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Course Two

Lecture 10: Magnetic Resonance Imaging (MRI)
(Introduction)

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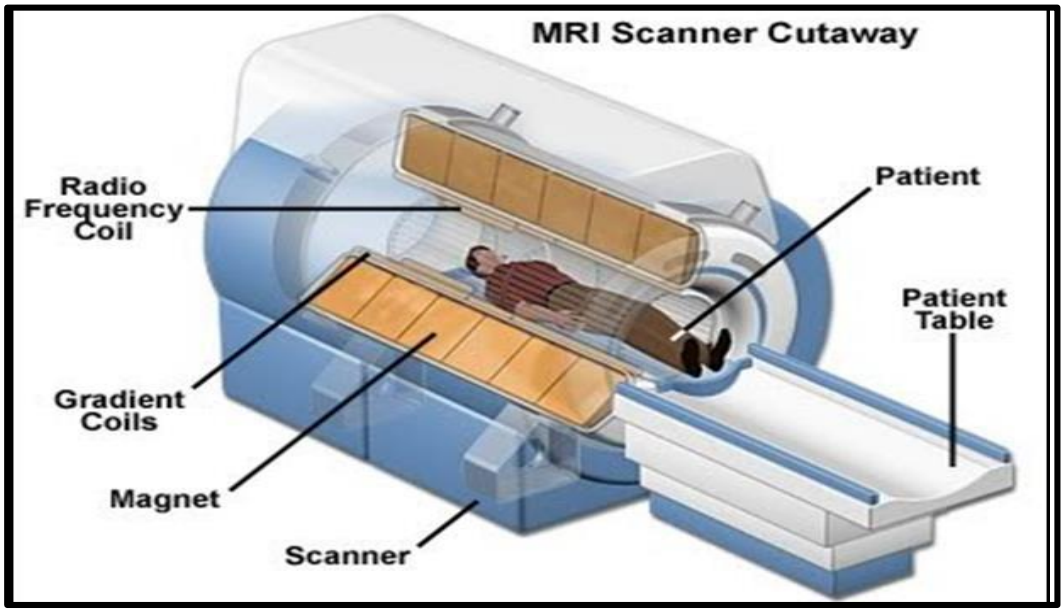
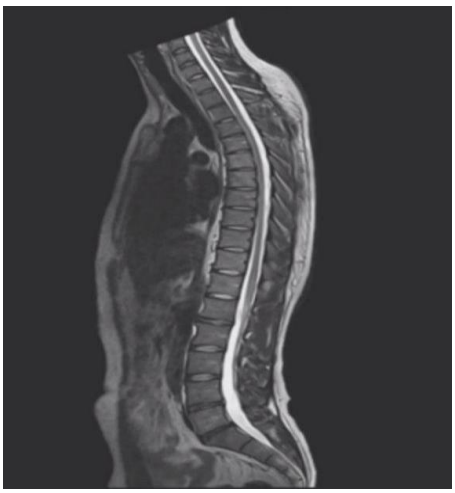
Introduction

The magnetic resonance imaging (MRI) was discovered in 1970, by Paul C Lauterbur, Stony Brook, at New York. Magnetic resonance imaging (MRI) is an imaging technique used primarily in medical settings to produce high quality images of the inside of the human body. MRI is based on the principles of nuclear magnetic resonance (NMR) Use of the RF region of the electromagnetic spectrum to produce an image is especially spectacular.



CT **MRI**



Comparison CT scan vs. MRI

1. CT scans utilize X-rays to form images inside the body
   while MRI (magnetic resonance imaging) uses powerful magnetic fields and radiofrequency pulses to produce detailed pictures of organs and other internal body structures.
2. CT scans use radiation (X-rays), and MRIs do not.
3. MRIs provide more detailed information about the inner organs (soft tissues) such as the brain, skeletal system, reproductive system and other organ systems than is provided by a CT scan.
4. CT scans are quick, painless, and noninvasive.
5. MRI scans are not invasive, but they are noisy, take more time, and may cause claustrophobia (anxiety due to being in the enclosed space of the machine).
6. MRI scans are costlier than CT scans.
7. MRI scanners may cause a safety issue due to its strong magnets.

CT scan (Computed Tomography scan) work

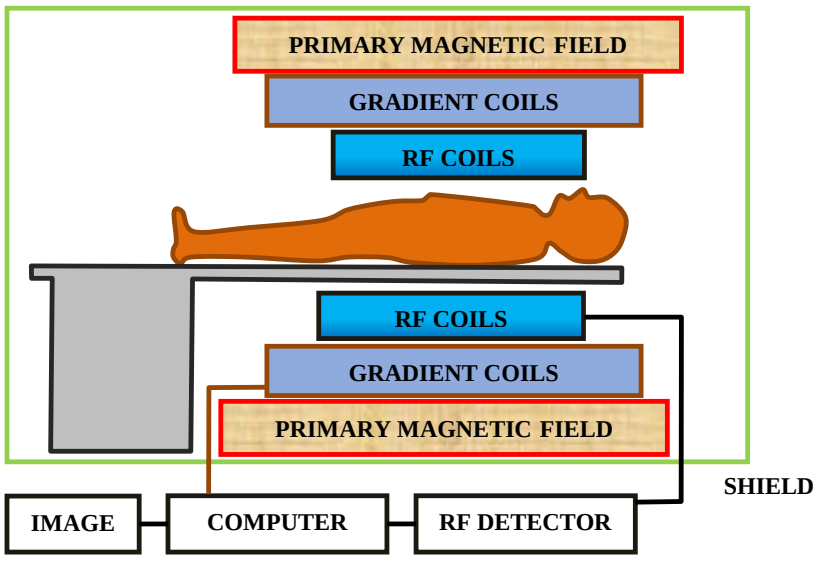
A CT scan works by taking multiple X-rays at various angles and then utilizes those X-rays to form a three-dimensional image of whatever organ system is being examined. A computer examines synthesizes the images to form a three-dimensional computer model of internal organs.

MRI (Magnetic Resonance Imaging scan) work

- MRIs use and send superconducting magnet and radiofrequency waves into the body (hydrogen).
- The magnetic field lines up atoms either in a north or south position with a few atoms that are unmatched (keep spinning in a normal fashion).
- When radiofrequency is added, the unmatched atoms spin in an opposite direction, and when the radiofrequency is turned off those unmatched atoms return to the normal position emitting energy. The energy emitted sends a signal to the computer and the computer uses mathematical formulas to convert the signal into an image.

The Basic MRI System Components

An MRI scanner is made up of four components: the magnet, gradient coils, RF transmitter and receiver, and the computer (see figure below).



Types of Magnets

- The design of MRI is essentially determined by the type and format of the main magnet, i.e. closed and open MRI.

1. Permanent magnet

These types of magnets are usually limited to maximum field strengths of 0.4 T. Although they have the advantage of being inexpensive and easy to maintain, they are very heavy and weak in intensity.

2. Resistive electromagnets

The principal disadvantage of this type of imaging system is electric power consumption and require a cooling system.

3. Superconducting electromagnets

The most commonly used magnets are superconducting electromagnets. These consist of a coil that has been made superconductive by helium liquid cooling, and immersed in liquid nitrogen. They produce strong, homogeneous magnetic fields, but are expensive and require regular upkeep (namely topping up the helium tank).

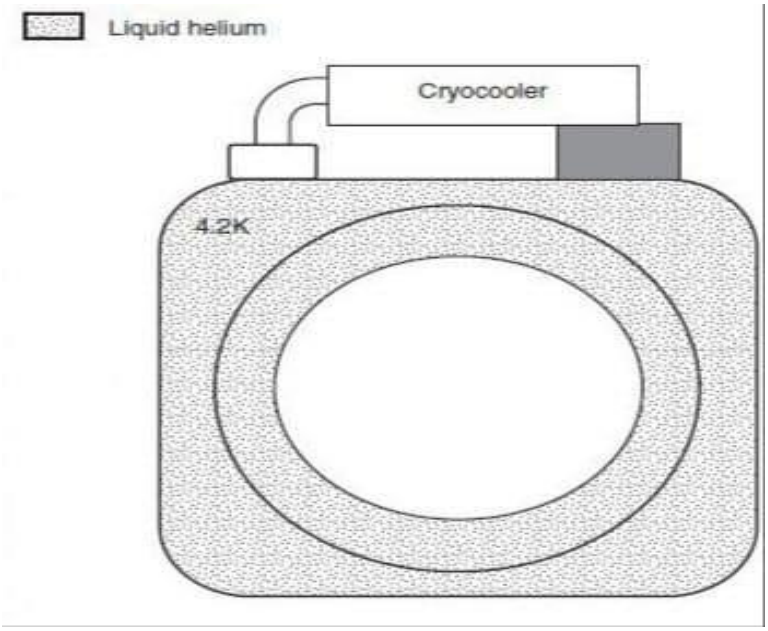


Table 1: Characteristic Features of Magnetic Resonance Imaging Systems

Feature	Permanent Magnet	Resistive magnet	Superconducting Magnet
Magnetic field (B_0) intensity	0.1-0.4 T	0.2 T	0.5-4 T
Power requirements	Low (20)	Very high (80)	Low (25)
Cooling requirements	None	Water	Cryogenic
Weight	90,000 kg	4000 kg	10,000 kg

Characteristics of the main magnet

The main characteristics of a magnet are:

- ✓ Type (superconducting or resistive electromagnets, permanent magnets)
- ✓ Strength of the field produced, measured in Tesla (T). In current clinical practice, this varies from 0.2 to 3.0 T. In research, magnets with strengths of 7 T or even 11 T and over are used.
- ✓ Homogeneity

Shim Coils

To obtain the most homogeneous magnetic field, the magnet must be finely tuned ("shimming"), either passively, using movable pieces of metal, or actively, using small electromagnetic coils distributed within the magnet

Radiofrequency (RF coil) system components

The radiofrequency system comprises the set of components for transmitting and receiving the radiofrequency waves involved in exciting the nuclei

- Radiofrequency (RF) shielding of an MR scanner is mandatory and serves two function

1. To prevent extraneous electromagnetic radiation from contaminating/distorting the MR signal, and
2. To prevent RF generated by the MR scanner from causing interference in nearby medical devices.

RF Coils Types (H.W)

Gradient Coils

As we explained previously to produce an image, you must stimulate the hydrogen nuclei in the body, and then determine the location of those nuclei within the body. These tasks are accomplished using the gradient coil.