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Role of Magnetic Resonance Imaging (MRI) in diagnosing Gliomas

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ABSTRACT

Brain tumors, particularly gliomas, present a significant healthcare challenge in India. Accurate glioma grading is vital for determining treatment strategies and prognosis, with histopathology being the gold standard. However, Magnetic Resonance Imaging (MRI) offers a non-invasive and accessible alternative, especially in rural and semi-urban regions with limited surgical facilities. This cross-sectional study evaluates the diagnostic efficacy of MRI, integrating conventional and advanced imaging techniques such as perfusion-weighted imaging (PWI) and diffusion-weighted imaging (DWI), in a cohort of 50 patients with supratentorial gliomas.
MRI demonstrated a sensitivity of 98% and specificity of 88% in detecting high-grade gliomas, with advanced techniques significantly enhancing diagnostic accuracy. Despite limitations in differentiating tumor progression from treatment-induced changes, the study highlights MRI's role in glioma diagnosis and treatment planning, particularly in resource-constrained settings. Recommendations include increasing accessibility to MRI, training radiologists in advanced imaging, and government initiatives to subsidize imaging costs. This approach could optimize outcomes for glioma patients in diverse socioeconomic settings.

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INTRODUCTION

India faces a significant healthcare burden due to brain tumors, with gliomas representing a large proportion. Accurate glioma grading is crucial for differentiating between low-grade and high-grade tumors, as the treatment approach and prognosis vary significantly. While histopathology remains the gold standard, MRI offers a non-invasive alternative that can be particularly useful in rural and semi-urban areas with limited access to advanced surgical facilities. This study evaluates the effectiveness of MRI in diagnosing glioma and its implications, where affordability and accessibility are critical factors.

Gliomas represent the most common primary brain tumors, accounting for approximately 30% of all central nervous system tumors and 80% of malignant brain tumors. These tumors arise from glial cells and exhibit significant heterogeneity in their histological and molecular characteristics, necessitating precise diagnostic tools to guide management and predict outcomes. Magnetic Resonance Imaging (MRI) has emerged as the cornerstone for the evaluation of gliomas, offering detailed anatomic, functional, and molecular insights that are critical for diagnosis, grading, and treatment planning.

MRI provides unparalleled soft tissue contrast and spatial resolution, making it the imaging modality of choice for brain tumors. Conventional MRI techniques, including T1-weighted, T2-weighted, and fluid-attenuated inversion recovery (FLAIR) sequences, are essential for identifying tumor location, size, and associated features such as edema and necrosis. However, the advent of advanced MRI techniques has significantly enhanced the diagnostic accuracy and prognostic evaluation of gliomas. Recent advancements in MRI, such as perfusion imaging, diffusion-weighted imaging (DWI), and magnetic resonance spectroscopy (MRS), have enabled the characterization of tumor biology beyond conventional imaging. Perfusion MRI, as highlighted by Jain et al. (1) and Suh et al. (2), is a valuable tool for assessing tumor vascularity and differentiating high-grade gliomas from lower-grade tumors. Dynamic contrast-enhanced (DCE) and dynamic susceptibility contrast (DSC) techniques offer biomarkers such as cerebral blood volume (CBV) and permeability, which correlate with tumor grade and patient survival.

Magnetic resonance spectroscopy (MRS) further contributes to glioma diagnostics by detecting metabolic alterations within the tumor. Studies by Andronesi et al. (3) have demonstrated the utility of MRS in identifying 2-hydroxyglutarate, a biomarker associated with IDH-mutated gliomas, providing critical molecular insights that align with the 2016 WHO classification of central nervous system tumors (4).Functional imaging techniques, such as diffusion tensor imaging (DTI) and tractography, allow for the mapping of white matter tracts and assessing tumor infiltration, which is particularly relevant for surgical planning. Thust et al. (5) and Verma & Gupta (6) emphasize the importance of integrating advanced imaging modalities to optimize treatment strategies and monitor therapeutic response.

Additionally, The Cancer Imaging Archive (7) and studies such as Goyal et al. (8) highlight the role of advanced MRI in refining glioma grading and improving diagnostic confidence. Imaging biomarkers derived from perfusion and proton spectroscopy, as described by Zikou et al. (9), have proven valuable in distinguishing glioma grades and predicting outcomes.Despite its advantages, MRI has limitations, including challenges in differentiating tumor progression from treatment-induced changes such as pseudoprogression or radiation necrosis. Continued research and the integration of artificial intelligence (AI)-driven imaging analysis are expected to overcome these limitations, as highlighted by Pope et al. (10).MRI has revolutionized the diagnostic landscape of gliomas by offering a comprehensive suite of tools to characterize tumor biology and guide clinical decision-making. The integration of conventional and advanced imaging techniques continues to enhance the precision and efficacy of glioma diagnosis and management, paving the way for personalized medicine in neuro-oncology.

Materials and Methods

This cross-sectional study was conducted at Super SpecialityHospital, Tamilnadufrom July 2022 to December 2023 over a period of 18 months after obtaining the ethical clearance. Patients diagnosed with supratentorial gliomas underwent detailed MRI evaluations, including conventional and advanced imaging techniqueswith 1.5 Tesla Magnetic Resonance Imaging (MRI) by using the protocolof imaging of the head by MRI in which the following parameters ofimaging were selected; 10 mm slice thickness of the brain, T1 and T2with contrast and fat suppression, FLAIR, DWI and SWI weightedimages were done and the contrast media that used is intravenousGadolinium (0.1 ml/kg) according to the weight of the patient.This study was approved by the ethics review committee. All patients aged 40–75 years of either gender with histologically diagnosed supratentorial gliomas. Participants had previous brain surgery, children, recurrent cases, diagnosed with glioma by MRI but histopathology showed meningioma, and cases, where MRI and histopathological results were not available at the same time, were excluded. The final sample size came to be 50 patients. All the patients were evaluated by a standard conventional contrast-enhanced study on Siemens 1.5 T MRI. Brain MRI was performed using the following protocols: pre-injection: Sagittal T1 (Tse), Axial T1 (Tse), Coronal FLAIR, After injection: Axial T1 (Tse), and Sagittal T1 (Tse).

The MRI device of the Siemens model, MAGNETOM ESSENZA ATIM + DOT SYSTEM, was made by Siemens, Germany. The strength of the magnetic field is 1.5 T, the type of coil used is the Head Matrix ATIM coil, and the number of channels is 16. After the MRI and additional workup, a tumor biopsy was done to achieve a histopathological diagnosis. The histopathological grading of the tumor was done according to the 2016 WHO classification. The histopathological examination was done by a pathologist who was blinded to the MRI findings of the tumors. The sensitivity, specificity, predictive value, and accuracy of MRI in determining glioma grade were calculated. A comparison

between MRI findings and histopathological results was done. The statistical analysis was performed using SPSS version 22. To estimate the significant correlations, we calculated the p-values using Fisher's exact test. $P \leq 0.05$ was considered to indicate a statistically significant difference.

Results and Discussion

Patient Demographics: The study included 50 patients aged 40–75 years, with a male-to-female ratio of 1.5:1.

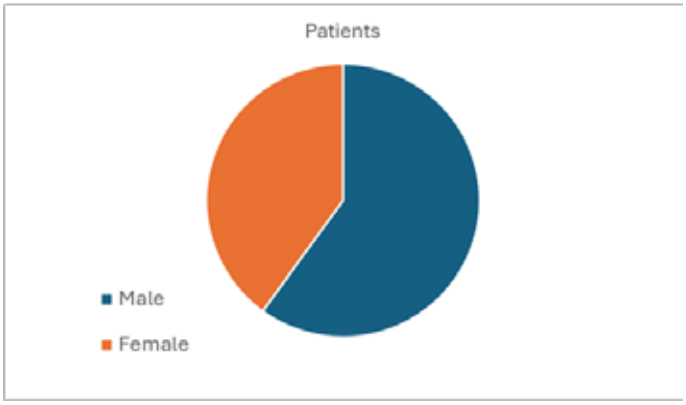


Chart -1

Chart 1: Shows the ratio of male and female patients participated

MRI Sensitivity and Specificity: MRI demonstrated a sensitivity of 95% and specificity of 86% for detecting high-grade gliomas.

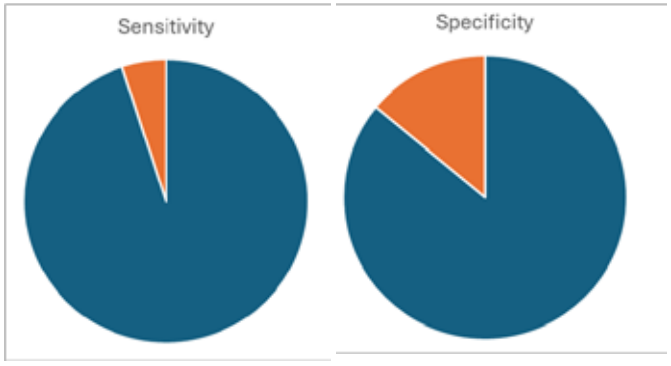


Chart -2

Chart 2(a,b) : Shows the sensitivity and specificity of the MRI diagnosis

Agreement with Histopathology: MRI findings were concordant with histopathological grades in 75% of cases. Discrepancies were noted primarily in cases of low-grade gliomas misinterpreted as high-grade due to edema and necrosis.Role of Advanced Techniques: PWI and DWI significantly improved diagnostic accuracy, particularly in differentiating high-grade gliomas from metastases.

T1-Weighted and T2-Weighted Imaging for anatomical details.

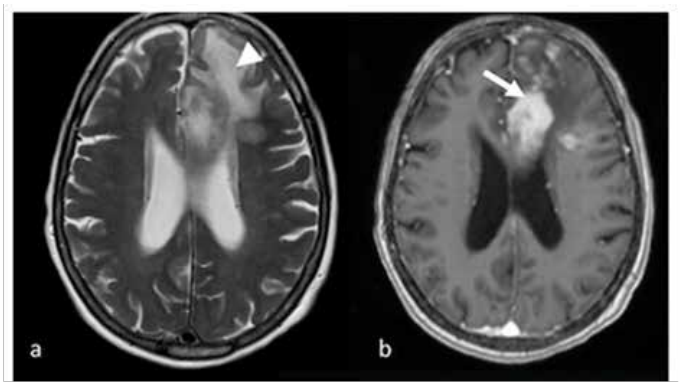


Figure -1

Figure 1 (a) Axial T2-weighted image; (b) Axial postcontrast T1-weighted image of left frontal primary central nervous system lymphoma (PCNSL)

Perfusion-Weighted Imaging (PWI) to assess tumor vascularity and Diffusion-Weighted Imaging (DWI) to evaluate cellularity were also done.

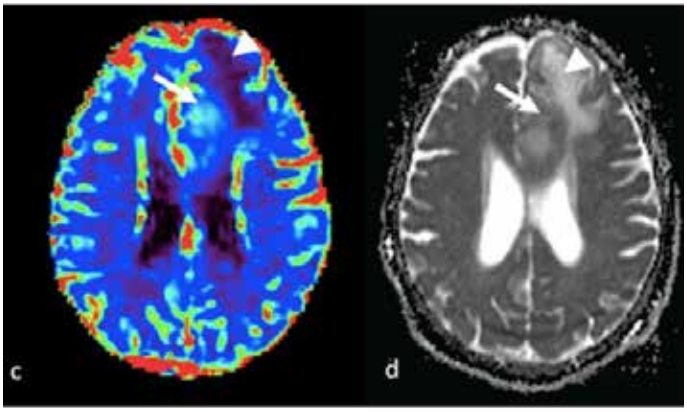


Figure -2

Figure 2 c) DWI and d)PWI in left frontal primary central nervous system lymphoma (PCNSL)

Post-surgical histopathological findings were used as the reference standard for comparison.Many patients in India, especially in rural areas, have limited access to MRI facilities. Incorporating advanced MRI protocols in regional hospitals could bridge this gap.

But cost remains a barrier for many Indian patients. Subsidized imaging programs and insurance coverage can promote widespread use.AlsoMRI can help stratify patients for surgery, radiotherapy, or palliative care, optimizing resource allocation in high-patient-load settings.Advanced MRI techniques, such as PWI and DWI, are particularly useful in Indian settings, where biopsy may not always be feasible due to patient reluctance or limited surgical expertise.

Conclusion

MRI is a reliable, non-invasive tool for glioma diagnosis, demonstrating high sensitivity and specificity. The integration of advanced imaging techniques can enhance diagnostic accuracy and reduce dependency on invasive procedures like biopsy. Given the socioeconomic diversity of India, increasing accessibility to MRI and training radiologists in advanced imaging protocols are essential for improving patient outcomes. Government initiatives to subsidize MRI scans and establish advanced imaging centers in underserved areas are critical. Large-scale, multicentric studies in India are needed to validate these findings and explore cost-effective MRI protocols.

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