Basics of MRI

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Outline

1. Medical Imaging Overview
   - General Imaging Principles
   - PET
   - X-Ray/CT
   - Ultra-sound
   - MRI

2. MRI - Breaking down the acronym
   - Magnetic
   - Resonance

3. Imaging
   - Location Encoding
   - Image Contrast

4. MR Safety
   - Why
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General Principles

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**Fig. 1.1. A drawing of a section through the human eye with a schematic enlargement of the retina.**
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- MRI: Emit radio waves (≈ radar), then look at properties of “reflected” signals to produce images.
X-Ray/CT

- High voltage power supply (generator)
- kV
- mA
- Grid
- Photostimulable Storage Phosphor
- Filter
- Collimator
Ultra-sound
Similar principle to X-Ray and Ultra-sound: transmit something known.
MRI

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- Measure characteristics of modified signal that comes back to derive images.
MRI

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- Measure characteristics of modified signal that comes back to derive images.

- Much richer and subtle encoding scheme: can enhance contrast between tissues (and even between oxygenated and deoxygenated hemoglobin - basis of BOLD MRI / FMRI).
Figure 2.2 Schematic organization of the fMRI scanner and computer control systems. Two systems are important for fMRI studies. The first is the hardware used for image acquisition. In addition to the scanner itself, this hardware consists of a series of amplifiers and transmitters responsible for creating the gradients and pulse sequences (shown in black), and recorders of the MR signal from the head coil (shown in red). The second system is responsible for controlling the experiment in which the subject participates, and for recording behavioral and physiological data (shown in green).
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Magnetic

- Certain nuclei (odd number of protons and/or neutrons) have magnetic properties (i.e. magnetic moment - 1952 Nobel Prize in Physics, to Bloch and Purcell).
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Includes $^{13}\text{C}$, $^{23}\text{Na}$, $^{31}\text{P}$, $^{129}\text{Xe}$, and ...
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- $^1\text{H}$
Resonance
Resonance
Resonance

Precession

Spin

Applied Magnetic Field
Planck and Larmor Equations

\[ E = h\nu = hf_0 \]

\[ 2\pi f_0 = \omega_0 = \gamma B_0 \]
Resonance - resulting from precession

https://www.youtube.com/playlist?list=PLAE12114468910462

(Tyler Moore - Videos for MR Tutorial)
Resonance - resulting from precession

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Precession
Resonance - resulting from precession

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(Tyler Moore - Videos for MR Tutorial)

- Precession

- Resonance and excitation
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Imaging Gradients
Imaging Gradients
Imaging Gradients
Slice Encoding/Selection
Slice Encoding/Selection
Frequency Encoding
Frequency Encoding
Phase Encoding

Consider two-dimensional object

Phase encode step 1
Step 2 (twice the gradient strength)

voxel magnetization $M_\perp$

After applying phase encode gradient
($G_y$ for $\tau$ seconds)

Gradient $G_y(t)$

Gradient $G_x(t)$

Phase of voxel magnetization $e^{i\phi}$:

$$e^{iG_y y \tau} \cdot e^{iG_x x \tau}$$

Fund Biolmag 2014
Creating image from signal
Creating image from signal
Creating image from signal
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- Data acquisition in “Fourier domain” encoded with spatial gradients.
Creating image from signal

- Data acquisition in “Fourier domain” encoded with spatial gradients.

- Fourier transform acquired data to give image.
Creating image from signal

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- Fourier transform acquired data to give image.

- Nobel Prize in Physiology or Medicine in 2003 to Lauterbur and Mansfield.
Creating image from signal

Paper on Fourier Transform in MR: DOI:10.2214/AJR.07.2874

Relaxation times

https://www.youtube.com/playlist?list=PLAE12114468910462

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Relaxation times

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- Longitudinal (a.k.a $T_1$) relaxation
Relaxation times

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(Tyler Moore - Videos for MR Tutorial)

- Longitudinal (a.k.a $T_1$) relaxation
- Transverse (a.k.a $T_2$) relaxation
Basic tissue contrast
Basic tissue contrast
Basic tissue contrast
Basic tissue contrast
Basic tissue contrast

MP2-RAGE: NeuroImage:49 (2010), 1271 - 1281
Basic tissue contrast
Basic tissue contrast
BOLD contrast
BOLD contrast

BOLD contrast

BOLD contrast

BOLD contrast

BOLD contrast
BOLD contrast
BOLD contrast
BOLD contrast
Diffusion contrast
Diffusion contrast

![Diagram showing diffusion contrast](image)
Diffusion contrast

![Diffusion contrast diagram](image)

- $D = 1.2 \times 10^{-9} \text{mm}^2 \text{s}^{-1}$
- $D = 0.6 \times 10^{-9} \text{mm}^2 \text{s}^{-1}$

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**Corpus colossum**

**T1-weighted**

*Nature Reviews | Neuroscience*
Diffusion contrast
Diffusion contrast
Diffusion contrast
Other types of contrast
Other types of contrast

Other types of contrast


- MRM, 1992 Vol 23:37-45 - Detre et al. - Perfusion imaging
Other types of contrast


- MRM, 1992 Vol 23:37-45 - Detre et al. - Perfusion imaging

- MRM, 1989 Vol 10:135-144 - Wolff and Balaban - Magnetization Transfer
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Hazards around MR
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- Static strong magnetic field $\rightarrow$ motion
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- Radio-frequency fields → high power
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- Radio-frequency fields $\rightarrow$ high power
- Gradient fields $\rightarrow$ can induce currents
Hazards around MR

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NMR Center Safety class:
http://intranet.nmrf.nih.gov/safety_training.htm