QUANTITATIVE MRI AS A BIOMARKER IN NEUROLOGICAL DISEASE ASSESSMENT

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ABSTRACT
Magnetic Resonance Imaging (MRI) has emerged as a key component in the assessment, diagnosis, and monitoring of neurological diseases because of its high soft tissue contrast, non- invasiveness, and efficient provision of anatomical and functional details. This paper focuses on exploring the applications of MRI in the perception and diagnosis of different diseases like, stroke, brain tumor, Alzheimer disease, and other neurodegenerative diseases. The research examines the effectiveness of MRI on early detection, differentiation diagnosis, treatment site selection and disease progression tracking.
Keywords: *Magnetic Resonance Imaging (MRI), Neurological Disorders, Alzheimer, Small vessel disease (SVD), Brain Stroke*

INTRODUCTION

Magnetic Resonance Imaging (MRI) refers to a diagnostic imaging technique, non-invasive in nature, and that is designed to capture fine inner body structures (particularly soft tissues such as the brain, muscles and body organs) [1, 2].

Working Principle of MRI:

Nuclear magnetic resonance, which happens in atoms with an odd number of protons or neutrons, is the basis for the MRI principle [3]. A strong magnetic field (1.5, 3T) aligns hydrogen protons as the patient enters the MRI scanner, producing a net longitudinal magnetization (M_0). Depending on the flip angle (e.g., 90°), this magnetization is then tipped into the transverse plane by an RF pulse at the Larmor frequency. According to Faraday's Law, the transverse magnetization processes coherently, creating a detectable voltage in the receiver coil that results in the free induction decay (FID) signal [4]. Larmor equation informs us of the rate at which this precession occurs. In the most common atom in human body, hydrogen, the ratio of the absolute value of the gyromagnetic ratio (γ) is 42.58 (MHz/Tesla). So Larmor frequency of hydrogen in a 1.5 Tesla MRI scanner is:

$\omega 0=\gamma B0$ $\omega 0=42.58\times 1.5=63.87$
MHz
[5]

The Larmor equation, which uses gradient fields to produce minute spatial variations in frequency to enable signal localization and slice selection, is the basis for spatial encoding in MRI. Two relaxation processes take place following the RF pulse: T1 (spin-lattice) restores longitudinal magnetization through energy exchange with tissues, and T2 (spin-spin) induces transverse decay as a result of dephasing. A 180° refocusing pulse in spin-echo sequences can be used to correct for this decay (T2*), which is accelerated by field inhomogeneities. In MRI, signal location is determined by gradients in the magnetic field. By using a frequency-selective radiofrequency pulse to apply a gradient along one axis, slice selection is accomplished. After mapping spatial information into k-space using frequency and phase encoding, the final image is reconstructed in real space using an inverse Fourier transform [6].

Role of MRI in Alzheimer Disease:

The most prevalent neurodegenerative disease is the Alzheimer Disease, which mainly affects the memory and cognitive abilities, and in the final analysis, it also causes dementia. Structural MRI is significant in the identification of atrophy of the brain and in the follow-up of the neurofibrillary tentacles (NFTs) [7].

Role of MRI in Brain Tumor:

The Brain Tumor is cellular proliferation that is abnormal in the brain. These can be categorized as Benign and Malignant. For brain tumor MRI is Highly sensitive in the identification of abnormalities, location, size, mass effect, atrophy, hemorrhages. T1, T2, FLAIR, are employed to do the right diagnosis and therapy planning [8].

Role of MRI in Stroke:

Stroke is an acute and localized neurological condition, which occurs because of the disruption of blood flow to a section of the brain and the death of brain cells. Ischemic Stroke (approximately 85 percent of stroke) and Hemorrhagic Stroke (approximately 15 percent of stroke) are the types of strokes. MRI is very sensitive to acute and chronic hemorrhage. It Identifies changes in the ischemic condition earlier than the CT. T2 and FLAIR identify microbleeds and hemorrhage [9]. Role of MRI in Small Vessel Disease (SVD): Small Vessel Disease is a disease that affects small vessels of the blood in the brain (small arteries, arterioles, capillaries, and small veins).

White matter hyperintensities (WMH), Lacunes,
Microbleeds, and Microinfarcts are demonstrated by routine MRI (1.5, 3T). These key markers show SVD [10].

Role of MRI in Migraine:

Migraines are one of the frequent and disabled neurological conditions experienced in the contemporary society. Application of MRI in migraine is that the presence of White matter abnormalities (WMAs) in patients with migraine can often be diagnosed through MRI. Lesions are presented in the form of small and discrete foci in T2-weighted and proton density-weighted images [11, 12].

MATERIALS AND METHODS

MRI Protocol:

MRI scans were performed on a Canon Vantage Orian 1.5 Tesla MRI scanner, having the bore size of 71 cm (standard closed-bore design) with High-performance gradient coils with up to 45 mT/m amplitude and 200 T/m/s slew rate, supporting advanced imaging sequences. Slice thickness is 2.5 to 3.5 millimeters, Signal averages are 0.85 to 1 and the Acquisition time is 13-17 minutes. The contrast agent used for lesion enhancement are gadolinium-based (omniscan, magnovist, and dotarem). The study was set up in collaboration with Bahawal Victoria Hospital (BVH) Bahawalpur.

Age Range:

A total of 20 patients who had brain MRI for neurological assessment were included in this study. The participant's age ranges between 25 and 70 years. Radiant DICOM Viewer was used to analyze MRI images, and Microsoft Excel was used to record the results.

RESULTS AND DISCUSSION

A 25-year-old male has developed an abnormal signal intensity lesion predominantly cystic with single eccentric mural nodule (12 x 13 mm) centring left sided cerebellar hemisphere & vermis (29 x 32 x 35 mm (TR x AP x CC dimensions)). Relative to cerebellar parenchyma mural nodule show isointense signals on T1W1, hyperintense on T2WI / FLAIR & avid enhancement on post contrast images. There is also significant mass effect in form of notable peri-lesional edema (on adjacent brainstem, cerebellar hemisphere and left cerebellar peduncle) along with effacement of forth ventricle.

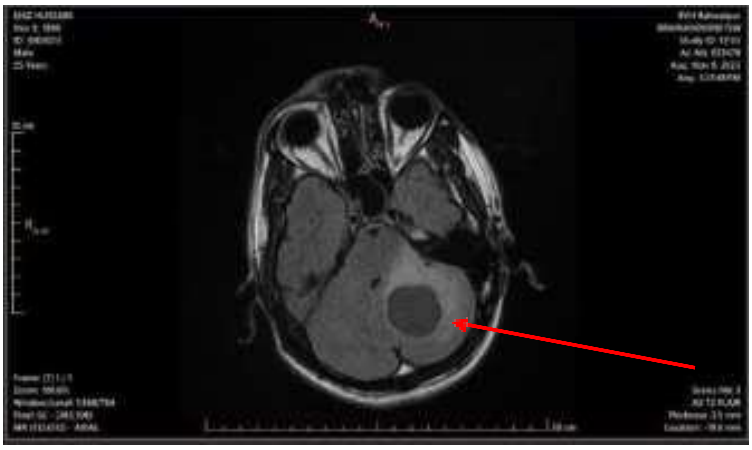


Figure 1: Axial T2 FLAIR showing signal intensity lesion

A 28-year-old male's axial slices showed hyperdense areas, which demonstrated that there is acute intracranial bleeding. These hemorrhagic regions indicate a moderate to large volume bleed. Such findings are in agreement with parenchymal or even subarachnoid bleed. The hemorrhage is bright, which shows that its acute.

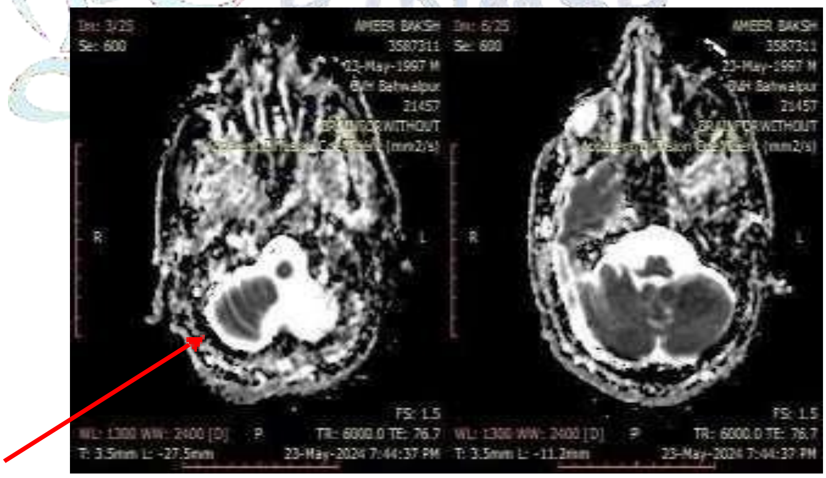


Figure 2: Axial Slices showing hemorrhagic lesions

A 67-year-old male has developed hyperintense periventricular and deep white matter lesions. The lesions are punctate to confluent and some periventricular around the lateral ventricles. The brain parenchyma presents with mild generalized atrophy, which is age-related and chronic small vessel ischemic disease.

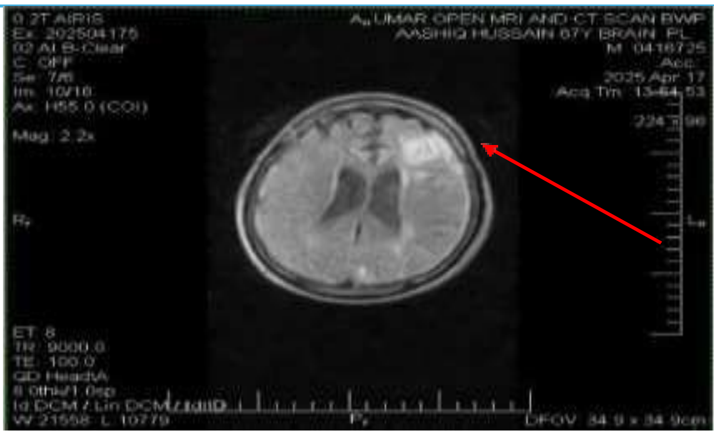


Figure 3: T2 images indicating white matter lesions

A 65-year-old female's brain MRI reveals moderate to severe cortical atrophy especially of the medial temporal lobes (hippocampi) and parietal cortices with resulting secondary enlargement of lateral ventricles. The imaging pattern is very much indicating the neurodegenerative process, most likely to be Alzheimer disease.

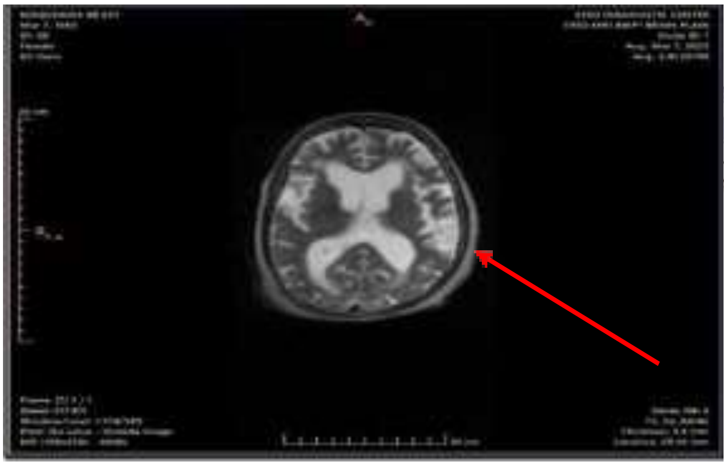
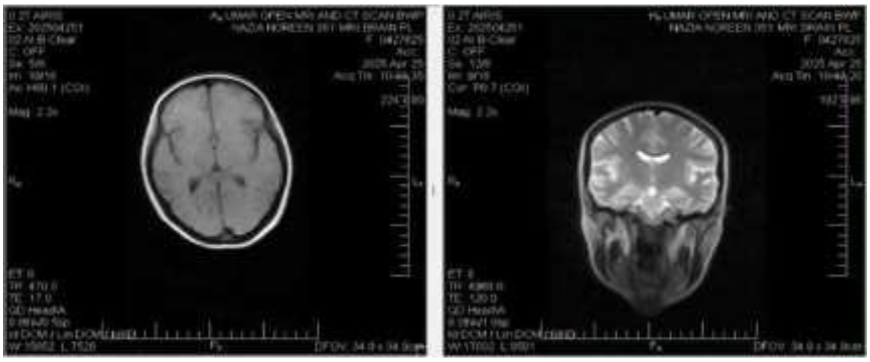


Figure 4: Axial T2 image indicating the secondary enlargement of lateral ventricles

A 35-year-old female's MRI does not indicate any structural abnormalities, white matter lesion or demonstrate demyelination. The brain parenchyma, ventricles and sulci are normal. No mass lesions, hemorrhages, infarcts or regions of abnormal signal intensity on either T1 or T2 sequences. Such results correspond to normal MRI of a patient admitted with migraine or primary headache, and no radiologic correspondence of secondary pathology.



CONCLUSION

This research highlights the crucial part of Magnetic Resonance Imaging (MRI) in determination and treatment of neurological disorders. MRI allows high-resolution imaging of the brain structure with no use of ionizing radiation, which makes it effective and safe to use considering other sophisticated imaging methods. Its utility in the detection of brain tumors, hemorrhages, small vessel ischemic disease (SVID), Alzheimer, and headache are highlighted in the findings. Combining the usage of clinical symptoms and MRI allows improved diagnostic performance and improved treatment planning.

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