Tumour Detection and Tissue Segmentation in Magnetic Resonance Imaging

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Abstract- Magnetic Resonance Imaging (MRI) is a cross sectional diagnostic imaging modality that functions based strong magnetic fields and radio waves to produce detailed cross sectional images of internal structures of the body.[1] This investigation focuses on the detection of tumors and tissue segmentation in MRI, especially in cases of neoplastic and degenerative diseases. Secondary data was obtained from the Harvard Brain Web Repository, covering situation such as gliomas, metastatic carcinomas, meningiomas, sarcomas, and neurodegenerative diseases like Alzheimer's and Huntington's disease.[2] The results highlight the significant role of MRI in detecting pathological changes in the brain, differentiating normal and diseased tissues, and aiding in early diagnosis of the diseases and treatment planning. The study also identifies variability in MRI exposure parameters across centers, affecting image quality and diagnostic accuracy.[3]

Keywords- Magnetic Resonance Imaging (MRI), Tumor Detection, Neoplastic Diseases, Degenerative Diseases, Tissue Segmentation, Brain Imaging

1. INTRODUCTION

Magnetic Resonance Imaging (MRI) also known as nuclear magnetic resonance (NMR) operates using radiofrequency pulses in the range of 1-80 MHz and is a critical tool in medical imaging. The origins of MRI trace back to nuclear magnetic resonance (NMR), a technique discovered independently by two scientist Felix Bloch and Edward Purcell in 1946[4]. Their work laid the institution for modern MRI, which became clinically viable in the 1980s[5]. MRI is particularly useful for diagnosing brain pathologies, including neoplastic and degenerative diseases, as it provides high-resolution images that allow for detailed tissue characterization.[6]

MRI with contrast enhancement is an essential tool for detecting cranial nerve diseases, offering early and precise diagnosis. In the field of neuroscience, MRI is combined with automated and semi-automated analysis methods to detect progressive lesions in the brain and spinal cord. It is particularly valuable in assessing conditions like multiple sclerosis, where brain atrophy is a common marker of disease progression.[7] Tissue atrophy in the central nervous system is often associated with inflammation, axonal injury, neuronal loss, and abnormal iron deposition. MRI plays a crucial role in measuring these changes and predicting disease progression.[8]

Neoplastic diseases involve abnormal cell growth that leads to tumor formation, which may be benign or malignant.[9] Brain tumors, such as gliomas and metastatic cancers, can be visualized on MRI scans, allowing for precise localization and differentiation. Degenerative diseases, including Alzheimer's, Huntington's, and motor neuron diseases, cause progressive loss of neuronal function.[10] MRI aids in detecting structural brain changes, helping in early diagnosis and disease monitoring.[11]

This study aims to detect tumors and perform tissue segmentation using MRI data obtained from the Harvard Brain Web Repository. It focuses on MRI features such as T1, T2, coronal, sagittal, transverse, and FLAIR sequences to analyze neoplastic and degenerative diseases.[2]

MATERIALS AND METHODS

This research utilized secondary data from the Harvard Brain Web Repository, consisting of MRI scans of patients with neoplastic and degenerative diseases. The study analyzed different MRI sequences to examine tumor characteristics and brain abnormalities.

Neoplastic Diseases Analyzed

The study considered the following neoplastic conditions:

- Glioma TITc. Spect
- Glioma EDGE-PET
- Glioma FDG-PET 2
- Metastatic adenocarcinoma
- Metastatic bronchogenic carcinoma
- Meningioma
- Sarcoma

Degenerative Diseases Analyzed

The study also included neurodegenerative conditions such as:

- Alzheimer's disease (mild and advanced)
- Huntington's disease
- Motor neuron disease
- Cerebral calcinosis
- Pick's disease
- Alzheimer's disease with visual agnosia

MRI sequences analyzed included T1-weighted, T2-weighted, coronal (COR), sagittal (SAG), transverse (TRN), and FLAIR images. These sequences provided insights into lesion location, tissue characteristics, and structural abnormalities associated with each disease.

RESULTS AND DISCUSSION

Glioma TITc. Spect

MRI images revealed that the lower part of the glioma lesion extended from the left medial occipital lobe to the right hemisphere, likely following fiber tracts in the splenium of the corpus callosum. Neoplastic disease which will consist of Glioma TITc. Spect with a tour

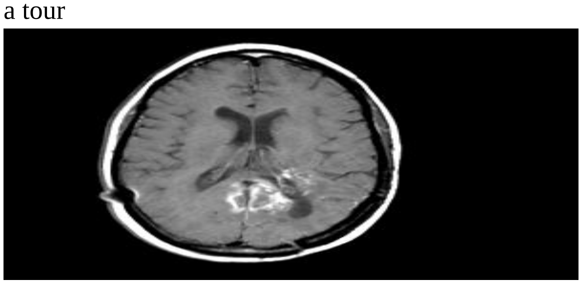


Figure 1: At this level, it can be observed that the lower part of the injury affects the left medial occipital lobe and extends to the right side, likely following the fiber tract in the splenium of the corpus callosum

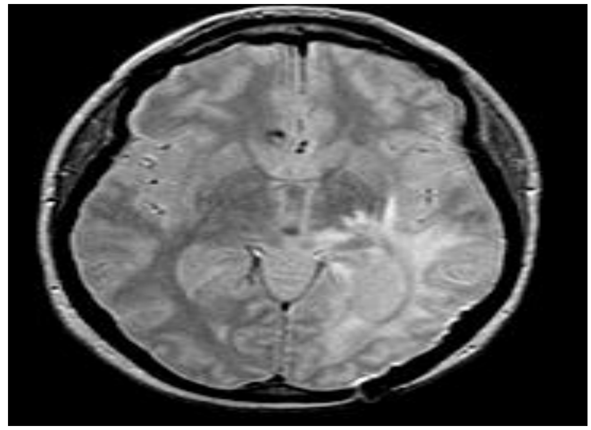


Figure 2: observe the dark line located right under the lining of the left lateral ventricle in this section. This tract is known as the geniculocalcarine tract

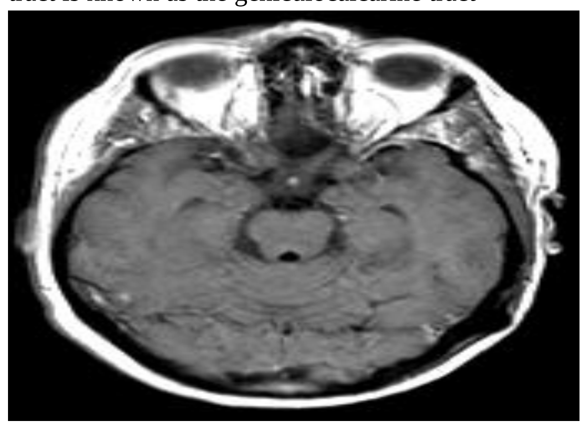


Figure 3: The pituitary stalk is illuminated due to its absence of the barrier present in the majority of the brain. This formation, also called the infundibulum, is found clustered with other 'circumventricular organs' that all possess the characteristic of being beyond the blood-brain-barrier.

Glioma EDGE-PET

Contrast-enhanced MRI showed a new region of decreased signal in the left parietal-occipital area, suggesting either tumor recurrence or radiation necrosis. The lesion displayed cystic components with increased uptake in thallium scans, indicating possible tumor recurrence. The MR images did not reveal it prior to contrast administration, however, a new region of decreased signal was observed in the left parietal-occipital area. Contrast agent increased the signal intensity significantly in image 49 and surrounding slices, suggesting either tumor recurrence or radiation necrosis. This differed from the prior contrast-enhanced MR.

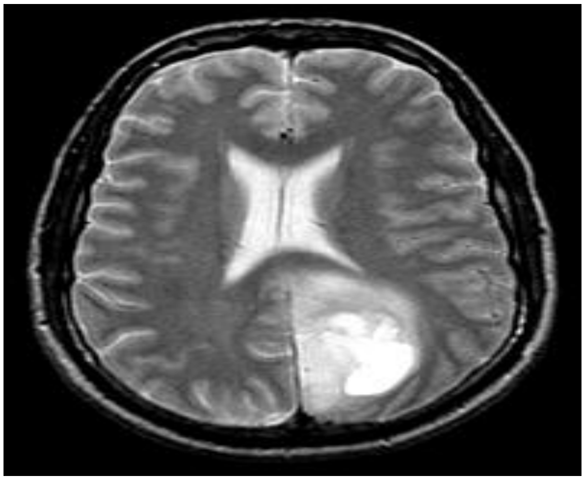


Figure 4**:** The MRI shows a region in the left occipital area with mixed signal intensity on proton density (PD) and T2-weighted (T2) images. Enhancing the contrast reveals that the lesion contains cystic components. Thallium scan reveals increased uptake along the front edge, indicating a small area of tumor recurrence.

Glioma TITc. Spect

MRI images revealed that the lower part of the glioma lesion extended from the left medial occipital lobe to the right hemisphere, likely following fiber tracts in the splenium of the corpus callosum.

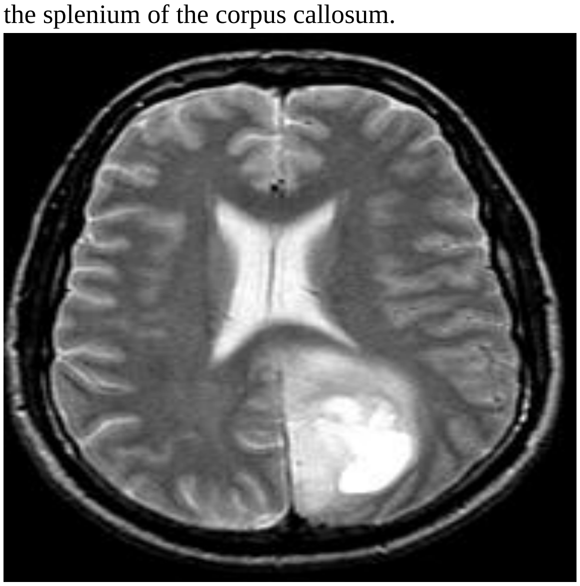


Figure 5: The MRI shows a region in the left occipital area with mixed signal intensity on both proton density and T2-weighted images. Enhancement with contrast reveals cystic elements within the lesion4.4 Metotastic adenocarcinoma

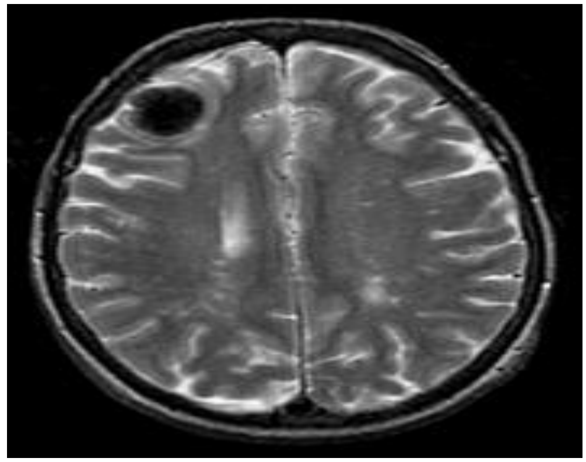


Figure 6: The MRI shows a lesion in the right second frontal convolution and another in the cerebellum, close to the fourth ventricle, as observed on the sagittal image as well. Both lesions display heightened contrast enhancement along their borders. Metastatic brain lesions typically occur as more than one, although they are not consistently multiple. The T2 weighted images show a mild signal in the frontal cortical structure. Alternatively, a cerebellar injury can result in considerable swelling and potentially displace the underlying brainstem, posing a risk as it is close to vital brainstem centers that regulate important functions such as breathing. This injury required immediate attention and careful monitoring.

Metastatic bronchogenic carcinoma

MRI revealed a high signal intensity lesion in the left temporal lobe with surrounding edema. The lesion had a cystic component, and a noticeable shift in midline structures was observed due to swelling.

Figure 7: Brain scans show a notable increase with swelling surrounding it, and compression on adjacent

midbrain structures. The tumor appears as a high signal intensity area on proton density (PD) and T2-Weighted (T2) images in a significant left temporal area on the magnetic resonance imaging (MR). Enhancement through contrast highlights the existence of a cystic element within the lesion. The decreased sulci seen at higher levels indicate a visibly enlarged left hemisphere.

Meningioma

MRI images showed increased reflexes and localized brain tissue loss. Lesions exhibited clear demarcation with contrast enhancement, helping to distinguish between benign and malignant growths.

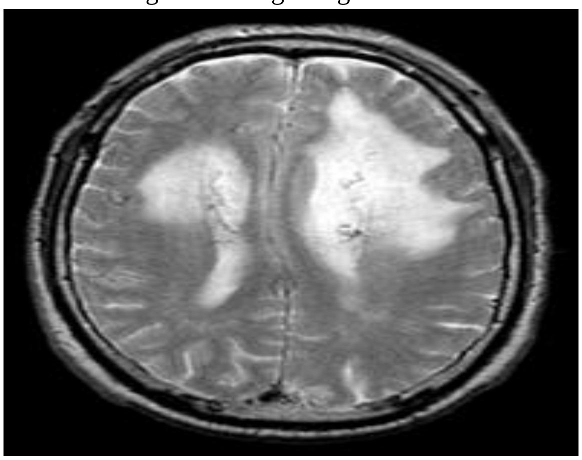


Figure 8: Sarcoma

MRI images showed increased reflexes and localized brain tissue loss. Lesions exhibited clear demarcation with contrast enhancement, helping to distinguish between benign and malignant growths.

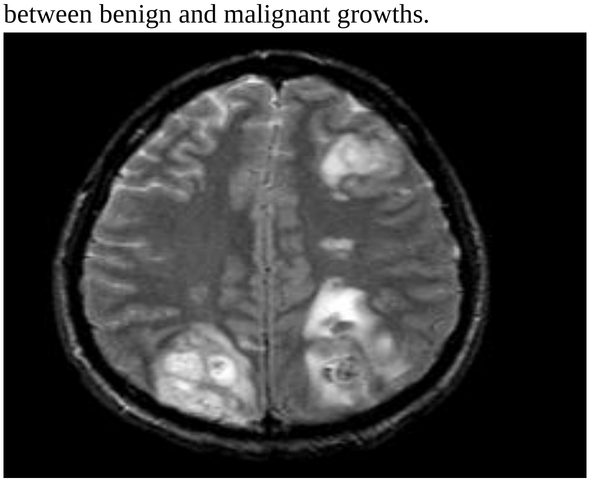


Figure 9: The picture displays left lower quadrant visual field loss, increased reflexes in the right lower limb, and a positive extensor response in the right foot

Degenerative Disease:

New: Mild Alzheimer's disease. FDG-PET and MRI

Figure 10: The MRI reveals enlarged sulci throughout the hemispheres, with a particular emphasis on the parietal lobes. There is a significant abnormality in regional cerebral metabolism, showing reduced metabolic activity in the anterior temporal and posterior parietal regions. Both sides are impacted by the changes, but the right hemisphere experiences slightly more effects than the left, while th posterior cingulate remains relatively unaffected.

Alzheimer's Disease with Tour

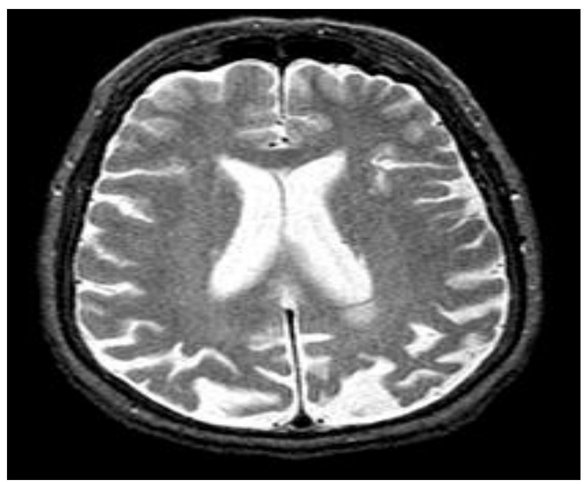


Figure 11: At this decreased level, there is also noticeable extreme widening of the intraparietal sulci, and shrinkage of the inferior parietal lobules, while the frontal gyri remain relatively unaffected. Also take note of the dilated lateral ventricles. Alzheimer's disease with functional MRI

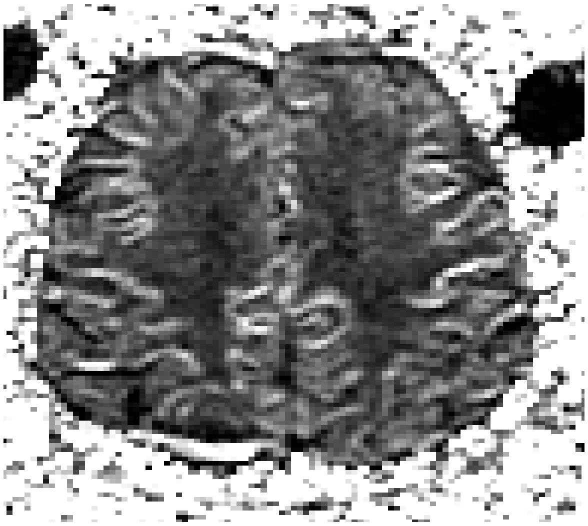


Figure 12: Functional MR imaging has the potential to be beneficial for assessing brain function in Alzheimer's disease. We conducted a comparison between FMRI and perfusion SPECT in 16 probable AD patients (based on NIH criteria), as well as 10 age-matched control individuals.4.11 Alzheimer’s disease

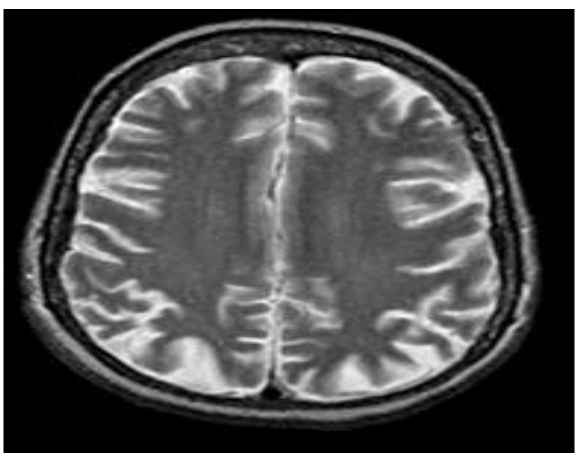


Figure 13: The MRI reveals moderate cerebral atrophy with mild expansion of the sulci in the hemispheres, particularly noticeable in the parietal and perisylvian areas. Perfusion SPECT shows irregularities typical of Alzheimer's disease, with decreased blood flow in temporal-parietal areas in contrast to frontal regions

Huntingtons disease

Marked brain volume loss was observed, affecting both grey and white matter. Significant atrophy of the caudate and putamen was evident. Post-mortem findings confirmed typical Alzheimer’s-related brain changes in some cases.

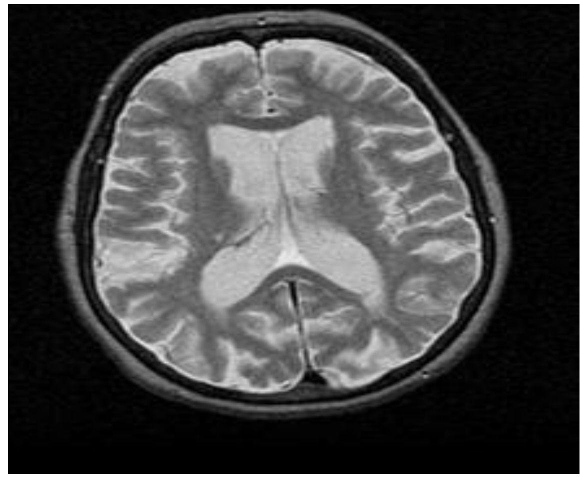


Figure 14: There is a decrease in brain volume that affects both grey and white matter throughout the cerebral hemispheres, including significant atrophy in the caudate and putamen on both sides.

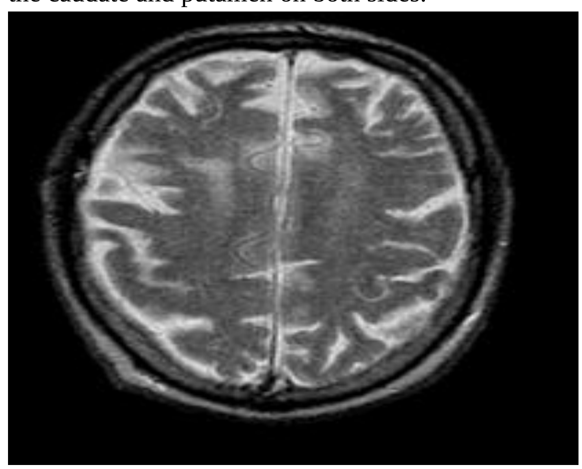


Figure 15: At post-mortem brain changes typical of Alzheimer’s disease were found.

Cerebral Calcinosi

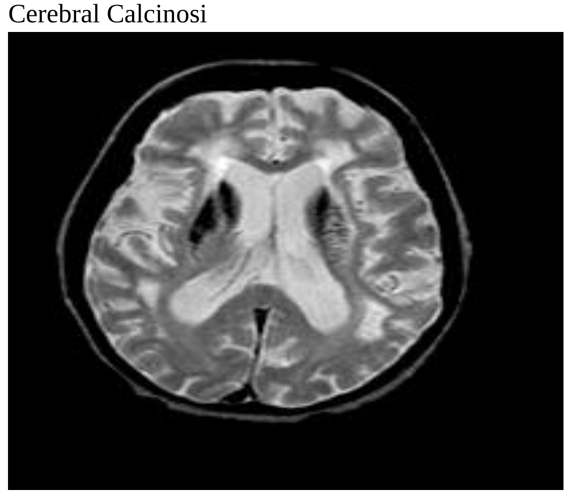
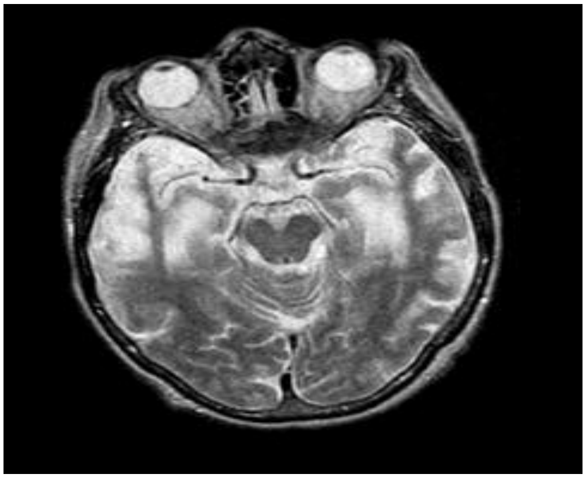


Figure 16: Pick’s disease



The pictures show significant localized reduction in size of both temporal and frontal lobes on both sides.

Alzheimer's Disease, Visual Agnosia

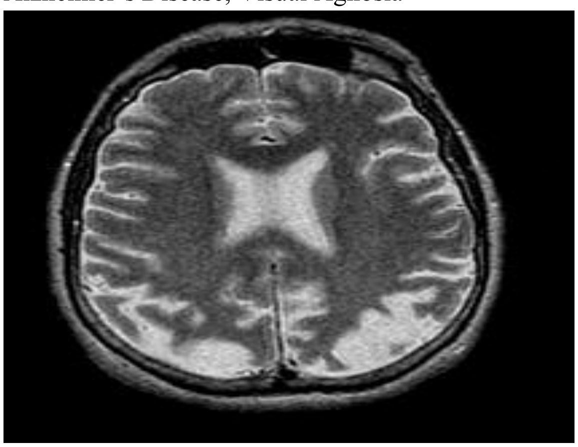


Figure 17: The picture shows significant focal shrinkage in the lateral occipital areas, along with decreased blood flow that spreads into the lateral parietal and temporal regions.

Neoplastic Disease Findings

Glioma TITc. Spect

MRI images revealed that the lower part of the glioma lesion extended from the left medial occipital lobe to the right hemisphere, likely following fiber tracts in the splenium of the corpus callosum.

Glioma EDGE-PET

Contrast-enhanced MRI showed a new region of decreased signal in the left parietal-occipital area, suggesting either tumor recurrence or radiation necrosis. The lesion displayed cystic components with increased uptake in thallium scans, indicating possible tumor recurrence.

Metastatic Adenocarcinoma

MRI scans showed lesions in the right second frontal convolution and the cerebellum, with enhanced contrast along the lesion borders. Significant swelling was noted, which could lead to brainstem compression.

Metastatic Bronchogenic Carcinoma

MRI revealed a high signal intensity lesion in the left temporal lobe with surrounding edema. The lesion had a cystic component, and a noticeable shift in midline structures was observed due to swelling.

Meningioma and Sarcoma

MRI images showed increased reflexes and localized brain tissue loss. Lesions exhibited clear demarcation with contrast enhancement, helping to distinguish between benign and malignant growths.

Degenerative Disease Findings

Alzheimer's Disease

MRI scans showed cortical atrophy, particularly in the parietal and perisylvian regions. Functional MRI (fMRI) and perfusion SPECT confirmed reduced metabolic activity in the temporal and posterior parietal regions.

Huntington's Disease

Marked brain volume loss was observed, affecting both grey and white matter. Significant atrophy of the caudate and putamen was evident. Post-mortem findings confirmed typical Alzheimer's-related brain changes in some cases.

Pick's Disease and Visual Agnosia in Alzheimer's Disease

Severe localized shrinkage of the temporal and frontal lobes was seen in Pick's disease, while Alzheimer's patients with visual agnosia exhibited focal atrophy in the lateral occipital areas, along with reduced blood flow to lateral parietal and temporal regions.

MRI findings confirmed the importance of advanced imaging in diagnosing and monitoring neurodegenerative conditions.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study highlights the critical role of MRI in diagnosing neoplastic and degenerative brain diseases. The ability to distinguish between different tissue types and detect abnormalities early allows for improved treatment planning and patient outcomes. However, variations in MRI scanning parameters across different centers affect image quality and diagnostic consistency.

Neoplastic diseases such as gliomas and metastatic carcinomas display unique MRI characteristics, including contrast enhancement and cystic components. Degenerative diseases like Alzheimer's and Huntington's disease exhibit progressive brain atrophy, which MRI effectively visualizes. The study underscores MRI's significance in clinical practice and research for early disease detection and management.

Limitations

One limitation of the study was the reliance on secondary data, restricting control over scanning parameters. Additionally, subjective interpretation of MRI images by different radiologists could introduce variability in assessments. Future studies should standardize MRI acquisition protocols to improve diagnostic accuracy.

ABBREVIATIONS

- MRI: Magnetic Resonance Imaging
- BOLD: Blood Oxygen Level Dependent
- CM: Contrast Medium
- FOV: Field of View
- FSE: Fast Spin Echo
- SE: Spin Echo
- T1: Longitudinal Relaxation
- T2: Transverse Relaxation Time
- TE: Time of Echo
- TRN/AXIAL: Transverse / Axial
- COR: Coronal

ACKNOWLEDGMENT

The authors would like to thank Mewar University for hosting the research. We thank Mr Aminu Shehu Sulaiman for his help towards the accomplishment of study. Additionally, gratitude is extended to the technical staff for their support.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

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