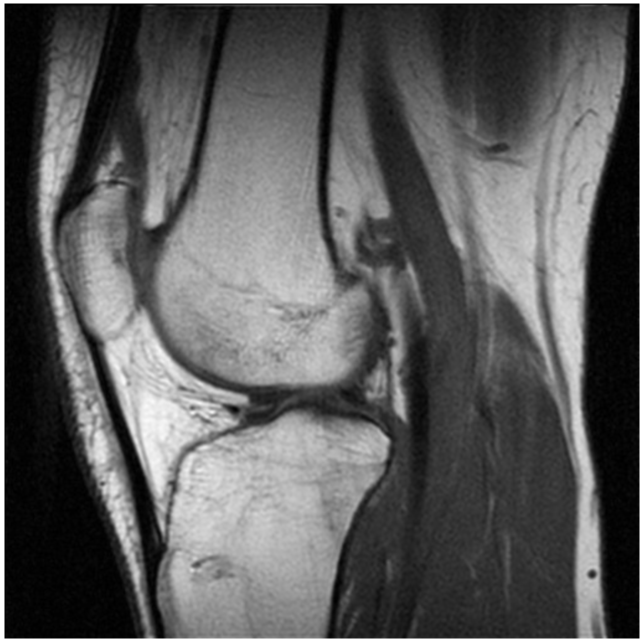
4. Medical Applications

A. Static Scenes

- Brain imaging
- Tumor diagnosis
- Musculosceletal system
- ...







4. Medical Applications

Spin echo imaging (see lecture 2) can be applied $\Rightarrow T_1$- and T_2- weighted images

$$I(x,y) = \rho(x,y)\left[1 - \exp^{-T_R/T_1(x,y)}\right]\exp^{-T_E/T_2(x,y)}$$

MRI contrast agents can be used to increase the contrast between healthy and diseased tissue:

Paramagnetic agents:

- "Caged" metal ions like Gd^{3+} with high magnetic moment
- Interaction between the unpaired electrons and water molecules shortens the proton T_1 relaxation time.
- Often used in the diagnosis of brain disorders.

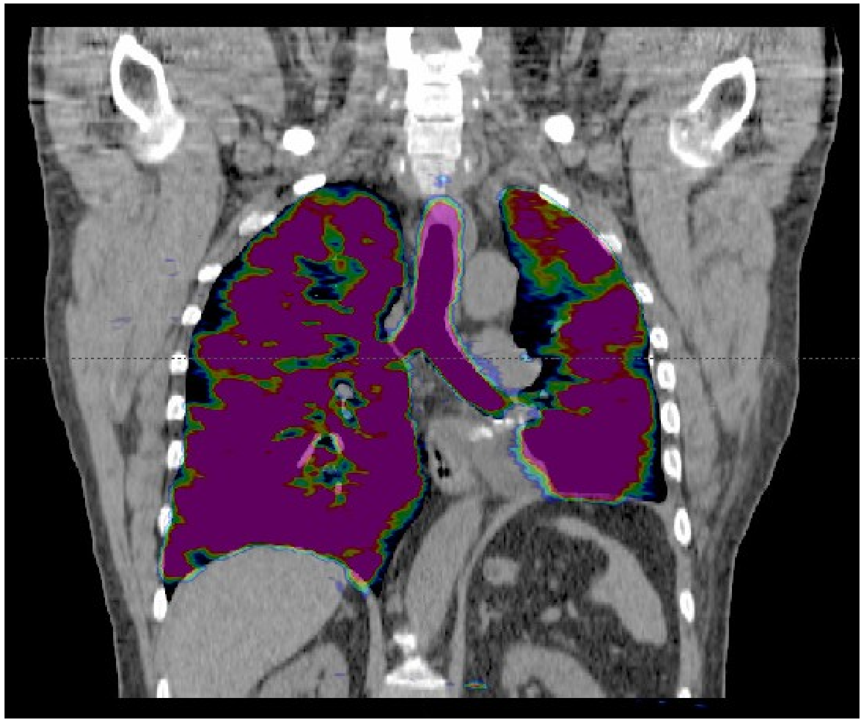
Ferromagnetic agents

- Ferromagnetic crystals like Fe_2O_3 and Fe_3O_4 mixture coated in a polymer matrix
- Shorten the proton T_2 relaxation time.
- Accumulate primarily in healthy rather then pathological tissue.

4. Medical Applications

B. Non-static Scenes

- Lung and liver imaging
- Real time heart imaging
- Swallowing and snoring,

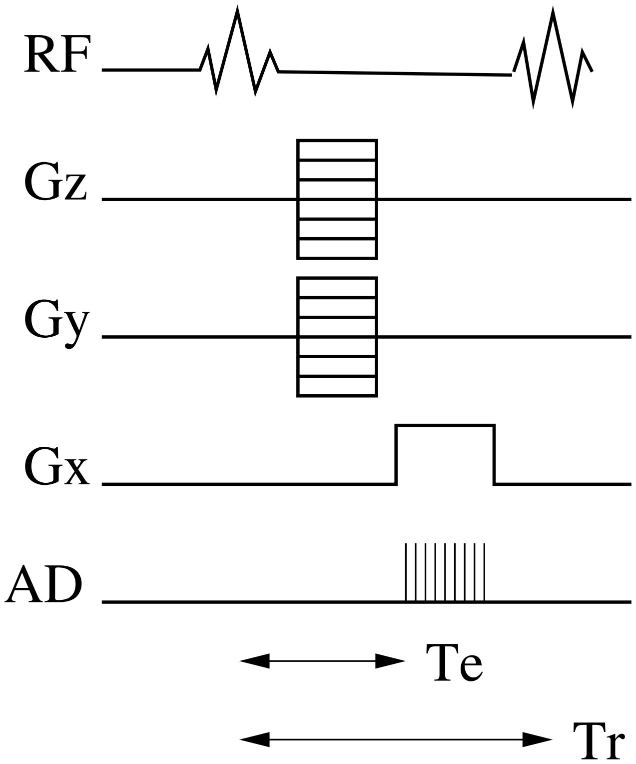


Fast imaging needed! If possible, apply motion compensation using e.g. a respiratory sensor.

4. Medical Applications

(1) Rapid gradient–echo imaging + 3D imaging

- Omit π-pulse for refocusing and long TR-delay for T_1 relaxation.
- Omit slice selection.
- Use two gradients for phase encoding.



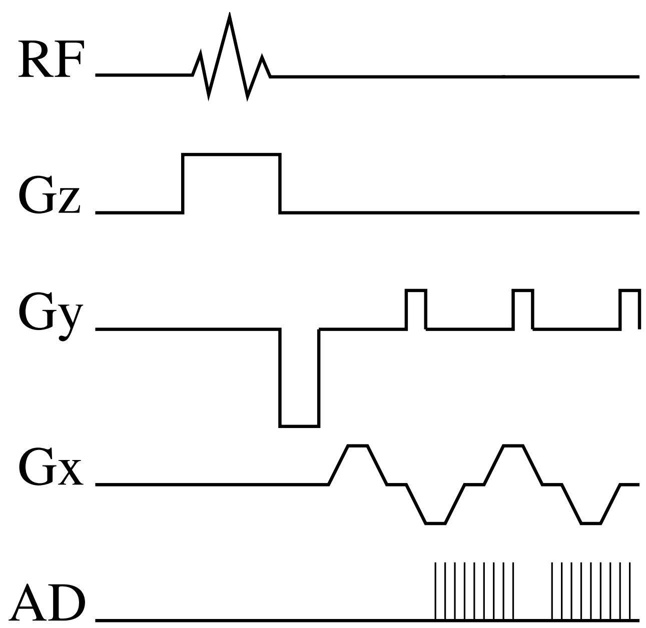
4. Medical Applications

Total transverse magnetization is

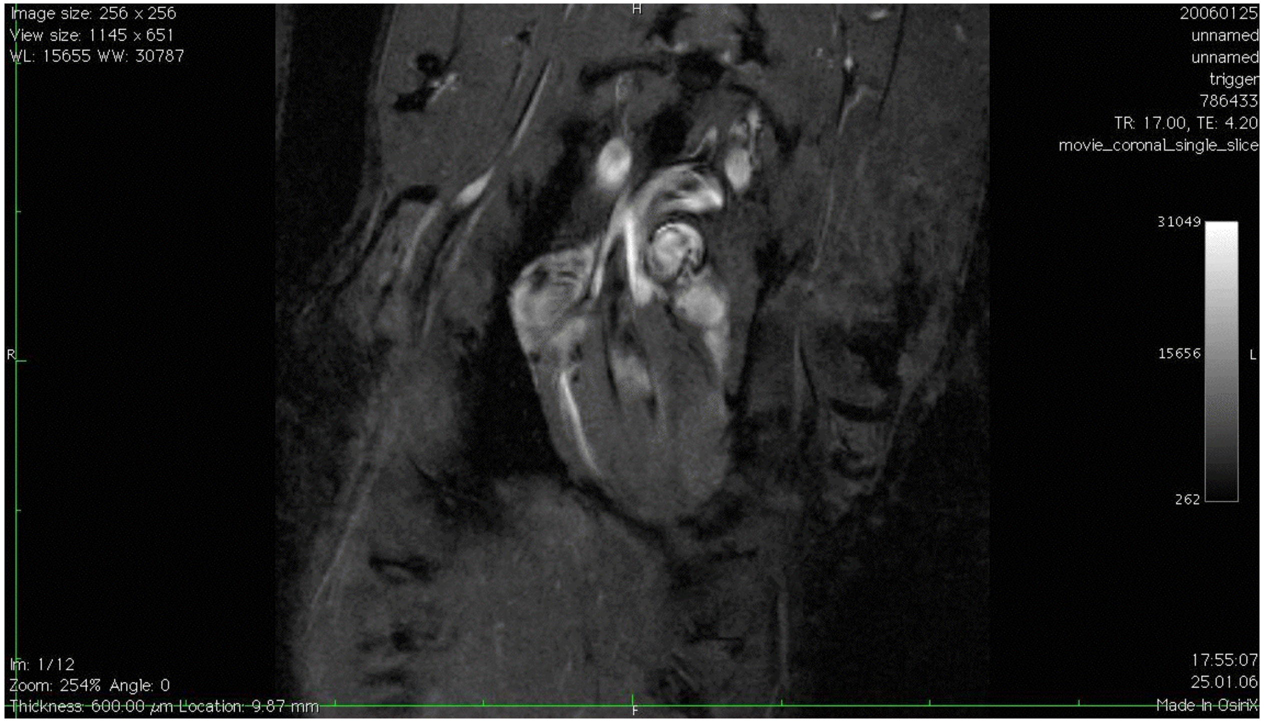
$$M_T(t) = e^{-i\gamma B_0 t} \iiint dx dy dz\, M_T(x, y, 0) \exp\Big[-i\Big(k_x(t)x + k_y(t)y + k_z(t)z\Big)\Big]$$

(2) Echo-Planar Imaging

- Omit π-pulse for refocusing and long TR-delay for T_1 relaxation.
- Use a single $\pi/2$-pulse followed by full k-space sampling.



4. Medical Applications



C. Imaging flows

Angiography

- Shorten the effective T_1 for blood.
- Time of flight angiography: Apply $\pi/2$ and π-pulses with different frequencies.
- Phase contrast angiography: Induce phase shifts in the precessing magnetization of flowing blood.
- Contrast enhancement: Shorten T_1 relaxation time of blood by application of contrast agents.

D. Diffusion Imaging

Bloch equation for the transverse magnetisation in presence of (anisotropic) diffusion:

$$\dot{M}_T = -i\gamma\big[B_0 + \vec{g}(t)\cdot\vec{r}\big]M_T + \nabla(D\nabla M_T)$$

where D denotes the diffusion tensor. This gives

$$M_T(t) = M_T(0)\exp\big[-i\vec{k}(t)\cdot\vec{r}\big]\exp\Big[-\int_0^t \vec{k}(t')\cdot D\cdot\vec{k}(t')dt'\Big]$$