Vol 4| Issue 4| 2014 | 185-193.

e-ISSN 2248 – 9142
print-ISSN 2248 – 9134

International Journal of
Current Pharmaceutical & Clinical Research

www.ijcpcr.com

AN OVERVIEW ON MRI PHYSICS AND ITS CLINICAL APPLICATIONS

Muhammad Idrees *

*Dept. of Science, Prince Sultan Military College of Health Sciences, Ministry of Defence and Aviation, Dhahran-31932, Kingdom of Saudi Arabia.

ABSTRACT

Imaging of human internal organs with exact and non-invasive methods is very important for medical diagnosis, treatment, monitoring and follow-up. Magnetic resonance imaging (MRI) is one of the advanced, reliable and harmless imaging techniques. It uses radio waves and magnetic field to generate image of the affected part of the body whereas CT examinations and X rays use ionizing radiations. MRI has replaced several invasive modes of examination and thereby reduced the risk and discomfort for many patients. MRI is based on the interaction of magnetic properties of hydrogen with both a large external magnetic field and radio waves, which results in the production of highly detailed images of the human body. MRI is safe but if patient’s safety parameters are overlooked it can cause life threatening situation so great care needs to be taken by the radiologist, medical physicist, technologist and nurses conducting MRI examination. This paper provides a brief history of MRI, MRI Physics, working principle, MRI applications in medical diagnosis, MRI contrast agents and MRI safety concerns.

Key words: MRI, Image quality, MRI Physics, MRI working Principle, Diagnosis, MRI Safety.

INTRODUCTION

In 1946 Felix Bloch proposed new magnetic properties of the atomic nucleus in his Nobel Prize winning paper. He stated that the nucleus of the atom behaves like a tiny magnet. Paul Lauterbur is also regarded as the pioneer of MRI. In 1960 Nuclear Magnetic Resonance (NMR) spectrometer was introduced and during the same time Raymond Damadian discovered that malignant tissues and normal tissues have different NMR parameters. He thought that based on these difference, it is possible to do tissue characterization [1]. At that time MRI was known as NMR ‘Nuclear magnetic resonance’ Later it was thought that the term nuclear would not get accepted amongst the people so it was changed to MRI (Magnetic Resonance Imaging).

X-rays give a gray and flat image. The contrast resolution of x-rays is very poor. To increase the image quality and contrast resolution iodine or barium based media are utilized in X-rays procedures. The basic advantage of MRI is its excellent contrast resolution. With this quality minor lesions in the soft tissue can be detected. One more advantage of MRI is that its image can be constructed in any plane of dimension. MRI scans are the diagnostic tool of choice for soft tissue – organs, ligaments, the circulatory system (spinal column and cord). They help physicians to identify multiple sclerosis, tumors, tendonitis, strokes and many other ailing conditions. While X-rays and CT Scans are useful for looking at bones structures.

MRI Basic Physics

MRI Physics and our earth planet have a lot of things in common. Our earth is like a big sphere which is floating in the space around the sun and also spinning about its own axis. It has a moon orbiting around it. It has electrical charge inside it. About 70% of our earth consists of water. Due to spinning motion, our earth has a magnetic field which is 30μT at the poles and 70μT at the equator (T for Tesla unit of magnetic fields) [1]. We may assume that our earth is like a giant spinning bar magnet, which is also very wet.

Our body also consists of a lot of tiny particles (atoms). Atoms have nucleus which carries positive charge

Corresponding Author :- **Muhammad Idrees** Email:-iamidrees@hotmail.com

and also spinning about its own axis. Electrons are revolving around the nucleus. Our body contains about 80% of water same like our earth. A water molecule consists of 2 hydrogen and 1 oxygen atom. Hydrogen atom has one proton in the nucleus and one revolving electron around the nucleus. This hydrogen atom may be considered as a tiny bar magnet with north and south poles. In our body these tiny bar magnets are arranged in such a way that our body is magnetically balance. No net magnetization over the body [2].

Why We Use Hydrogen As MRI Imaging Source

The first reason is that our body has abundance of hydrogen atoms and second reason is Gyro Magnetic Ratio: This ratio is different for each proton. It is largest for the hydrogen 42.57 MHz/T. Third reason is that hydrogen has large magnetic moment (tendency to align its axis of rotation to an applied external magnetic field). Nuclei that participate in the MRI process must possess some specific magnetic properties. In order to interact with a magnetic field, the nuclei themselves must be small magnets and have a magnetic property or *magnetic moment.* Fig 1 shows magnetic and non magnetic properties of certain nuclei. The magnetic characteristic of an individual nucleus is determined by its nucleus composition. Any element with odd number of particles in the nucleus can be used for MRI so hydrogen is not the only element which is used for MR imaging. Table 1 shows MRI friendly elements.

Spins

Protons and neutrons that make up a nucleus have an intrinsic angular momentum or *spin*. Pairs of protons and neutrons align in such a way that their spins cancel. However, when there is an odd number of protons or neutrons (odd mass numbers), some of the spins will not be canceled and the total nucleus will have a net spin characteristic. It is this spinning characteristic of a particle with an electric charge (the nucleus) that produces a magnetic property known as the *magnetic moment.* The magnetic property, or magnetic moment, of a nucleus has a specific direction. The direction of the magnetic moment is indicated by an arrow drawn through the nucleus. It is also known as axis of spinning proton. Fig 1 shows the direction of magnetic moment. Fig. 2 shows arrangement of hydrogen magnet in the body in the absence of external magnetic field.

When we put a patient inside the bore of the MRI scanner. The strong magnetic field of the scanner (B_o) causes the individual hydrogen protons to align with the magnetic field. This is done in two ways;

I. Align **anti-parallel** to the main magnetic field (B_0). Anti-parallel also known as high energy state.

II. Align **parallel** to the main magnetic field (B_0). Parallel also known as low energy state. Fig. 3 shows alignment of hydrogen protons with the applied magnetic field of the MRI machine.

The distribution of the protons for both the states is not same. Fig 5 (a) shows the distribution of hydrogen protons. The protons are like many people, lazy. Most of them would like to stay in low energy state (Parallel with main magnetic field). The number of excess protons align parallel with the magnetic field is proportional to the strength of magnetic field (B_o). This is also the reason why 1.5 T make better image than the system with lower field strength.

Precession

When external magnetic field is applied, the north and south poles of the tiny hydrogen magnet do not exactly align with the external magnetic field. The axes of spinning protons oscillate or wobble with a slight tilt from a position which was parallel with the flux of external magnet. This tilting or wobbling is called precession. The precessing motion is a physical phenomenon that results from an interaction between the magnetic field and the spinning momentum of the nucleus. Precession is often observed with a child's spinning top. A spinning top does not stand vertical for long, but begins to tilt/wobble, or precess. In this case of spinning top, the precession is caused by an interaction between the earth's gravitational field and the spinning momentum of the top. Fig 4 shows precession of protons.

Larmor Frequency

The Larmor frequency can be calculated with this formula [2].

$$\omega_o = \gamma B_o$$

ω_o = Larmor Frequency (MHz)

γ = Gyro Magnetic Ratio (MHz/T)

B_o = Magnetic field strength (T)

Larmor frequency is important to calculate because it defines the operating frequency of the MRI. MRI system with 1.5 T has Larmor frequency $42.57 \times 1.5 = 68.85$ Mhz. The resonant frequency is also known as Larmor frequency. The sum of all the tiny hydrogen magnet gives a net magnetization in the direction of applied magnetic field (B_o). Net magnetization is denoted by a vector M_Z which is directed along the Z-axis. Z-axis always points in the direction of main magnetic field (B_o) and X and Y axis are at right angled to Z-axis. Net magnetization is also known as Longitudinal magnetization. Fig 5 (b) shows Net magnetization vector M_Z.

Radio Frequency Pulse

Before the use of MRI a pre scan is made to determine at which frequency the protons are spinning (Larmor Frequency). This frequency is also known as centre frequency. System uses this frequency in the next steps during MRI process. Once the centre frequency is determined the system starts acquisition. Now RF (Radio Frequency) pulse is sent into the patient's body and observed. For 1.5 T system the operating frequency or centre frequency is 63.85MH_Z. in order to manipulate the net magnetization vector, RF pulse of the same frequency (63.85 MH_Z) has to be sent. This creates a resonance and that is why it got the name Magnetic renounce imaging [3]. Only protons that spin with the same frequency as the RF pulse will respond to that RF pulse. If we would send an RF pulse with a different frequency, suppose 59.347 MHz, nothing would happen.

RF fields may interact with both tissues and foreign bodies, such as metallic implants. During the imaging process, the majority of RF power is transformed into heat within the patient's tissue. Absorption of energy from RF fields by tissues results in generation of heat due to resistive losses. This local heating will be dissipated by the tissues [7]. This ohmic heating of tissue is greatest at the surface and minimal at the centre of the patient's body. The thermal characteristics of different organs and parts of organs are different. Limbs will dissipate thermal energy more rapidly than internal parts of the abdomen. The eyes are an example of an organ that have very little blood flow, therefore, takes time to dissipate thermal energy. The testes which is separated from the main volume of the body is regarded as heat sensitive.

A rise of 1°C is generally acceptable to a normal healthy body [7]. The actual temperature rise at any time depends on the balance between the energy absorbed and the energy transferred from the region of the body concerned. The ambient temperature and humidity play a major role in the rate of dissipation. The lower the ambient temperature and the lower the humidity the greater the transfer.

RF Flip

If longer the RF pulse is applied, the greater the angle of rotation. If pulse is of sufficient intensity (duration), it will rotate the net tissue magnetization vector into a transverse plane (XY plane), which is perpendicular to longitudinal alignment (Z-Axis) and cause all the protons to precess (wobble) in phase, this is referred to as a 90^0 RF pulse or a flip angle of 90^0. Fig 6 shows flip angle of 90^0. At this precise moment, a maximal RF signal is induced in a receiver coil. This signal depends on the presence or absence of hydrogen and also all the degree to which hydrogen is bound within a molecule. eg: Bone – due to presence of tightly bound hydrogen atoms, they do not align themselves with external magnetic field and do not produce a usable signal.

When net magnetization is rotated 90^oin the XY-plane, it lifts the protons in higher energy state. This happens because protons absorb energy from RF pulses. This is a stage that the protons do not like. This situation can be compared like walking on hands, it is possible but one does not like for long time. They prefer to align with the main magnetic field or in low energy state. This is termed as Relaxation. Relaxation can be divided into two parts, i.e T_1 Relaxation and T_2 Relaxation.

T-1 Relaxation

The protons want to go back to their original state known as equilibrium state. They do it by releasing the energy in the form of RF waves. After the RF excitation pulse stops, the net magnetization rotates back and re grow to align itself in the direction of Z-axis with the emission of RF waves. During T-1 relaxation energy is released from individual hydrogen nuclei to the surrounding tissues (lattice). T-1 relaxation describes what happen along the z-direction. Fig 7 demonstrates this process.

All the protons are not bond in the same way in all the tissues. They are different for each tissue. One ^1H atom may be bound very tight, such as in fat tissue, while the other has a much looser bond, such as in water. Tightly bound protons will release their energy much quicker to their surroundings than protons, which are bound loosely. The rate at which they release their energy is therefore different. Fig 8 shows the rate of T1 relaxation. Each tissue releases energy (Relaxes) at different rate and that is why MRI has such a good contrast resolution. T1 is defined as the time it takes for the longitudinal magnetization (Mz) to reach 63 % of the original magnetization. Fig 8 shows T-1 relaxation curve.

T-2 Relaxation

Right after the 90º RF-pulse all the magnetization is "flipped" into the XY-plane. The net magnetization changes its name and is now called Transverse magnetization (M_{XY}) Transverse magnetization rotates in XY-plane. Before 90^o RF pulse they may be rotating with the same speed but not spinning in-phase. When 90^o RF pulse is applied, apart from flipping the net magnetization vector into xy-plane, the protons start to rotate in-phase. All the individual vectors point in the same direction as they are in-phase but they do not stay like this. Each proton in MRI behaves as a tiny bar magnet with north and south pole and is represented by a vector. The magnetic field of each vector is affected by one another therefore one vector may slow down while the other may speed up. The vector will rotate at different speed and they will no longer point in the same direction and start de-phasing [3]. "This process of getting from a total in-phase situation to a total out-of-phase situation is called T2 relaxation". All the de-phased vectors will rotate around the z-axis in xy-plane. . B_o is along Z-axis. Fig 9 shows T-2 relaxation process

Relaxation Curve

T-2 relaxation does not occur at once. It depends how strongly or loosely hydrogen atom is bound in a tissue and it is different for each tissue.Right after the 90º RF-pulse all the magnetization is "flipped" into the XY-plane. The net magnetization changes its name and is now called M_{XY} (Transverse magnetization). At time = 0 all spins (Vectors) are in-phase, but immediately start to de-phase. T2 relaxation is also a time constant. T2 is defined as "The time it takes for the spins (vectors) to de-phase to 37% of the original value. The rate of de-phasing is different for each tissue. Fat tissue will de-phase quickly, while water will de-phase much slower. Fig. 10 shows T-2 relaxation curve.

Important

It is important to remember that T-1 and T-2 relaxation do not depend on each other. The only common thing between them is that both occur simultaneously. T-1 describes what happen along z-axis and T-2 describes what happens in xy-plane.T-2 much faster than T-1. When both relaxation processes are finished the net magnetization vector is aligned with the main magnetic field (B_0) again and the protons are spinning Out-Of-Phase; it becomes the same situation as before the transmission of 90º RF-pulse.

Receive Coil & Acquisition

During the relaxation process, the absorbed energy is radiated in the form of RF waves. In order to produce an image we need to pick up this energy before it disappears in the space. This is done with the receive coil. The most import thing about the receive coil is its position. The receive coil must be positioned at right angled with the main magnetic field (B_o). When magnetic field goes through the coil, current is induced in the coil. B_o is much stronger than RF signal which we are going to receive. Huge current is induced by B_o and small current is induced by RF waves. It will generate a lot of speckles known as noise in the image. Therefore we have to make sure that receive coil is positioned at right angled with the main magnetic field to avoid this disturbance.

According to **Faraday** a Radio Frequency wave has an electric AND a magnetic component, which are at a right angles from one another, have a 90º phase difference and both move in the same direction with the speed of light. It is the magnetic component in which we are interested because that induces the current in the receive coil.

Positioning the receive coil at 90^0 to B_o serves one more purpose. we can only receive signals from processes that happen at right angles to B_0, which happens to be T2 relaxation. T2 relaxation is a decaying process, which means phase coherence is strong in the beginning, but rapidly becomes less until there is no phase coherence left. Consequently, the signal that is received is strong in the beginning and quickly becomes weaker due to T2 relaxation.

The signal is called: Free Induction Decay. The FID is the signal we would receive in absence of any magnetic field. Fig. 11 shows FID process. The received signal is fed into the computer and it amazing produces the image on the screen in a fraction of second.

Gradient Coils/Magnets

Gradient coils are a set of wires in the magnet, which enable us to create additional magnetic fields, which are, in a way, superimposed on the main magnetic field B_0. There are three gradient coils known as X,Y and Z coil. Fig. 12 shows gradient coils/magnets. X-coil creates varying magnetic field from left to right across the scanning tube. Y-coil creates varying magnetic field from top to bottom across the scanning tube. Z-coil creates varying magnetic field from head to toe within scanning tube [9]. All of them are far less powerful than the main magnet B_0. They modify the magnetic field at very particular points and work in conjunction with the RF pulses to produce the scanner's picture by encoding the spatial (having the nature of space) distribution of the water protons in the body. When rapidly turned on and off (which causes that banging noise), the gradient magnets allow the scanner to image the body in slices – sort of like a loaf of bread. Using medical terminology, the transverse (or axial, or x-y) planes slice you from top to bottom; the coronal (x-z) planes slice you lengthwise from front to back; and the sagittal (y-z) planes slice you lengthwise from side to side. However, the x, y and z gradients can be used in combination to generate image slices that are in any direction, which is one of the great strengths of MRI as a diagnostic tool. Fig.13 shows sagittal, Transverse and coronal plane slices of human brain.

T1 & T2 Weighted Image Description

A T1 weighted image is produced by a short repetition time between RF pulses and a short signal recovery time. Because T1 is all exponential growth time constant, a tissue with short T1 produces all intense MR signal and is displayed as bright white in a T1 weighted image. A tissue with long T1 produces a – low intensity signal and appears dark in MR image.

A T2-weighted image is acquired using a long repetition time between RF pulses and a long signal recovery time. A tissue with a long T2 produces a high-intensity signal and is bright in the image. One with short T2 produces a low-intensity signal and is dark in the image [2].

What is Contrast?

A contrast material (gadolinium) may be used during the MRI scan to show certain structures more clearly in the pictures. The contrast material may be used to check blood flow, find some types of tumors, and show areas of inflammation or infection. The contrast material may be put in a vein in your arm or directly into the part of the body under observation. Gadolinium does not contain iodine (Iodine/barium contrast agents are used in X-rays) and, therefore, rarely causes an allergic reaction or other problem. However, if you have a history of kidney or liver disease, you should advice the technologist or radiologist before the MRI procedure begins.

Clinical Applications of MRI

There are various types of clinical applications of MRI scans that may be ordered by the doctor for certain investigations and diagnosis [4-6].

A Head MRI can look at the brain for tumors, an aneurysm (a sac formed by abnormal dilation of the weakenedwall of a blood vessel), bleeding in the brain, nerve injury, and other problems, such as damage caused by a stroke. A head MRI can also find Problems of the eyes and optic nerves, and the ears and auditory nerves.

A Chest MRI can look at the heart, the heart valves, and coronary blood vessels. It can show if the heart or lungs are damaged. An MRI of the chest may also be used to look for breast or lung cancer. These can also be ordered after a mammogram (Mammography is the process of using low-energy X-rays (usually around 30 kVp) to examine the human breast, which is used as a diagnostic and screening tool. The goal of mammography is the early detection of breast cancer, typically through detection of characteristic masses and/or microcalcifications) exam has been given to see areas of the breast tissue in more detail.

MRA or Magnetic Resonance Angiography is a type of magnetic resonance image (MRI) scan. MRI scans are used to look at blood vessels, and the flow of blood through them is called magnetic resonance angiography (MRA). MRA scans can find problems of the arteries and veins, such as an aneurysm, a blocked blood vessel, or the torn lining of a blood vessel (dissection). Sometimes contrast material is used to see the blood vessels more clearly. Like an MRI, magnetic resonance angiograms (MRA) use a magnetic field and pulses of radio wave energy to make pictures of blood vessels inside the body.

Abdomen and Pelvis MRI Scans can find problems in the organs and structures in the belly, such as the liver, gallbladder, pancreas, kidneys, and bladder. They can be used to find tumors, bleeding, infection, and blockage. In women, MRI scans can look at the uterus and ovaries. In men, they can look at the prostate.

Bone and Joint MRI can check for problems such as arthritis, problems with the temporomandibular joint, bone marrow problems, bone tumors, cartilage problems, torn ligaments or tendons, or infection. These MRI scans may also be used to tell if a bone is broken when X-ray results are not clear. MRI scans are done more commonly than other tests to check for some bone and joint problems.

A Spine MRI can check the discs and nerves of the spine for conditions such as spinal stenosis (A constriction or narrowing of a duct or passage or vessel of the body), disc bulges, and spinal tumors.

Fig.16 shows MRI scans for Chiari Malformation ('kee-AH-ree-mal-for-MAY-shun' is a condition in which brain tissue extends into spinal canal. It occurs when part of the skull is abnormally small or misshapen, pressing on the brain and forcing it downward.)

Fig.16 shows patient's syrinx (A pathological tube-shaped cavity in the brain or spinal cord.) pointed by arrows (left, before surgery), and the reduction in the size of the syrinx after surgery (right, arrows). After the surgery, cerebrospinal fluid surrounding the cerebellum also returns to normal.

Safety Concerns

The potential benefits of MRI are numerous. However, there are hazards intrinsic to the MR environment which must be understood, acknowledged and respected. Several incidents involving MR have been reported in ECRI Health Device Alerts (HDA), U.S. Food and Drug Administration (FDA) Medical Device Reporting (MDR) [7].

The powerful magnetic field of the MR system will attract iron-containing (also known as ferromagnetic) objects and may cause them to move suddenly and with great force. This can pose a possible risk to the patient or anyone in an object's "flight path." Great care is taken to be certain that objects such as ferromagnetic screwdrivers and oxygen tanks are not brought into the MR system area. As a patient, it is vital that you remove all metallic belongings in advance of an MRI exam, including watches, jewelry, and items of clothing that have metallic threads or fasteners. Additionally, makeup, nail polish, or other cosmetics that contain metallic particles should be removed if applied to the area undergoing the MRI examination.

The powerful magnetic field of the MR system will pull on any iron-containing object in the body, such as certain medication pumps or aneurysm clips. Every MRI facility has a comprehensive screening procedure and protocol that, when carefully followed, ensures that the MRI technologist and radiologist know about the presence of metallic implants and materials so that special precautions can be taken. In some unusual cases, due to the presence of an unacceptable implant or device, the exam may have to be canceled. For example, the MRI exam will not be performed if a ferromagnetic aneurysm clip is present because there is a risk of the clip moving or being dislodged. In some cases, certain medical implants can heat substantially during the MRI examination as a result of the radiofrequency energy that is used for the procedure. Therefore, it is very important to inform the MRI technologist about any implant or other internal object that you may have.

The magnetic field of the MR system may damage an external hearing aid or cause a heart pacemaker, electrical stimulator, or neuro stimulator, to malfunction or cause patient injury. If you have a bullet or other metallic fragment in your body (e.g., any metallic foreign body) there is a potential risk that it could change position, possibly causing injury.

Items Need to be Removed Before MRI

Items that need to be removed by patients and individuals before entering the MR system room include [7].

- Purse, wallet, money clip, credit cards, cards with magnetic strips
- Electronic devices such as beepers or cell phones
- Hearing aids
- Metal jewelry, watches
- Pens, paper clips, keys, coins
- Hair barrettes, hairpins
- Any article of clothing that has a metal zipper, buttons, snaps, hooks, underwire, or metallic threads Shoes, belt buckles, safety pins

Table 1. MRI Friendly Elements [1]

Isotope	Symbol	Spin Quantum Number	Gyro Magnetic Ratio (MHz/T)
Hydrogen	^{1}H	1/2	42.6
Carbon	^{13}C	1/2	10.7
Oxygen	^{17}O	5/2	5.8
Fluorine	^{19}F	1/2	40.0
Sodium	^{23}Na	3/2	11.3
Magnesium	^{25}Mg	5/2	2.6
Phosphorus	^{31}P	1/2	17.2
Sulphur	^{33}S	3/2	3.3
Iron	^{57}Fe	1/2	1.4

Fig. 1 Magnetic Properties of Nuclei

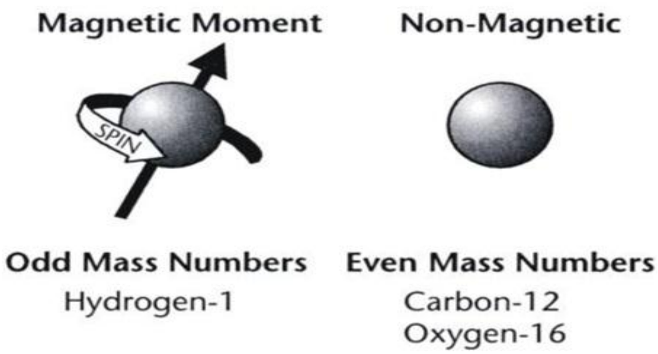

Fig. 2. Arrangement of Hydrogen Magnet in the Body in the Absence of External Magnetic Field

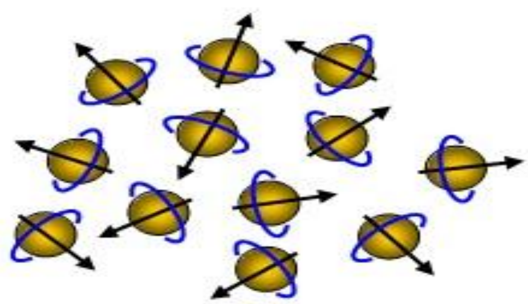

Fig. 3. Alignment of Hydrogen Protons With the Applied Magnetic Field of the MRI Machine

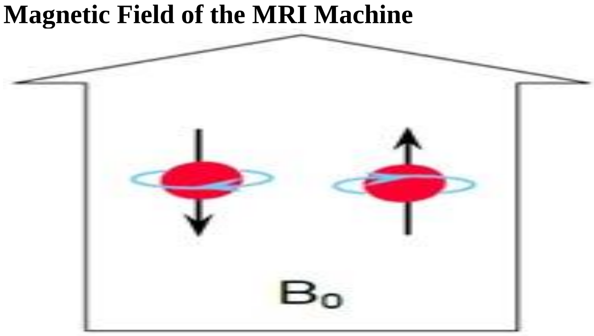

Fig. 4. Precessing Proton

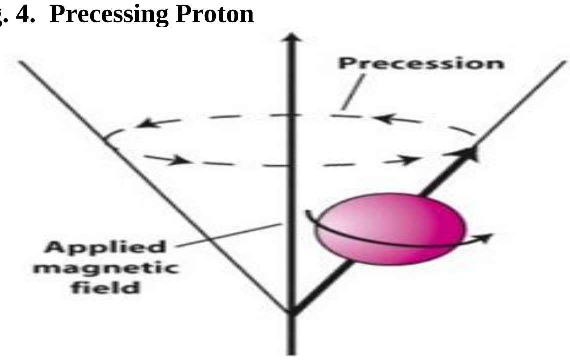

Fig. 5. Net Magnetization Vector (M_Z)

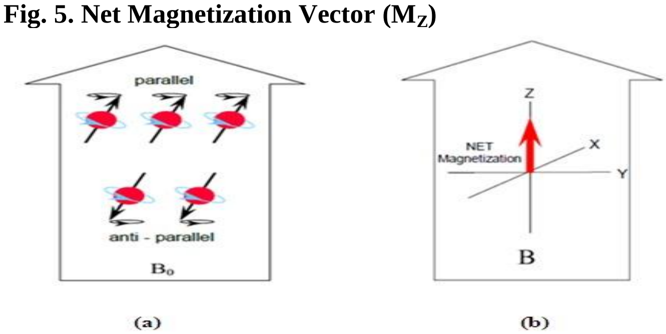

Fig. 6 Flip Angle of 90^{O} [1]

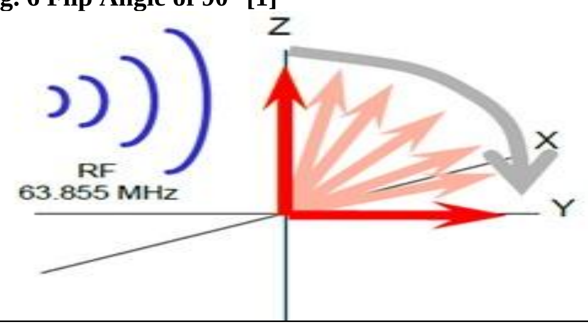

Fig. 7. T-1 Relaxation Process and Variation of Net Magnetization Vector [1]

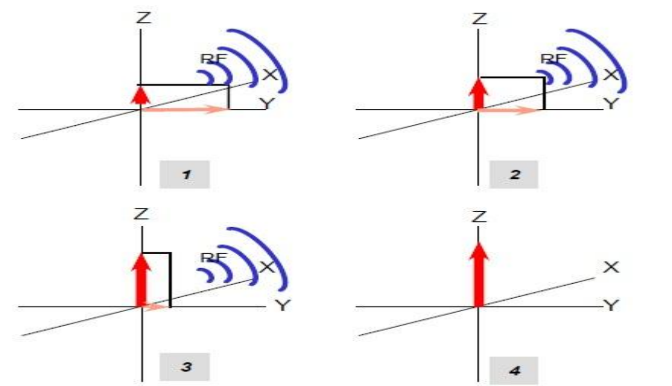

Fig. 8 T-1 Relaxation Curve

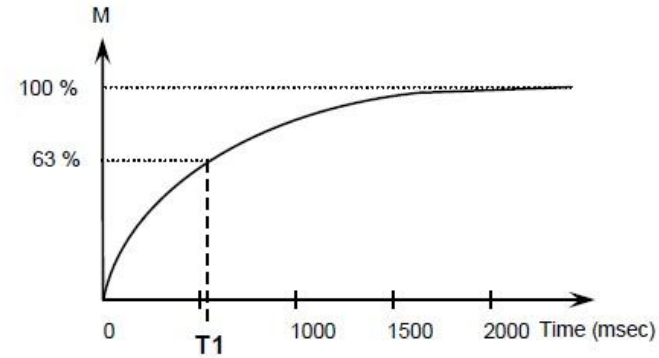

Fig 9. T-2 Relaxation : Total in Phase Situation to Total Out of Phase Situation in XY Plane

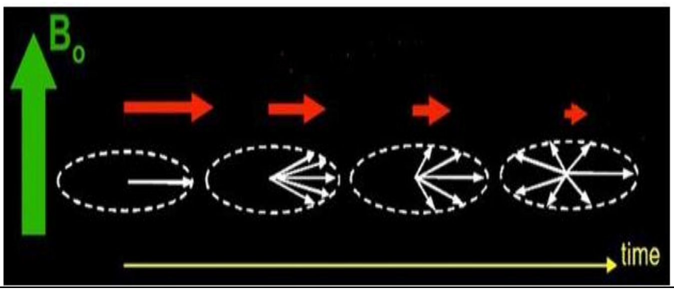

Fig 10. T-2 Relaxation Curve

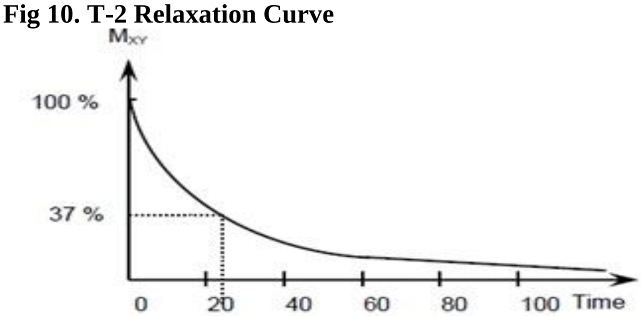

Fig. 11. Free Induction Decay (FID)

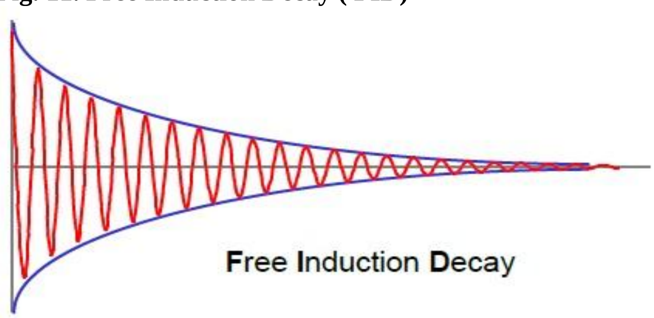

Fig.12 Gradient Coils or Magnet

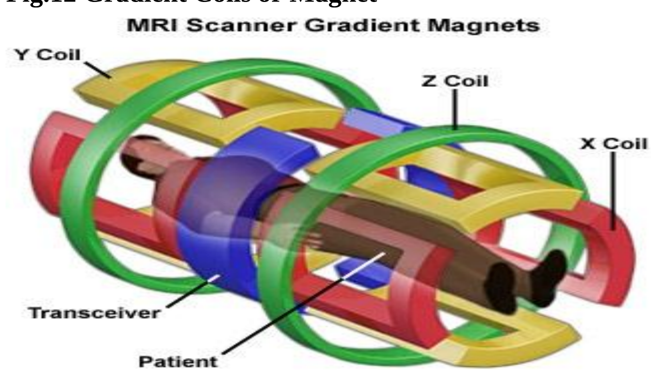

Fig.13. Slices of the Brain with the Gradient Coils

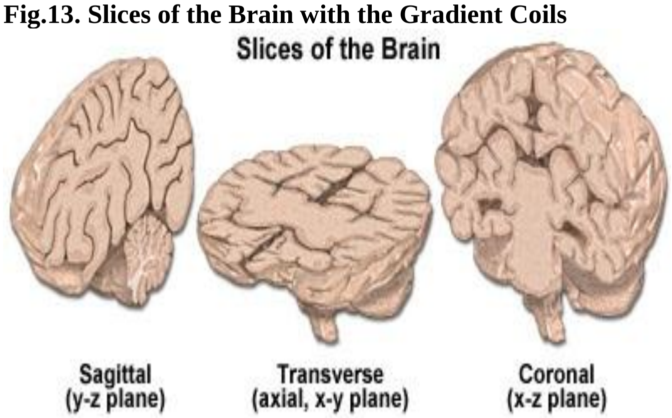

Fig. 14 T1 & T2. Weighted Images of Cerebral Lymphoma

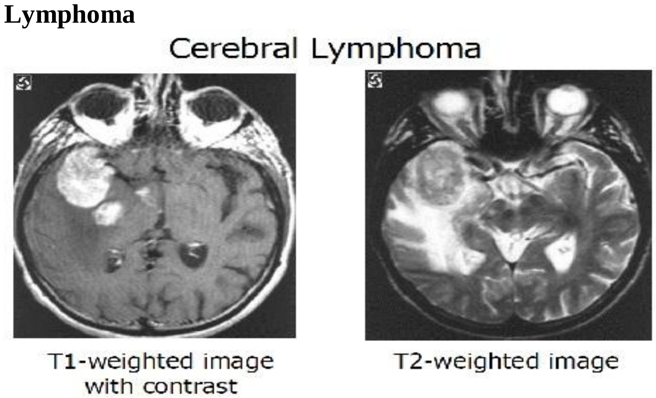

Fig. 15. Fat Suppressed, Contrast Enhanced, T1 Weighted Image of Breast Carcinoma Arrow Shows Tumor

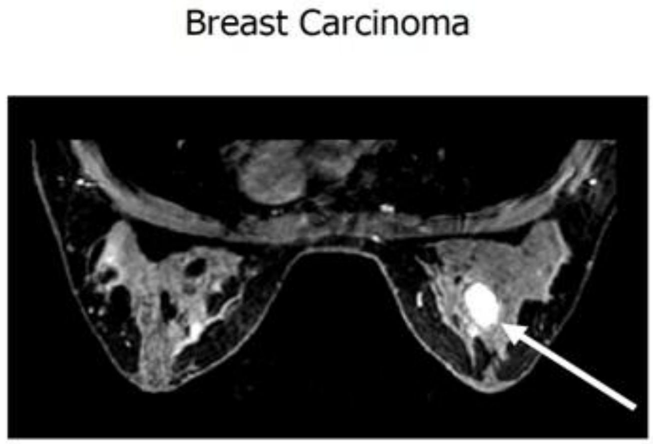

Fig. 16. MRI Scans Showing Chiari Malformation

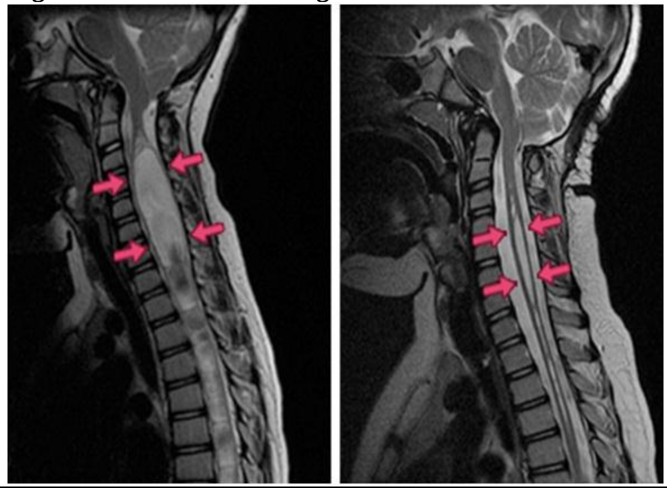

Fig. 17. Standard MRI Machine

Fig. 18. Open MRI Machine

Fig. 19. MR Safety Warning Sign [8]
New MR safety warning sign designed to help control access to the MR environment. This sign should be placed on the door to the MR system room.

CONCLUSION

Magnetic resonance imaging (MRI) is the diagnostic tool that currently offers the most sensitive non-invasive way of imaging the brain, spinal cord, or other areas of the body. An MRI is used to investigate or diagnose conditions such as tumours, joint or spinal injuries or diseases, soft tissue injuries or diseases of internal organs such as the brain or heart. MRI has made it possible to visualize and understand much more about the underlying pathology of the disease. Its clinical effectiveness demands appropriate understanding of the Physics concepts by the radiologists, technologists medical Physicists and all those involved and all those involve in MRI procedures. There are many excellent books and review and research papers are available on MRI working principles, its health effects and safety [1-10]. MRI is now considered as the gold standard for imaging the brain, spinal cord, musculoskeletal system, head & neck, and complex congenital heart malformations [10]. The studies discussed in this review paper provide strong evidence that the technology is safe and may allow patients to undergo MRI.

REFERENCES

1. Evert J Blink. Basic mri Physics, Application specialist MRI, 2004.
2. Pekar JJ. A brief introduction to functional MRI. Engineering in Medicine and Biology Magazine. *IEEE*, 25(2), 2006, 24-6.
3. White SC, Pharoah MJ. Oral radiology: principles and interpretation. Mosby, St Louis 2000, 205-6.
4. Brady TJ,Rosen BR, Pykett IL, McGuire MH, Mankin HJ, Rosenthal DI. NMR imaging of leg tumors. *Radiology*, 149, 1983, 181-7.
5. Chafetz NI, Genant HK, Moon KL, Helms CA, Morris JM. Recognition of lumbar disk herniation with NMR. *AJR*, 141, 1983, 1153-6.
6. Cohen MD, Klatte EC, Baehner R et al. Magnetic resonance imaging of bone marrow disease in children. *Radiology*, 151, 1984, 715-8.
7. Magnetic Resonance Imaging: Health Effects and Safety Kwan-Hoong Ng, Azlan C Ahmad, MS Nizam, BJJ Abdullah Department of Radiology University of Malaya Kuala Lumpur Malaysia.
8. Shellock FG. Signs to help control access to the magnetic resonance environment, 2003.
9. Roguin A, Goldsher D. Magnetic resonance imaging and implantable cardiac electronic devices: it's not what we can do, it's what we should do. *Isr Med Assoc J*, 12, 2010, 436–438.
10. Marcu CB, Beek AM, van Rossum AC. Clinical applications of cardiovascular magnetic resonance imaging. *CMAJ*, 175, 2006, 911–7.