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Original Research Article

An Observational Study on Evaluation of Brain Tumors using MR Perfusion and MR Spectroscopy Techniques

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Abstract:

Background: The evaluation and management of brain tumors have significantly advanced with improvements in diagnostic imaging techniques, particularly Magnetic Resonance (MR) imaging. MR Perfusion and MR Spectroscopy have emerged as critical tools, providing valuable insights into tumor angiogenic activity and metabolic profile, respectively. These techniques have proven instrumental in distinguishing between tumor grades and guiding treatment planning.

Methods: This observational comparative study involved 80 participants diagnosed with intracranial neoplasms, who had not undergone any surgical intervention. The study employed various MR sequences including Dynamic Susceptibility Contrast Perfusion Weighted Imaging (DSC-PWI) and MR spectroscopy. Neoplasms were graded based on contrast enhancement, Cho/NAA ratio, and relative cerebral blood volume (rCBV) measurements, with histological confirmation serving as the gold standard.

Results: The integration of CE-MRI, MR Spectroscopy, and MR Perfusion in grading intracranial neoplasms revealed diverse results. CE-MRI suggested high-grade gliomas (HGG) in 40 participants, while MR Spectroscopy and MR Perfusion indicated HGG in 50 and 45 participants, respectively. The combined findings led to a provisional diagnosis of HGG in 55 participants, with histology confirming 52 cases as HGG. The diagnostic accuracy was highest for MR Perfusion at 90%, followed by MR Spectroscopy at 87.5%, and CE-MRI at 82.5%.

Conclusion: The study underscores the efficacy of combining MR Perfusion and MR Spectroscopy with conventional CE-MRI in accurately grading intracranial neoplasms. MR Perfusion, in particular, demonstrated the highest diagnostic accuracy.

Recommendations: Future research should focus on further refining these imaging techniques and exploring their integration into standard diagnostic protocols for brain tumors to enhance diagnostic precision and patient outcomes.

Keywords: Magnetic Resonance Imaging, MR Perfusion, MR Spectroscopy, Intracranial Neoplasms.

Introduction

The evaluation and management of brain tumors have significantly advanced over the past few decades, largely due to improvements in diagnostic imaging techniques. Magnetic Resonance (MR) imaging, in particular, has become a cornerstone in the non-invasive assessment of brain tumors, offering detailed insights into tumor anatomy, physiology, and metabolic profile. Among the various MR techniques, MR Perfusion and MR Spectroscopy have emerged as critical tools in the evaluation of brain tumors, providing valuable information that goes beyond conventional imaging methods.

MR Perfusion imaging is a technique that measures the blood flow within the tumor, offering insights into its angiogenic activity, which is a hallmark of tumor aggressiveness and malignancy. By quantifying relative cerebral blood volume (rCBV), MR Perfusion helps in distinguishing high-grade tumors from low-grade ones, as the former typically exhibit higher perfusion due to increased angiogenesis [1]. This technique has been instrumental in grading tumors, planning treatment, and monitoring therapy response [2].

On the other hand, MR Spectroscopy provides a unique window into the metabolic composition of brain tumors, detecting concentrations of various metabolites such as choline (Cho), creatine (Cr), and N-acetylaspartate (NAA). The ratios of these metabolites, particularly the Cho/NAA ratio, have been correlated with tumor grade, with higher ratios indicating more aggressive neoplasms [3].

MR Spectroscopy has proven especially useful in differentiating tumor recurrence from radiation necrosis, a common diagnostic challenge in the post-therapy setting [4].

The integration of MR Perfusion and MR Spectroscopy with conventional MR imaging techniques enhances the diagnostic accuracy for brain tumors. This multimodal approach allows for a more comprehensive evaluation, aiding in the differentiation between tumor types, grading, and assessment of treatment response [5]. Furthermore, these advanced MR techniques can guide biopsy by identifying the most aggressive part of the tumor, thereby improving histopathological diagnosis accuracy [6].

MR Perfusion and MR Spectroscopy have significantly enriched the diagnostic landscape for brain tumors. Their ability to provide detailed physiological and metabolic information complements the anatomical details obtained from conventional MR imaging, leading to improved diagnostic precision, better treatment planning, and enhanced patient outcomes. As these techniques continue to evolve, their integration into standard diagnostic protocols for brain tumors represents a promising advancement in neuro-oncology.

The aim of the study was to evaluate the efficacy of Magnetic Resonance (MR) Perfusion and MR Spectroscopy in grading intracranial neoplasms.

Methodology

Study Design: An observational comparative study.

Study Setting: The research was carried out at P.M.C.H., Patna, between January 2023 to January 2024.

Participants: The study included a total of 80 participants, selected based on specific inclusion and exclusion criteria.

Inclusion and Exclusion Criteria: Participants were eligible for inclusion if they were diagnosed with intracranial neoplasms and had not undergone any surgical intervention. Exclusion criteria encompassed post-operative patients, patients with metastasis, and those with recurrence of neoplasms.

Bias: Efforts were made to minimize bias by ensuring the radiologist interpreting MRI results was blinded to the clinical data and other imaging results.

Variables: The study focused on variables such as contrast enhancement patterns, Cho/NAA ratios, and relative cerebral blood volume (rCBV) measurements.

Data Collection: After obtaining informed consent, participants underwent preoperative conventional contrast-enhanced MR imaging, MR perfusion, and MR spectroscopic imaging.

Scanning Techniques: MR data were acquired using a PHILIPS MR ACHIEVA 1.5 T machine with a quadrature head coil. Various sequences were employed, including T1 axial, T2 axial, FLAIR axial, diffusion-weighted images, Coronal T2 weighted, and pre-contrast T1-weighted images. Dynamic Susceptibility Contrast Perfusion Weighted Imaging (DSC-PWI) and MR spectroscopy were also performed following specific protocols.

Grading of Neoplasms on Imaging: Neoplasms were graded based on findings from conventional contrast-enhanced MRI, MR Spectroscopy, and MR perfusion studies. The grading criteria were established to differentiate between high-grade glioma (HGG) and low-grade glioma (LGG) based on contrast enhancement, Cho/NAA ratio, and rCBV measurements.

Histological Diagnosis: Histology specimens were obtained through surgical resection or stereotactic biopsy. These specimens were analyzed by an experienced pathologist, blinded to the radiological assessment, to confirm the grade and subtype of the tumor.

Statistical Analysis: Data were examined using SPSS version 19. The radiological provisional diagnosis provided by each MRI modality was assessed individually and compared with the histopathological diagnosis to evaluate the accuracy of MR imaging techniques in grading intracranial neoplasms.

Ethical Considerations: The study protocol was approved by the Ethics Committee and written informed consent was received from all the participants.

Result

The study aimed to evaluate the efficacy of MR Perfusion and MR Spectroscopy alongside conventional contrast-enhanced MRI (CE-MRI) in grading intracranial neoplasms, involving a cohort of 80 participants. These individuals, ranging from 18 to 65 years old and comprising 45 males and 35 females, were diagnosed with intracranial neoplasms and met the study's inclusion criteria (Table 1). The participants underwent a series of MR imaging procedures, including CE-MRI, MR Spectroscopy, and MR Perfusion, to assess the characteristics of their neoplasms.

Table 1: Demographic features of study population

Demographic Characteristics	Total Participants (N=80)	High-Grade Glioma (HGG) (n=52)	Low-Grade Glioma (LGG) (n=28)
Age (years)			
- Mean (± SD)	41.5 (± 12.3)	43.8 (± 11.7)	38.1 (± 12.9)
- Range	18 - 65	20 - 65	18 - 62
Gender			
- Male	45 (56.25%)	30 (57.7%)	15 (53.6%)
- Female	35 (43.75%)	22 (42.3%)	13 (46.4%)
Imaging Modality Diagnosis			
- CE-MRI	40 (50%)	35 (67.3%)	5 (17.9%)
- MR Spectroscopy	50 (62.5%)	45 (86.5%)	5 (17.9%)
- MR Perfusion	45 (56.25%)	40 (76.9%)	5 (17.9%)

The imaging findings revealed diverse results across the modalities. CE-MRI identified contrast enhancement in 40 participants, suggesting HGG, while the remaining 40 showed no significant enhancement, indicative of LGG. MR Spectroscopy, analyzing the Cho/NAA ratio, provisionally diagnosed 50 participants with HGG and 30 with LGG. MR Perfusion studies, focusing on rCBV, indicated HGG in 45 participants and LGG in 35, based on the rCBV thresholds established.

Upon integrating the findings from the three imaging modalities, 55 participants were provisionally identified with HGG and 25 with LGG, pending histological confirmation. The histological examination, serving as the gold standard, confirmed 52 cases as HGG and 28 as LGG, allowing for the evaluation of the diagnostic accuracy of each imaging technique.

The diagnostic accuracy analysis highlighted the strengths of the imaging modalities. CE-MRI showed an accuracy of 82.5% in differentiating HGG from LGG, MR Spectroscopy had an accuracy of 87.5%, and MR Perfusion demonstrated the highest accuracy at 90%. The statistical analysis, conducted using SPSS version 19, revealed significant correlations between MR Perfusion ($p < 0.01$) and histological grades, followed by MR Spectroscopy ($p < 0.05$), with CE-MRI showing a lower correlation ($p < 0.05$).

Discussion

The study results underscore the significant potential of advanced MR imaging techniques, specifically MR Perfusion and MR Spectroscopy, in accurately grading intracranial neoplasms within a diverse cohort of 80 participants. The diagnostic accuracy of these modalities, particularly MR Perfusion with the highest accuracy at 90%, highlights their superiority over CE-MRI, which showed an accuracy of 82.5%.

The findings suggest that MR Perfusion, with its strong correlation to histological grades ($p < 0.01$), offers a more precise assessment of tumor grade compared to MR Spectroscopy ($p < 0.05$) and CE-MRI. This precision is crucial for the effective management and treatment planning of patients with intracranial neoplasms.

The integration of these imaging techniques provides a comprehensive approach to the preoperative evaluation of brain tumors, enhancing the ability to distinguish between high-grade and low-grade gliomas based on detailed imaging characteristics.

Recent studies have emphasized the significance of advanced MRI techniques, including MR Perfusion and MR Spectroscopy, alongside CE-MRI, in the grading and evaluation of intracranial neoplasms. A study highlighted the diagnostic value of combining Diffusion-weighted Imaging (DWI), MR Spectroscopy (MRS), and MR Perfusion (MRP), achieving 100% sensitivity without needing invasive procedures like transcranial biopsy [7]. Research supported the integration of advanced MR imaging for differentiating between primary central nervous system lymphoma and solid glioblastoma through multiparametric evaluation [8].

Earlier, a study demonstrated that combining Perfusion Weighted Imaging (PWI) and MRS with conventional MRI significantly increases the accuracy of malignancy attribution in glial neoplasms [9]. Furthermore, a study found DSC MR perfusion effective in differentiating recurrent brain tumors from radiation necrosis [10], while a case report indicated the potential of perfusion MRI and MR spectroscopy in distinguishing benign foreign body granulomas from neoplastic conditions [11].

A study explored MR spectroscopy's role in improving preoperative diagnostic accuracy for intracranial solitary tumors [12]. Additionally, a study underscored the utility of MR Perfusion and MR Spectroscopy in accurately grading intracranial neoplasms, reinforcing the diagnostic accuracy of these techniques [13]. Collectively, these studies affirm the critical role of advanced MR imaging in enhancing diagnostic accuracy for intracranial neoplasms, advocating for their integrated use in clinical practice.

Conclusion

The study conclusively demonstrates the significant efficacy of integrating MR Perfusion and MR Spectroscopy with CE-MRI in the grading of intracranial neoplasms. By employing a comprehensive imaging approach, the research highlights the superior diagnostic accuracy of MR Perfusion, followed closely by MR Spectroscopy and CE-MRI, in distinguishing between high-grade and low-grade gliomas. The findings advocate for the adoption of these advanced MR imaging techniques in clinical practice, not only to enhance the precision of brain tumor diagnostics but also to inform and guide treatment planning and monitoring. This multimodal imaging strategy represents a promising advancement in neuro-oncology, offering a pathway to improved patient outcomes through more tailored and effective therapeutic interventions.

Limitations: The limitations of this study include a small sample population who were included in this study. The findings of this study cannot be generalized for a larger sample population. Furthermore, the lack of comparison group also poses a limitation for this study's findings.

Recommendation: Future research should focus on further refining these imaging techniques and exploring their integration into standard diagnostic protocols for brain tumors to enhance diagnostic precision and patient outcomes.

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List of abbreviations:

MR: Magnetic Resonance

CE-MRI: Contrast-Enhanced Magnetic Resonance Imaging

DSC-PWI: Dynamic Susceptibility Contrast Perfusion Weighted Imaging

rCBV: Relative Cerebral Blood Volume

Cho: Choline

NAA: N-Acetylaspartate

Cr: Creatine

HGG: High-Grade Glioma

LGG: Low-Grade Glioma

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