MRI

1.1. Historical Introduction

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),** a spectroscopic technique used by scientists to obtain microscopic chemical and physical information about molecules. The technique was called magnetic resonance imaging rather than nuclear magnetic resonance imaging (NMRI) **because of the negative connotations associated with the word nuclear in the late 1970's.**

Why MRI?

When using x-rays to image the body one doesn't see very much. The image is gray and flat. The overall contrast resolution of an x-ray image is **poor**. In order to increase the image contrast one can, administer some sort of contrast medium, such as barium or iodine-based contrast media.

The principal advantage of MRI is its excellent contrast resolution. With MRI it is possible to detect minute contrast differences in (soft) tissue, even more so than with CT images. By manipulating the MR parameters one can optimize the pulse sequence for certain pathology. **Another advantage of MRI** is the possibility the make images in every imaginable plane, something, which is quite impossible with x-rays or CT.

In general, one can use **x-ray and CT** to visualize bone structures whereas MRI is extremely useful for detecting soft tissue lesions. Before beginning a study of the science of MRI, it will be helpful to reflect on the brief the hardware of MRI.

The Hardware

Scanners of magnetic resonance imaging (MRI) come in many varieties. There is a **permanent magnet type**, **resistive, superconducting,** and **opening or bore, with or without helium, high field strength or low.**

1.2 Magnet Types

The static magnetic field (Bo) in MRI systems can be created by: **Permanent magnets** and **Electromagnets.**

1.2.1 Permanent Magnets

A **permanent magnet** that originates from permanently ferromagnetic materials, which does not lose the magnet field, that remains over time without weakening. Due to weight considerations, **these types of magnets** are usually limited to maximum field strengths of 0.4 T (the unit for magnetic field strength is Tesla: 1 Tesla = 10000 Gauss). Permanent magnets have usually an open design system (see Figure 1) which has ample open space which is more comfortable for the patient. So, the open design accommodates extremely large patients and dramatically reduces anxiety for all patients especially those who have claustrophobic tendencies or have larger body structures.

ADVANTAGES	DISADVANTAGES
Low power consumption	Limited field strength (<0.3T)
Low operating cost	Very heavy
Small fringe field	No quench possibility
No cryogen	

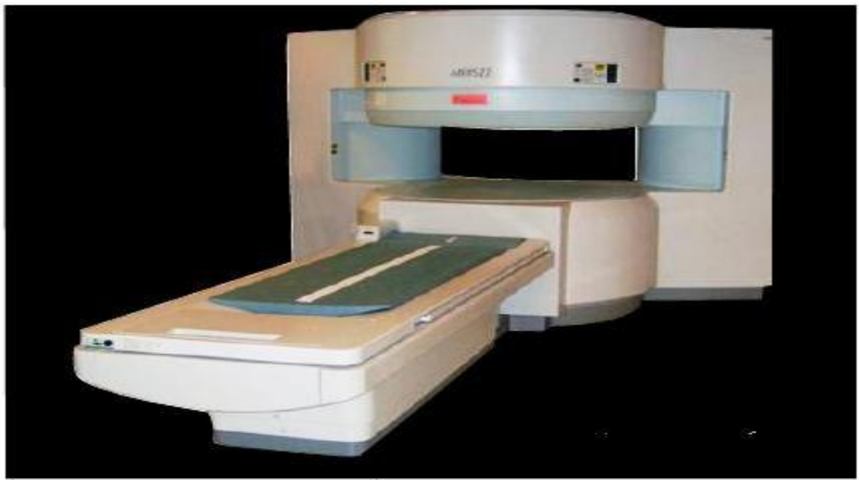
Figure 1: Open MRI system "OPER".

1.2.2 Electromagnets

There are two categories can be used in MR scanner: Resistive and Superconducting Magnets.

1.2.2.1. Resistive Magnets

Resistive magnets are made from loops of wire wrapped around a cylinder through which a large electric current is passed. These magnets are very large that utilizes the principles of electromagnetism to generate the magnetic field. They are lower in cost, but need a lot of power to run that means, large current values which runs through loops of wire because of the natural resistance of the wire. Therefore they produce a lot of heat, which requires significant cooling of the magnet coils. Resistive magnets come in two general categories: iron-core and air-core. Resistive magnets are typically limited to maximum field strengths can be up to 0.6 Tesla. They usually have an open design, which reduces claustrophobia. Figure 2 shows Hitachi's Airis 0.3 Tesla (air-core) system.



ADVANTAGES	DISADVANTAGES
Low capital cost Light weight Can be shut off	High power consumption Limited field strength (<0.2T) Water cooling required Large fringe field

Figure 2: Hitachi's Airis 0.3 Tesla (air-core) system.

1.2.2.2 Superconducting Magnets

Superconducting magnets are Today's most commonly used in MRIs. These superconductors, such as niobium-tin and niobium-titanium are used to make the coil windings for superconducting magnets. The magnetic field is generated by a passing electrical current through coils of wire. The wire is surrounded with a coolant, such as liquid helium, to reduce the electric resistance of the wire. At 4 Kelvin (-269 ^{o}C) electric wire loses its resistance. Once a system is energized, it won't lose its magnetic field. Superconductivity allows for systems with very high field strengths up to 12 Tesla. The ones that are most used in clinical environments run at 1.5 Tesla. Most superconducting magnets are bore type magnets. A number of vacuum vessels, which act as temperature shields, surround the core. These shields are necessary to prevent the helium to boil off too quickly. Another advantage of superconducting magnets is the high magnetic field homogeneity (see Figure 3).

ADVANTAGES	DISADVANTAGES
High field strength	High capital costs
High field homogeneity	High cryogen costs
Low power consumption	Acoustic noise
High SNR	Motion artifacts
Fast scanning	Technical complexity

Figure 3: bore type magnets.

[In 1997 Toshiba introduced the world's first open superconducting magnet. The system uses a special metal alloy, which conducts the low temperature needed for superconductivity. The advantage of this is that the system does not need any helium refills, which dramatically reduces running costs. The open design reduces anxiety and claustrophobia. Figure 4 shows Toshiba's OPART 0.35 Tesla system, which combines an open design with the advantages related to superconducting magnets.]

Figure 4: Toshiba's OPART 0.35 Tesla system, which combines an open design.

Thank you