Magnetic Resonance Imaging (MRI)

BASIC PRINCIPLE & APPLICATIONS

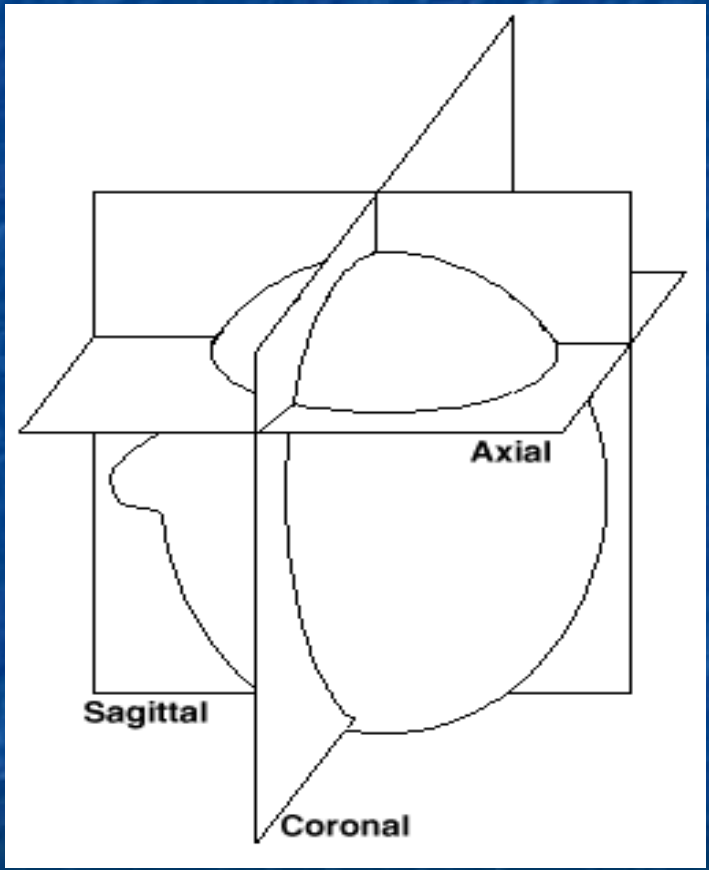
Introduction

- What is MRI?
  - Magnetic resonance imaging (MRI) is a spectroscopic imaging technique used in medical settings to produce images of the inside of the human body.
  - MRI is based on the principles of nuclear magnetic resonance (NMR), which is a spectroscopic technique used to obtain microscopic chemical and physical data about molecules
  - In 1977 the first MRI exam was performed on a human being. It took 5 hours to produce one image.

- How Does it Work?
  - The magnetic resonance imaging is accomplished through the absorption and emission of energy of the radio frequency (RF) range of the electromagnetic spectrum.

- Why MRI ?
  - Utilizes non ionizing radiation. (unlike x-rays).
  - Ability to image in any plane. (unlike CT scans).
  - Very low incidents of side effects.
  - Ability to diagnose, visualize, and evaluate various illnesses.

The only better way to see the insides of your body is to cut you open!



The Components:

- A magnet which produces a very powerful uniform magnetic field.
- Gradient Magnets which are much lower in strength.
- Equipment to transmit radio frequency (RF).
- A very powerful computer system, which translates the signals transmitted by the coils.

The Magnet

- The most important component of the MRI scanner is the magnet:
  - The magnets currently used in scanners today are in the .5-tesla to 2.0-tesla range (5,000 to 20,000-gauss).

    Higher values are used for research.

  - Earth magnetic field: 0.5-gauss

The Magnet (cont.)

- There are three types of magnets used in MRI systems:
  - Resistive magnets
  - Permanent magnets
  - Super conducting magnets (the most commonly used type in MRI scanners).

- In addition to the main magnet, the MRI machine also contains three gradient magnets. These magnets have a much lower magnetic field and are used to create a variable field.

The Technology

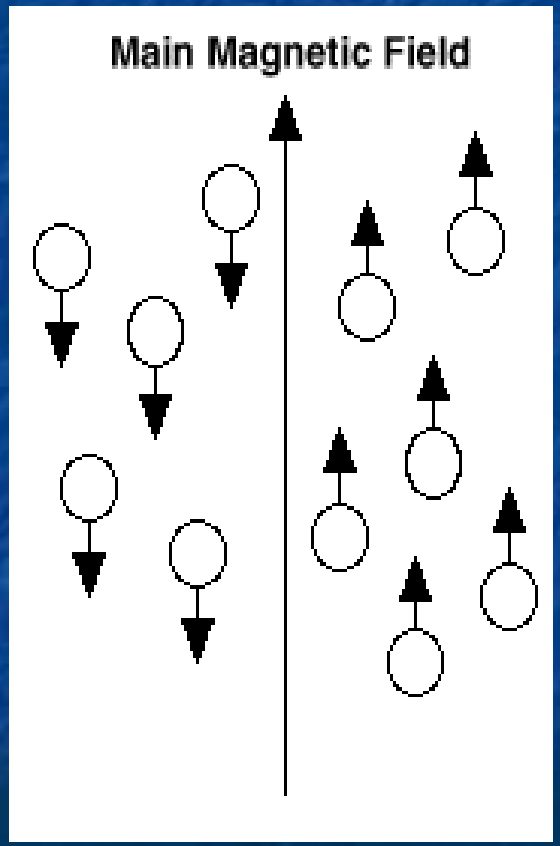
- How Does It All Work?
- **Spin:**
  - The atoms that compose the human body have a property known as spin (a fundamental property of all atoms in nature like mass or charge).
  - Spin can be thought of as a small magnetic field and can be given a + or – sign and a mathematical value of multiples of ½.
  - Components of an atom such as protons, electrons and neutrons all have spin.

- **Spin** (cont.):
  - Protons and neutron spins are known as nuclear spins.
  - An unpaired component has a spin of ½ and two particles with opposite spins cancel one another.
  - In NMR it is the unpaired nuclear spins that produce a signal in a magnetic field.

- Human body is mainly composed of fat and water, which makes the human body composed of about 63% hydrogen.

- Why Are Protons Important to MRI?
  - positively charged
  - spin about a central axis
  - a moving (spinning) charge creates a magnetic field.
  - the straight arrow (vector) indicates the direction of the magnetic field.

- When placed in a large magnetic field, hydrogen atoms have a strong tendency to align in the direction of the magnetic filed
- Inside the bore of the scanner, the magnetic field runs down the center of the tube in which the patient is placed, so the hydrogen protons will line up in either the direction of the feet or the head.
- The majority will cancel each other, but the net number of protons is sufficient to produce an image.



- Energy Absorption:
  - The MRI machine applies radio frequency (RF) pulse that is specific to hydrogen.
  - The RF pulses are applied through a coil that is specific to the part of the body being scanned.

Resonance (cont.)

The gradient magnets are rapidly turned on and off which alters the main magnetic field.

- The pulse directed to a specific area of the body causes the protons to absorb energy and spin in different direction, which is known as resonance

Frequency (Hz) of energy absorption depends on strength of external magnetic field.

The Technology (cont.)

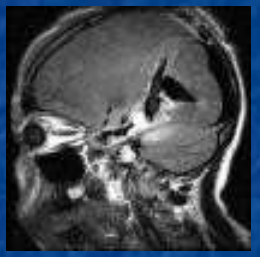
- Imaging:
  - When the RF pulse is turned off the hydrogen protons slowly return to their natural alignment within the magnetic field and release their excess stored energy. This is known as relaxation. -> two time-scales (see later)

- What happens to the released energy?
  - Released as heat

    OR
  - Exchanged and absorbed by other protons

    OR
  - Released as Radio Waves.

- Measuring the MR Signal:
  - the moving proton vector induces a signal in the RF antenna
  - The signal is picked up by a coil and sent to the computer system.
    the received signal is sinusoidal in nature
  - The computer receives mathematical data, which is converted through the use of a Fourier transform into an image.



Recap: What Does the Image Represent?

- For every unit volume of tissue, there is a number of cells, these cells contain water molecules, each water molecule contain one oxygen and two hydrogen atoms.
- Each hydrogen atom contains one proton in its nucleus. Different tissues thus produce different images based on the amount of their hydrogen atoms producing a signal

Magnetic Resonance Imaging (MRI) is a non-invasive medical imaging technique that has many applications. It's used to diagnose and monitor conditions of the brain, spine, muscles, ligaments, and tendons.

Brain and spine

- **Brain tumors**: MRI can help diagnose brain tumors and differentiate between white and gray matter
- **Brain injuries**: MRI can help detect damage from head injuries, such as brain aneurysms
- **Spinal cord injuries**: MRI can help detect injuries to the spinal cord, such as compression or inflammation
- **Multiple sclerosis**: MRI can help diagnose multiple sclerosis (MS)

Other applications

- **Musculoskeletal**: MRI can help image muscles, ligaments, and tendons
- **Blood flow**: Magnetic resonance angiography (MRA) can help evaluate blood flow through arteries and detect aneurysms
- **Brain function**: Functional MRI (fMRI) can help determine which areas of the brain are active during certain tasks
- **Pharmaceutical**: MRI can help track the fate of drugs in the body

MRI is a good choice when frequent imaging is needed because it doesn't use ionizing radiation like x-rays.