Review on Technological Aspects of Magnetic Resonance Imaging and Functional Magnetic Resonance Imaging

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Abstract - *Currently, with the advent of technological advancements, a number of tools and techniques are invented and modified to make the diagnosis of common and even rare diseases a lot more easier. These diagnostic tools make use of either machines or biologic studies and in some cases both. One of the most common ways to diagnose internal diseases is through imaging. In the laboratory, different types of sources are used to make the imaging possible; radiation, electricity, and magnetic fields are a few techniques. One type of imaging device that utilizes the magnetic and electrical sources of energy is what we call the MRI. Through some modifications in technological aspects, a sister –technique was created out of the MRI and was called as FMRI. This paper focuses on differences between MRI and FMRI.*

Keywords- *MRI – Magnetic Resonance Imaging, FMRI – Functional Magnetic Resonance Imaging.*

I. *INTRODUCTION*

Magnetic Resonance Imaging was invented by Paul C. Lauterbur in September 1971; he published the theory behind it, in March 1973 [1]. Lauterbur published images representing the Nuclear Magnetic Resonance response of hydrogen nuclei in a pair of water-filled glass capillaries [2]. One-dimensional (1-D) projections of this response were first obtained through a procedure that involved applying static magnetic field gradients to the sample, mapping NMR (Nuclear Magnetic Resonance) frequency onto source position. A series of 1-D projections, acquired along different gradient directions, were then combined to reconstruct a two-dimensional image, as illustrated in Figure. 1. The factors leading to image contrast (differences in tissue relaxation time values) had been described nearly 20 years earlier by Erik Odeblad (physician and scientist) and Gunnar Lindstrom. Two objects (water-filled capillaries) aligned with the z-axis are shown, along with their projection onto the x-y plane. Magnetic field gradients applied along various directions cause the NMR response to spread out in frequency, producing one dimensional projections reflecting the distribution of water (blue curves). Multiple projections, acquired along with different gradient directions (indicated by red arrows) are then combined to reconstruct a two dimensional image. Inset: Lauterbur's NMR image of two 1 mm inner diameter water-filled capillaries [1].

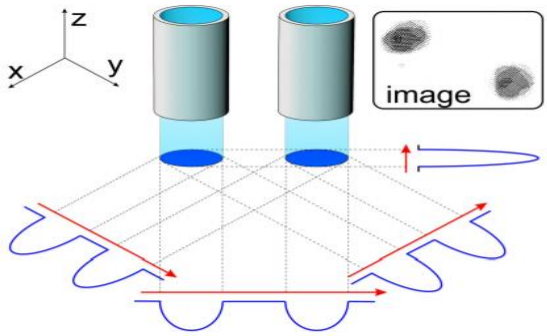

Figure 1: Principle underlying the first MR imaging experiment performed by P.C. Lauterbur [1].

Considering the fundamental importance and applicability of MRI in medicine, Paul Lauterbur of the University of Illinois at Urbana-Champaign and Sir Peter Mansfield of the University of Nottingham were awarded the 2003 Nobel Prize in Physiology or Medicine for their "discoveries concerning magnetic resonance imaging". The Nobel citation acknowledged Lauterbur's insight of using magnetic field gradients to determine spatial localization, a discovery that allowed rapid acquisition of 2D images. "Snapshot" acquisition schemes wherein entire 2-D images that could be obtained in a few tens of milliseconds [2]. Mansfield was credited with introducing the mathematical formalism and developing techniques for efficient gradient utilization and fast imaging. The actual research that won the prize was done almost 30 years before while Paul Lauterbur was a professor in the Department of Chemistry at Stony Brook University in New York [3].

A paper in the Journal Science was published in March 1971 by Raymond Damadian, an Armenian-American Physician and Professor at the Downstate Medical Center State University of

New York (SUNY). He reported that tumors and normal tissue can be distinguished in vivo by nuclear magnetic resonance ("NMR"). He suggested that by using these differences cancer could be diagnosed. Later researchers found that these differences, though real are too variable for diagnostic purposes. Damadian's initial methods were flawed for practical use, relying on a point-by-point scan of the entire body and using relaxation rates, which turned out not to be an effective indicator of cancerous tissue. While doing research on the analytical properties of magnetic resonance, Damadian created a hypothetical magnetic resonance cancer detecting machine in 1972. He filed the first patent for such a machine, U.S. Patent 3,789,832 on March 17, 1972, which was later issued to him on February 5, 1974. Zenuemon Abe and his colleagues applied the patent for targeted NMR scanner, U.S. Patent 3,932,805 on 1973. They published this technique in 1974.

The US National Science Foundation notes "the patent included the idea of using NMR to 'scan' the human body to locate cancerous tissue." However, it did not describe a method for generating pictures from such a scan or precisely how such a scan might be done. Meanwhile, Paul Lauterbur at Stony Brook University expanded on Carr's technique and developed a way to generate the first MRI images, in 2D and 3D, using gradients. In 1973, Lauterbur published the first nuclear magnetic resonance image and the first cross-sectional image of a living mouse in January 1974. In the late 1970s, Peter Mansfield, a physicist and professor at the University of Nottingham, England, developed the echo-planar imaging (EPI) technique that would lead to scans taking seconds rather than hours and produce clearer images than Lauterbur had. Damadian, along with Larry Minkoff and Michael Goldsmith, obtained an image of a tumour in the thorax of a mouse in 1976. They also performed the first MRI body scan of a human being on July 3, 1977. They published the studies in 1977. The apparatus looked as shown in Figure 2.

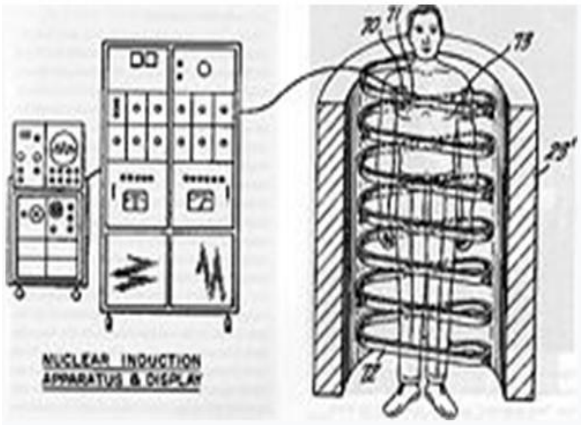

Figure 2: Raymond Damadian's "Apparatus and method for detecting cancer in tissue".

Figure 3: MRI Scanner Mark One. The first MRI scanner to be built and used in Aberdeen Royal Infirmary in Scotland.

During 1970s, a team led by John Mallard built the first full-body MRI scanner at the University of Aberdeen [3]. On 28th August 1980, they used this machine to obtain the first clinically useful image of a patient's internal tissues using MRI, which identified a primary tumour in the patient's chest, an abnormal liver and secondary cancer in his bones. This machine was used later at St. Bartholomew's Hospital, in London, from 1983 to 1993. Mallard and his team are credited for technological advances that led to the widespread introduction of MRI [8]. The first MRI scanner is shown in Figure 3.

During the late 19th century, Angelo Mosso invented the 'human circulation balance', which could non-invasively measure the redistribution of blood during emotional and intellectual activity. Mosso's manuscripts do not provide direct evidence that the balance was really able to measure changes in cerebral blood flow due to cognition. However. a modern replication performed by David T Field has now demonstrated using modern signal processing techniques changes in cerebral blood volume related to cognition can be detected [5].

A. Introduction to MRI

Magnetic Resonance Imaging (MRI) is a medical imaging process that uses a magnetic field and Radio Frequency (RF) signals to produce images of anatomical structures within the human body. MRI machine produces images that are distinctly different from the images produced by other imaging modalities. A primary difference is that, the MRI process can selectively image several different tissue characteristics. A potential advantage of this is that if a pathologic process does not alter one tissue characteristic and produce contrast, it might be visible in an image because of its effect on other characteristics. This causes the MRI process to be somewhat more complex than other imaging methods. In order to optimize an MRI procedure for a specific clinical examination, the user must have a good knowledge of the characteristics of the Magnetic Resonance Image (MRI) and how it's characteristics can be controlled [5]. The image created using MRI technology looks as in Figure 4. In clinical and research MRI machines, hydrogen atoms are most-often used to generate a detectable radio-frequency signal that is received by antennas in close proximity to the anatomy being examined. Hydrogen atoms exist naturally in people and other biological organisms in abundance, particularly in water and fat. Pulses of radio waves excite the nuclear spin energy transition and magnetic field gradients localize the signal in space. By varying the parameters of the pulse sequence, different contrasts can be generated between tissues based on the relaxation properties of the hydrogen atoms therein. Since its early development in the 1970s and 1980s, MRI has proven to be a highly versatile imaging technique. While MRI is most prominently used in diagnostic medicine and biomedical research, it can also be used to form images of non-living objects [8].

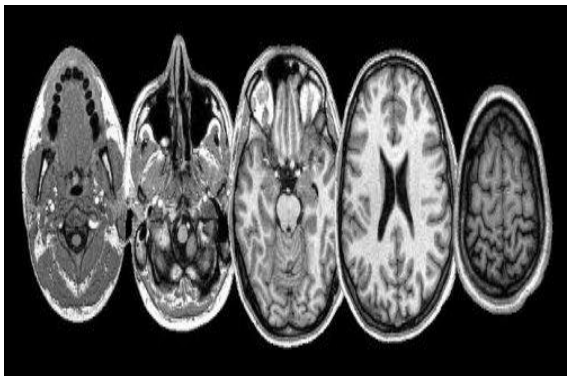

Figure 4: Image created using MRI technology.

B. Introduction to FMRI

FMRI is a functional neuroimaging procedure using MRI technology that measures brain activity by detecting changes associated with blood flow. This technique relies on the fact that cerebral blood flow and neuronal activation are coupled. When an area of the brain is in use, blood flow to that region also increases.

Functional Magnetic Resonance Imaging or FMRI is a non-invasive technique for imaging the activation of brain areas by different types of physical sensation (sight, sound, touch, taste, smell) or activity such as problem solving and/or movement (limited by the machine). Thus, FMRI scan is an increasingly common tool for "brain mapping" in cognitive science. The technique to measure blood flow to the brain was discovered by Linus Pauling and Charles Coryell in 1936 that oxygen-rich blood with Hb was weakly repelled by magnetic fields, while oxygen-depleted blood with dHb (deoxygenated Hemoglobin) was attracted to a magnetic field, though less so than ferromagnetic elements such as iron. Then Seiji Ogawa at AT&T Bell labs recognized that this could be used to augment MRI, which could study just the static structure of the brain, since the differing magnetic properties of dHb and Hb caused by blood flow to activated brain regions would cause measurable changes in the MRI signal. BOLD is the MRI contrast of dHb, discovered in 1990 by Ogawa.

Functional MRI (FMRI) is used to understand how different parts of the brain respond to external stimuli or passive activity in a resting state. Blood Oxygenation Level Dependent (BOLD) FMRI measures the hemodynamic response to transient neural activity resulting from a change in the radio of oxyhemoglobin and deoxyhemoglobin. Researchers use statistical methods to construct a 3D parametric map of the brain, which indicates the regions of the cortex that demonstrate a significant change in activity in response to the task [9]. The image created using FMRI technology looks as shown in Figure 5.

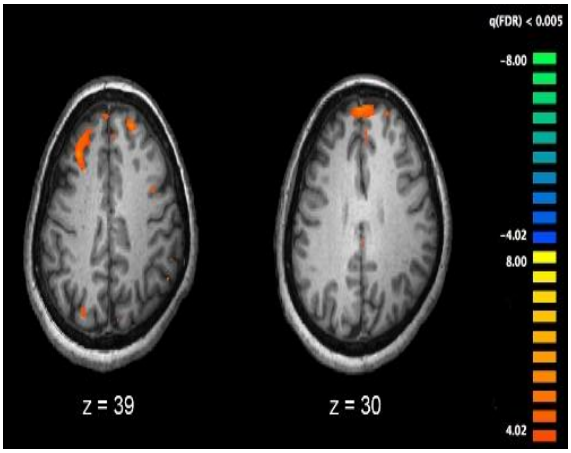

Figure 5: Image created using FMRI technology.

II. *TECHNIQUE OF IMAGE ACQUISITION*

This section explains the basic knowledge and overview of the MR image & FMR image, how the

image relates to specific tissue characteristics and how image quality characteristics can be controlled.

A. The constructional overview of MRI Machines

The MRI machine consists of three types of magnets which are used for generation of image, amplifiers, RF source, digitizer etc., as shown in the Figure 6.

Though design specifications, of design vary, the basic elements of an MRI scanner remain pretty much the same (see above). The scanner consists of a large magnet (blue) that creates the primary magnetic field. Magnet strength in MRI systems is measured in units of magnetic flux density called a "tesla". A telsa is enough magnetic force to induce 1 volt of electricity in a single-coil circuit during 1second of time for every square meter, 1 tesla is equivalent to 10,000 gauss. Another measure of magnetic force defined as one line of force per square centimeter per second of time. Current magnet strength varies from 0.5-tesla to 2.0-tesla. However, researchers developed 3-tesla MRI scanners in the late 90's, which are becoming more common. To put those numbers in perspective, the Earth's magnetic field is about 0.5-guass or .000005-tesla. In addition to the main magnet, there are also gradient coils (red). These gradient coils are electromagnetic coils which technicians use to alter the main magnetic field at very precise points and for very precisely controlled times. Gradient coils can be changed so as to adjust the machine for the type of body material to be imaged. Finally, MRI scanners also incorporate radio frequency coils, which can send a focused radio frequency pulse into the scanner chamber. Technicians can change the radio frequency coils to adjust for materials and body part [5].

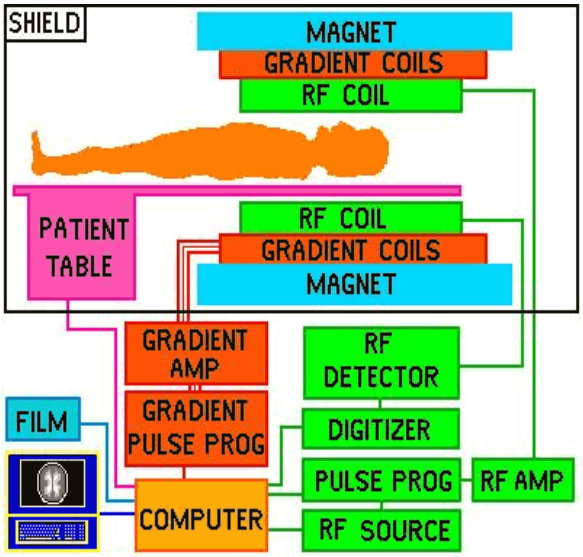

Figure 6: The constructional overview of MRI Machines

The most important part of an MRI scanner is the magnet, the "Magnetic" part in MRI. There is a long tube, the same one where the patient enters, that runs through a giant magnet from front to back. This tube is known as the "bore". But, the magnet used in MRI scanners is not like one of the magnets you stick on your kitchen fridge. These magnets are incredibly strong and able to produce a large, stable magnetic field.

Most MRI scanners use a superconductive magnet, which consist of coils of wire through which a current of electricity is passed, creating a magnetic field. Maintaining such a large magnetic field requires a large amount of energy, which is created by superconductivity, which means reducing the resistance in the wires to almost zero. This is done by continuously bathing the wires in helium at freezing 452.4 degrees below Fahrenheit. This cold is kept insulated by a vacuum. Superconductive magnets are very expensive, but the strong magnetic field they produce creates the highest-quality imaging. Other magnets such as Resistive magnets and Permanent magnets are used. The Resistive magnets, although they are structurally like a superconducting magnet, they do not have the liquid helium which means they require a huge amount of electricity to work and are expensive to operate.

There are three Gradient magnets in MRI scanners. These magnets have a much lower strength compared to the main magnet. While the main magnet is used to create intense, stable magnetic field around the patient, the Gradient magnets create smaller, variable fields around the parts of the body that need to be scanned.

Another part of the MRI system is a set of coils that transmit a radiofrequency waves into the patient's body. There is a different set of coils for different parts of the body, such as the knees, shoulders, neck and so on. These coils either conforms to the body part being imaged or are positioned very close to it during the exam. Other parts of the machine include an extremely powerful computer system and a patient table, which slides the patient into the bore [6].

B. The MR Image

Magnetic resonance imaging (MRI) has been established for over a decade as a superior research and clinical modality for anatomical imaging. With its high spatial and temporal resolution and its ability to acquire images from virtually any plane or volume, it has enabled the detection and diagnosis of a broad range of pathological conditions [3].

The MR image displays certain physical characteristics of tissue. 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). Figure 7 shows these characteristics.

The MR image is a display of RF signals that are emitted by the tissue during the image acquisition process. The source of the signals is a condition of magnetization that is produced in the tissue when the patient is placed in the strong magnetic field. The tissue magnetization depends on the presence of magnetic nuclei. The specific physical characteristic of tissue or fluid that is visible in the image depends on how the magnetic field is being changed during the acquisition process.

An image acquisition consists of an acquisition cycle like a heartbeat that is repeated many times. During each cycle the tissue magnetization is forced through a series of changes. .

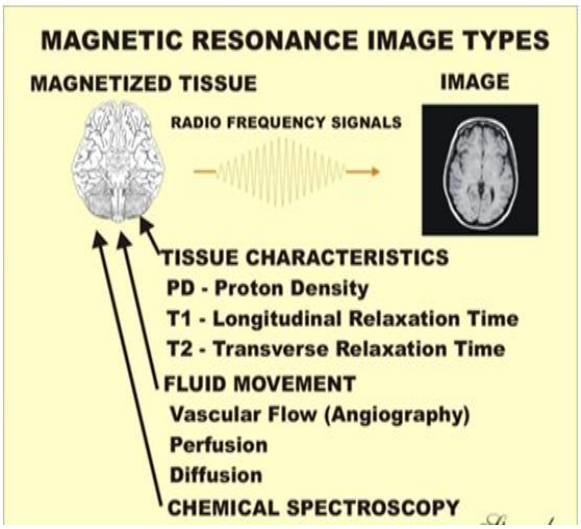

Figure 7: Physical characteristics of tissue and fluid movement that can be displayed in the magnetic resonance image.

It is the level of magnetization that is present at a special "picture snapping time" at the end of each cycle that determines the intensity of the RF signal produced and the resulting tissue brightness in the image.

The characteristics that can be used as a source of image contrast fall into three rather distinct categories. The first and most widely used category is the magnetic characteristics of tissues. The second category is characteristics of fluid (usually blood) movement. The third category is the spectroscopic effects related to molecular structure.

C. Magnetic Characteristics of Tissues

Tissue characteristics can be studied using Proton Density and relaxation times of the tissues.

1) Proton Density (PD) Images: The most direct tissue characteristic that can be imaged is the concentration or density of protons (hydrogen). In a proton density image the tissue magnetization, RF signal intensity and image brightness are determined by the proton (hydrogen) content of the tissue. Tissues that are rich in protons will produce strong signals and have a bright appearance.

2) Magnetic Relaxation Times — T1 and T2 Images: During an MRI procedure, the tissue magnetization is cycled by flipping it into an unstable condition and then allowing it to recover. This recovery process is known as relaxation. The time required for the magnetization to relax varies from one type of tissue to another. The relaxation times can be used to distinguish (i.e., produce contrast) among normal and pathologic tissues.

The relaxation constants are defined by processes which cause the MR signal to decay:

T1 relates to the time constant of the 'spin-lattice relaxation' this refers to the interaction of the protons spin with its surroundings into which energy is released as protons return to a lower state of alignment.

T2 relates to the time constant of 'spin-spin relaxation' this is caused by the loss of precession synchrony among the protons; prior to the radio frequency pulse that aligns the protons, the protons precession is random and out of phase, the radio frequency pulse aligns the protons and brings them into phase, However, when the pulse has passed, the protons revert to random states due to interactions with neighbouring protons whom they swap energy through random collisions.

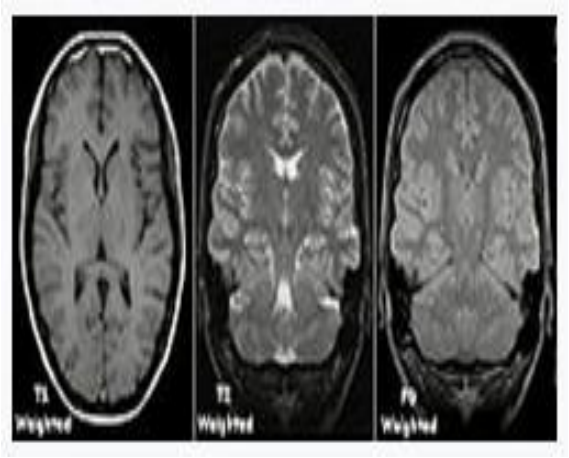

Figure 8: Example of T1 Weighted, T2 Weighted and PD Weighted MRI scans.

D. Characteristics of fluid movement

Fluid movement can be characterized using vascular flow, perfusion and diffusion.

1) Vascular Flow: The MRI process is capable of producing images of flowing blood without the use of contrast media. Although, flow effects are often visible in all types of images, it becomes the predominant source of contrast in images produced

specifically for vascular or angiographic examinations.

2) Perfusion and Diffusion: It is possible to produce images that show both perfusion and diffusion within tissue. These require specific imaging methods are often characterized as functional imaging.

E. Chemical Spectroscopy

The frequency of the RF signals emitted by tissue is affected to a small degree depending up on the size and characteristics of the molecules containing the magnetic nuclei. These differences in frequencies, the chemical shift can be displayed in images. It is also the basis of MR spectroscopy. Spectroscopy is the process of using magnetic resonance to analyze the chemical composition of tissue. Spectroscopy makes use of the fact that different molecular structures have different resonant frequencies. Typically, the MR signals from a tissue specimen are sorted and displayed on a frequency scale as shown in Figure 8. The signals from different chemical compounds will appear as peaks along the frequency scale. This leads to their identity and measure of relative abundance.

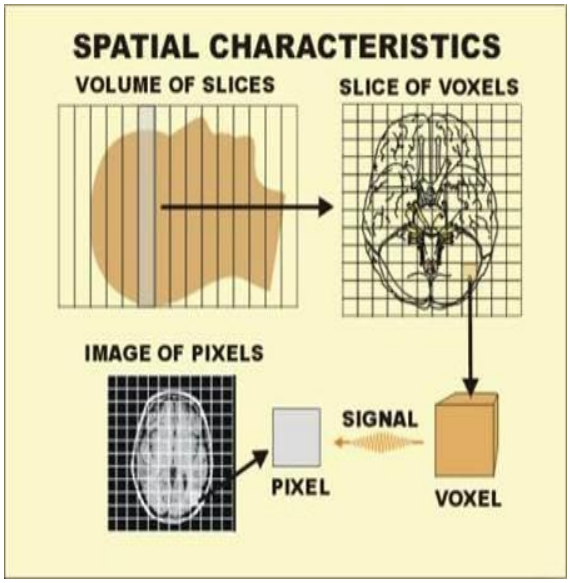

Figure 9: The spatial characteristics of MR images.

The Spatial characteristics include the importance of slices, voxels and image pixels.

***1) Slices*:** A typical examination will consist of at least one set of contiguous slices. In most cases the entire set of slices is acquired simultaneously. However, the number of slices in a set can be limited by certain imaging factors and the amount of time allocated to the acquisition process.

The slices can be oriented in virtually any plane through the patient's body. The major restriction is that images in the different planes cannot generally be acquired simultaneously. For example, if both axial and sagittal images are required, the acquisition process must be repeated. However, there is the possibility of acquiring 3-D data from a large volume of tissue and then reconstructing slices in the different planes.

***2) Voxel*:** Each slice of tissue is subdivided into rows and columns of individual volume elements or voxels. The size of a voxel has a significant effect on image quality. It is controlled by a combination of protocol factors and should be adjusted to an optimum size for each type of clinical examination. Each voxel is an independent source of RF signals. That is why voxel size is a major consideration in each image acquisition.

***3) Image Pixels*:** The image is also divided into rows and columns of picture elements, or pixels. In general, an image pixel represents a corresponding voxel of tissue within the slice. The brightness of an image pixel is determined by the intensity of the RF signal emitted by the tissue voxel [4].

Magnetic Resonance Spectroscopy (MRS) is used to measure the levels of different metabolites in body tissues. The MR signal produces a spectrum of resonances that corresponds to different molecular arrangements of the isotope being "excited". This signature is used to diagnose certain metabolic disorders, especially those affecting the brain, and to provide information on tumor metabolism. It combines both spectroscopic and imaging methods to produce spatially localized spectra from within the sample or patient. The spatial resolution is much lower (limited by the available SNR), but the spectra in each voxel contains information about many metabolites. This is because the available signal is used to encode spatial and spectral information, MRSI requires high SNR achievable only at higher field strengths (3 T and above) [8].

The condition within the tissue that produces the RF signal is magnetization. At this point, we will use an analogy to radioactive nuclide imaging. In nuclear medicine procedures it is the presence of radioactivity in the tissues that produces the radiation. In MRI it is the magnetization within the tissues that produces the RF signal radiation displayed in the image. Therefore, when we look at an MR image, we are seeing a display of magnetized tissue [4].

F. The basic physical principles

In order to understand how FMRI scans work one needs a rough understanding of the basic physical principles upon which the technology is built. The relevant physical principles are those involving the atom. Atoms are the smallest particles of an element, which still possess the properties of the elements. For instance, helium is an element. The smallest bit of helium that still has the properties of helium is a helium atom. Atoms are very

small. The diameter of an atom ranges from about 0.1 to 0.5 nanometers.

Most atoms are composed of three particles distinguished by their electrical charge; protons (positive), electrons (negative) and neutrons (neutral). Electromagnetic forces bind protons and neutrons together in an atom to form its center, i.e., its nucleus. The number of protons in an atom's nucleus determines the atom's elemental categorization. Hydrogen has the fewest protons with only one. Uranium has 92 protons. The number of neutrons is usually approximately equal to the number of protons, but there is variation in the number of possible neutrons in an atomic nucleus. Electrons circle around the nucleus. Since protons have a positive charge and electrons have a negative charge these particles attract each other thereby creating the stable electrically neutral structure of the average atom.

The electromagnetic forces that keep atomic structure relatively stable by keeping the electrons circling the nucleus also cause the nucleus to wobble or spin, that is the nucleus of the atom spins around as in the Figure 10. Nuclear spin or more precisely, the manipulation of nuclear spin is the basis for MRI imaging.

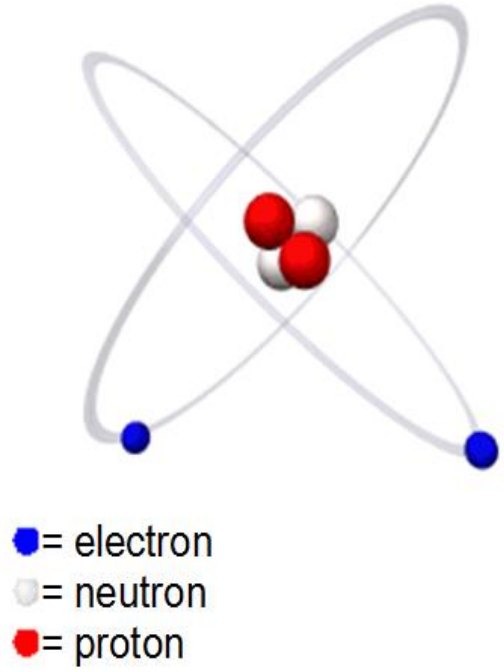

Figure 10: Model of a helium atom.

If one places an atom within a magnetic field plane, i.e., subject it to magnetic forces along two of the three dimensions, then the nucleus will orbit around the third (vertical) axis. This is called precession and is depicted as shown in Figure 11.

When one causes nuclei to process their spin will cause them to align themselves with the magnetic field. The spin of a nucleus is just like the ends of a bar magnet in that it can have a positive or negative value. Two negative or two positive ends of a magnet repel one another, but negative and positive ends attract each other. Similarly, all the negative spin atoms align themselves downward on the Z axis (towards the feet of the subject) and all the positive atoms align upward on the Z axis (towards the subject's head). Each atom with a positive spin cancels out (renders undetectable) an atom with a negative spin. There remain, however, a few atoms do not cancel one another out. At room temperature, there are always more positive spin atoms than negative spin atoms. These unmatched atoms are the important ones for MRI and FMRI.

Positive spin atoms are in a low energy state. The atoms achieve equilibrium magnetization value along the direction of the magnetic field, i.e., the Z axis. By introducing a pulse of magnetic energy perpendicular to the main magnetic field in the form of a radio frequency pulse that is specific to the type of atom (usually hydrogen), the MRI machine causes the unmatched atoms to resonate.

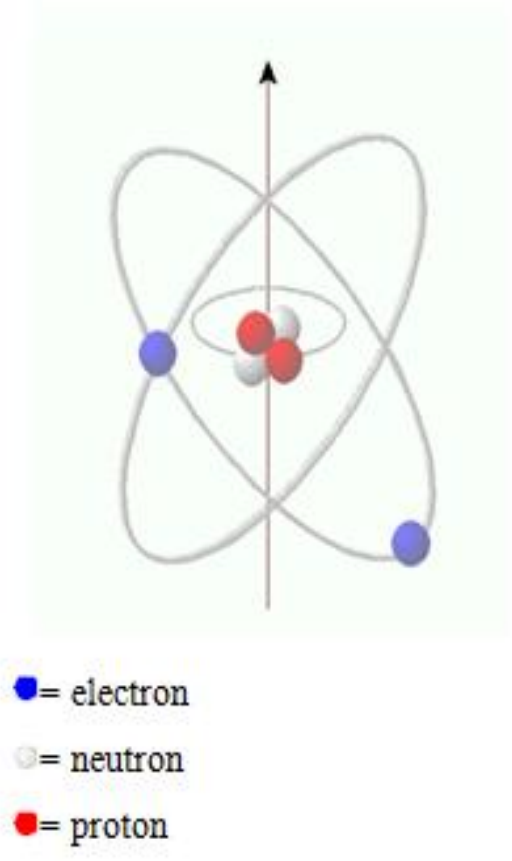

Figure 11: Nuclear spin of a helium atom.

Resonating atoms absorb the radio energy as a photon and go to the higher energy state, i.e., they become negative spin atoms and the

equilibrium magnetization value for the Z axis goes to 0. When the pulse is stopped, these atoms release their photon energy and "relax" back into the lower energy positive spin state. The signal that the MRI machine detects is the photon energy emitted by these unmatched atoms as they make a transition from the higher energy state to the lower energy state after the radio frequency pulse. The amount of time it takes for the atoms to return to their equilibrium value is called the "spin lattice relaxation time" or (T1) [7]. T1 is thus a measure of the half-life of inverted spins.

When one causes nuclei to process their spin will cause them to align themselves with the magnetic field. The spin of a nucleus is just like the ends of a bar magnet in that it can have a positive or negative value. The resonating atoms absorb the radio energy and go to the higher energy state, i.e., they become negative spin atoms relative to the XY axis (the transverse axis). The amount of time it takes for the atoms to return to their equilibrium magnetization value along XY axis (transverse axis) is called the "spin-spin relaxation time" or T2. T2 is, as a result, measures the rate of change of spin phases. Whereas a typical T1 (spin lattice relaxation time) is approximately 1 second, the T2 (spin-spin relaxation time) is usually less than 100ms. This difference in the relative times is what makes T2 better suited than T1 for functional metabolic imaging [4].

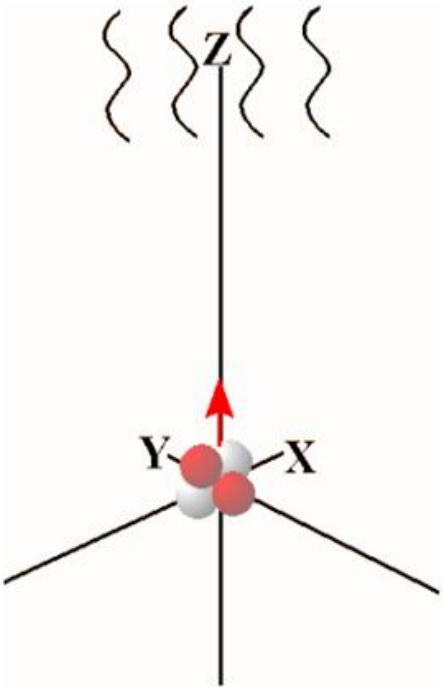

Figure 12: Spin-spin relation time T2

G. The FMRI

FMRI is based on the idea that blood-carrying oxygen from the lungs behaves differently in a magnetic field than blood that has already released its oxygen to the cells. In other words, oxygen-rich blood and oxygen poor blood have a different magnetic resonance. Scientists know that active areas of the brain receive more oxygenated blood. The FMRI picks up this increased blood flow to pinpoint greater activity. Imaging technique of FMRI is similar to MRI technique, particularly important for FMRI is the measure of decay of transverse magnetization, $T2^*$ which takes into account two important factors (1) molecular interactions and in homogeneities in the magnetic field. FMRI creates the images or brain maps of brain functioning by setting up and utilizing an advanced MRI scanner in such a way that increased blood flow to the activated areas of the brain shows up on the MRI scans [9]. The intensity of an MRI signal is determined by the level of magnetic resonance, specifically what is called the BOLD effect (Blood Oxygenation Level Dependent) on $T2^*$ [7].

While acquiring FMRI data the magnetic field can drift and fluctuate causing temporal changes in the field map that are ignored in “static” field map corrected image reconstruction. Such temporal changes arise from heating in passive shim elements in the scanner bore, motion and physiological processes such as respiration . These temporal changes can be partially corrected in real time while collecting the MR data using navigators or in the image reconstruction by updating the field map either before reconstructing each time frame or jointly [10]. However, the navigators correct only for spatially global off-resonance changes and even though updating the field map gives a voxel-based correction of the off-resonance, the image reconstruction methods are based on nonlinear iterative algorithms that can converge slowly [9].

Magnetic fields are altered by the presence of any substance to some extent. Many materials exhibit pronounced polarization in a magnetic field. The degree of this effect is referred to as the "magnetic moment" or "magnetic susceptibility". Spatial and temporal variation in local concentrations of deoxygenated haemoglobin (blood cells not carrying oxygen or Hb) to oxygenated haemoglobin (blood cells carrying oxygen or HbO_2) result in corresponding changes in magnetic susceptibility, which in turn cause the local T2* values to fluctuate. Oxygenated haemoglobin are diamagnetic (i.e., tend to take a position at right angles to the lines of magnetic force and are repelled by either pole of the magnet), while deoxygenated haemoglobin is paramagnetic (i.e., takes a position parallel and proportional to the intensity of the magnetizing field). Thus, MRI is able to detect a small difference (a signal of the order of 3%) between the two types of haemoglobin. This is called a blood-oxygen level dependent, or "BOLD" signal. Researchers are currently exploring

the precise relationship between neural activity and the BOLD signal. The relevant spatial unit for measuring local T2* for FMRI contrast called a "voxel". Voxel comes from the contraction for volume element. A voxel is smallest unit of MRI reconstruction and corresponds to a single pixel in an MRI display image. The relative ratio of deoxygenated to oxygenated haemoglobin within a voxel determines the T2* value for that voxel. Increases in metabolic function in a given brain region can trigger vasodilation (expansion of the vessel), thereby increasing oxygenated blood flow and altering the gradient of highly oxygenated haemoglobin to highly deoxygenated haemoglobin within the capillary bed. If one assumes that neuronal activation causes local vasodilatation absent a corresponding significant increase in oxygen metabolism, then increased oxygenated blood flow to a brain region results in a corresponding increase in local, intra voxel T2*. This T2* increase then causes a corresponding increase in image intensity.

The mechanism by which the neural system provides feedback to the vascular system of its need for more glucose is partly the release of glutamate as part of neuron firing. This glutamate affects nearby supporting cells, astrocytes, causing a change in calcium ion concentration. This, in turn, releases nitric oxide at the contact point of astrocytes and intermediate-sized blood vessels, the arterioles. Nitric oxide is a vasodilator causing arterioles to expand and draw in more blood.

A single voxel's response signal over time is called its time course. Typically, the unwanted signal called the noise from the scanner, random brain activity and similar elements is as big as the signal itself. To eliminate these, FMRI studies repeat a stimulus presentation multiple times.

Spatial resolution of an FMRI study refers to how well it discriminates between nearby locations. It is measured by the size of voxels as in MRI. A voxel is a three-dimensional rectangular cuboid, whose dimensions are set by the slice thickness, the area of a slice, and the grid imposed on the slice by the scanning process. Full-brain studies use larger voxels, while those that focus on specific regions of interest typically use smaller sizes. Sizes range from 4 to 5 mm to 1 mm.

Smaller voxels contain fewer neurons on average, incorporate less blood flow, and hence have less signal than larger voxels. Smaller voxels imply longer scanning times, since scanning time directly rises with the number of voxels per slice and the number of slices. This can lead both to discomfort for the subject inside the scanner and to loss of the magnetization signal. A voxel typically contains a few million neurons and tens of billions of synapses, with the actual number depending on voxel size and the area of the brain being imaged [5].

III. *CONCLUSION*

Therefore, MRI and FMRI differ from each other in a way that MRI views the anatomical structure while the FMRI views the metabolic function. An MRI studies the water molecule's hydrogen nuclei whereas an FMRI calculates the levels of oxygen. In atomic physics, the MRI's structural imaging views at a high resolution the difference between tissue types with respect to space. On the other hand, an FMRI's functional imaging views the tissue differences with respect to time. In addition to this, an MRI has a high, spatial resolution while an FMRI has a long-distance, superior, temporal resolution. In terms of the cost in buying the machine, the FMRI is considered to be more expensive than an MRI because of the additional software and hardware required for it. The price may reach up to hundreds of thousands to millions, and that is quite a lot of money. For a cheaper choice, the MRI is preferred.

Hence, it is clear, that neither an MRI nor an FMRI has an advantage over the other because both machines serve for different functions. Therefore appropriate method of diagnosis is used for different purposes.

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