CHAPTER 3

MEDICAL IMAGING TECHNIQUES

3.1 INTRODUCTION

If physical symptoms of a patient suspects the possibility of brain tumor, then the physician reviews medical history and performs a physical examination to evaluate brain and spinal cord functions (Neurologic Examination). It commonly involves testing reflexes, muscle strength, eye and mouth movement, coordination, alertness and other functions. If the results are abnormal, then the physician refers the patient to a neurologist or a neurosurgeon to perform a more detailed examination by recommending one of the medical imaging tests. The studies of images are viewed and interpreted by radiologists[5,10].

One of the principal problems faced by the physician in planning of the appropriate treatment by studying the images is the precise localization of critical brain structures with respect to the tumor to define the safest possible surgical approach. Two dimensional images accurately describe the size and location of anatomical objects or tumor which are often indistinguishable by the naked eye. This considerably helps the physician in planning of therapy or surgery. Two dimensional images of brainhelp
the surgeon review the images and analyze alternative navigational paths for the recommended treatment without disturbing the neighboring critical brain structures. In this view, different imaging modalities play an important role in diagnosis and treatment of brain tumor[12,16].

3.2 IMAGING TECHNIQUES

The various medical imaging methods generally recommended by the medical expert, their merits and demerits are explained below:

CT or CAT scan (Computed Tomography):

It combines sophisticated x-ray and computer technology to create a detailed picture of the body’s tissues and structures. CT can show a combination of soft tissue, bone and blood vessels. CT images can determine some types of tumors as well as help detect swelling, bleeding and bone and tissue calcification. Usually, iodine is the contrast agent used during a CT scan [8,11]. However, CT scans involve exposure to ionizing radiation, which is known to cause cancer. It is not as accurate as an MRI and does not detect about half of low-grade gliomas.

PET Scan (Positron Emission Tomography):

It provides a picture of the brain’s activity, rather than its structure. Here, the rate at which a tumor absorbs glucose is measured. This is also performed by tracking substances labeled with a radioactive tracer. The patient is injected with deoxyglucose that has been labeled with radioactive markers. The PET scan measures the brain’s activity and sends this information to a computer, which creates a live image. Experts use PET scans to see the difference between scar tissue, recurring tumor cells, and necrosis (cells destroyed by radiation treatment). PET is not routinely used for diagnosis, but it may supplement MRIs to help determine tumor grade after a diagnosis[5].

X-rays

X-Rays of the skull were once standard diagnostic tools but are now performed only when more advanced procedures are not available.

Angiogram:

This is another imaging test sometimes used in evaluating brain and spinal cord tumors. It involves injecting a special dye into blood vessels near the tumor and then
viewing the area with x-rays. This helps the physician to view the blood supply of a tumor. This test has largely been replaced by other tests like Computerized Tomographic Angiography (CTA) or Magnetic Resonance Angiography (MRA).

**MRI (Magnetic Resonance Imaging):**

MRI Scanner is a scanning device that uses magnetic fields and computers to capture images of the brain on film. It does not use x-rays. It provides two dimensional images of brain from various planes. These 2D images can be combined together to create a three-dimensional image of the tumor[14]. The MRI detects signals emitted from normal and abnormal tissue, providing clear images of most tumors.

MRI, in recent times, has gained huge popularity due to its unique advantages as mentioned below:

(i) Non-invasiveness due to use of non ionizing radiation
(ii) Extremely high contrast
(iii) Resolution of soft tissue
(iv) Ability to discriminate between various structures in a given plane.

Considering the merits of Magnetic Resonance Imaging and its popularity among medical experts, MR Images of brain tumor are utilized for the presented work.

**3.3. MAGNETIC RESONANCE IMAGING (MRI)**

Magnetic Resonance Imaging (MRI) is the most frequently used imaging technique in Clinical neuroscience and neurosurgery for non invasively establishing diagnosis, quantitatively evaluating disease processes and guiding therapy[15,16]. This is because of the absence of ionizing radiation, as opposed to other imaging methods.

MRI is an imaging technique based in the measurement of magnetic field vectors generated after an appropriate excitation with strong magnetic fields and radio-frequency pulses in the nuclei of hydrogen atoms present in the water molecules of the patient’s tissues. As the content of water differs for each type of tissue, it is possible to quantify the differences of radiated magnetic energy and have elements to identify each
tissue. When specific magnetic vectorial components are measured under controlled conditions, different images can be acquired, and information related to tissue contrast may be obtained. Multispectral data set of MR Images consists of three types of images, T1, T2 and PD-Proton Density. Typical MR Images are shown in figure 3.1

![Typical MR Images of Brain](image)

(i) T1  (ii) T2  (iii) PD

**Fig. 3.1 Typical MR Images of Brain**

3.3.1 Basic Principal and Conceptual Overview

In the year 1973, Lauterbur acquired the first MR image by using magnetic gradients and then reconstructed the image by back projection. MRI has developed significantly since then and has a very wide range of clinical applications [17].

Clinical MR images are based on proton density and proton relaxation dynamics. These vary according to the tissue under examination and reflect its physical and biochemical properties. Different tissues are characterized and discriminated according to the different properties of their constituents (water, iron, fat, blood). The MRI Unit is shown in Fig.3.2
The MR images are obtained by placing the patient or area of interest within a powerful, highly uniform, static magnetic field. Magnetized protons (hydrogen nuclei) within the patient align like small magnets in this field. Radio frequency pulses are then utilized to create an oscillating magnetic field perpendicular to the main field, from which the nuclei absorb energy and move out of alignment with the static field, in a state of excitation. As the nuclei return from excitation to the equilibrium state, a signal induced in the receiver coil of the instrument by the nuclear magnetization can then be transformed by a series of algorithms into diagnostic, digital images[17,18].

During a single image acquisition, several components of the received signals are recorded, the most common being the proton densities and the relaxation time constants T1 and T2. Hence, an image represents the spatial distribution of several distinct tissue related parameters. Each pixel/voxel is a feature vector of these properties. T1 (spin-lattice relaxation time) describes the relaxation time of the nuclei as
projected on the longitudinal $z$-axis, $z$ being the direction of the main constant magnetic field[19]. T2 (spin-spin relaxation time) describes the relaxation time as projected on the transverse $xy$-plane.

### 3.3.2 Image Artifacts and Limitations

The quality of image processing is limited by the quality of the underlying imaging technique. Thus, it is important to know and understand the characteristics and limitations of MRI [67, 70]. This section provides a qualitative overview of common artifacts seen in clinical magnetic resonance images and comments on its limitations with respect to imagery of pathologic brain.

**(i) Dropouts and Shifts**

Shift artifacts cause displacement of a reconstructed object from its true position in the image and local image distortions. They are due to susceptibility artifacts (change of magnetic susceptibility at tissue boundaries) or chemical shifts (shift of frequency response due to the chemical environment) and occur where air/tissue, tissue/bone, or tissue/metal form boundaries[17]. A second effect of susceptibility artifacts is signal dropout, which appear near air-tissue and tissue-bone interfaces.

**(ii) Motion**

Motion artifacts appear as repeating densities oriented in the scanning direction or ‘ghost images’. This results from motion during the acquisition of a sequence. In brain imagery, this artifact is most commonly caused by physical movement of the subject during image acquisition [19].

**(iii) Partial Volume Effect**

The partial volume effect results from the finite spatial resolution of the MR image, a pixel may represent more than one kind of tissue type. As a result, borders between two different tissues types are blurred or misrepresented. In brain imagery, this typically appears at the interfaces brain surface with cerebro-spinal fluid (CSF) where CSF may appear as white matter[21].

**(iv) Noise**

The signal-to-noise (SNR) ratio increases proportional to the pixel size (i.e. the field of view (FOV) and the resolution), proportional to the square root of the imaging
time and is determined to a significant extent by the strength of the external magnetic field.

(v) Geometric and Signal Distortions

Inhomogeneities in the static or gradient magnetic field cause systematic geometric and intensity signal distortions. Gradient field inhomogeneities may distort an image to a bow tie, barrel or potato chip shape. A nonlinear static magnetic field causes the intensity signal of a tissue type to vary spatially.

3.3.3 Relaxation Time constants

The energy that is absorbed by the nuclei from RF pulse is emitted back when the RF pulse is with drawn. By doing so the excited nuclei relaxes and the energy that is emitted back is measured in the form of FID signal. At macroscopic level the NMV returns back to its original position. The rate with which the nucleus relaxes is the characteristic of individual tissue. There are two mechanisms for relaxation[18].

3.3.3.1 Spin-Spin Relaxation time (T2):

At the end of RF pulse, all the spins are in phase coherence. As $M_{xy}$ rotates at larmor frequency, there is a loss of phase coherence of individual spins, resulting in exponential decay of $M_{xy}$. Micro magnetic inhomogeneities intrinsic to the structure cause this. The elapsed time between peak transverse signal and 37% (100/e) of peak level is called T2 relaxation time. The dephasing gets faster in the presence of external magnetic inhomogeneities resulting in a smaller spin-spin relaxation time, T2*. 

![Fig. 3.3 RF pulse Transverse Magnetization illustrating T2](image-url)
3.3.3.2 Spin-Lattice Relaxation time (T1):

The loss of transverse magnetization also occurs due to return of net magnetization vector to equilibrium. The T1 relaxation time is time needed to recover 63% of longitudinal magnetization. It depends on the characteristic of interaction of spin with lattice. T1 is always much greater than T2 and T2 is greater than T2*. It is the differences in T1, T2, T2* and spin densities that provide the extremely high contrast of MRI.

![Fig. 3.4 RF pulse Longitudinal Magnetization illustrating T1](image)

**SUMMARY**

MRI Scanner is a scanning device that uses magnetic fields and computers to capture images of the brain on film. It provides two dimensional images of brain from various planes. These two dimensional images can be combined together to create a three-dimensional image of the tumor. The MRI detects signals emitted from normal and abnormal tissue, providing clear images of most tumors.

MRI is popular due to its unique advantages as non-invasiveness due to use of non ionizing radiation, extremely high contrast and ability to discriminate between various structures in a given plane.
MRI is an imaging technique based in the measurement of magnetic field vectors generated after an appropriate excitation with strong magnetic fields and radio-frequency pulses in the nuclei of hydrogen atoms present in the water molecules of the patient’s tissues. As the content of water differs for each type of tissue, it is possible to quantify the differences of radiated magnetic energy, and have elements to identify each tissue. When specific magnetic vectorial components are measured under controlled conditions, different images can be acquired, and information related to tissue contrast may be obtained. Multispectral data set of MR Images consists of three types of images, T1, T2 and PD-Proton Density.

The quality of image processing is limited by the quality of the underlying imaging technique. The common artifacts seen in magnetic resonance images are dropouts and shifts, motion artifacts and noise.