Original Article

Diagnostic Accuracy of Perfusion MRI and MR Spectroscopy in Differentiating Tumor Recurrence from Radiation Necrosis

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Abstract

Background: Differentiating tumor recurrence from radiation necrosis after treatment of intracranial tumors is challenging because both conditions often appear similar on conventional MRI. Advanced imaging techniques such as perfusion MRI and magnetic resonance spectroscopy (MRS) may improve diagnostic accuracy. The aim is to evaluate the diagnostic accuracy of perfusion MRI and MRS in differentiating tumor recurrence from radiation necrosis. **Material and Methods:** This prospective observational study included 100 patients with suspected post-treatment intracranial lesions who underwent perfusion MRI and MRS. Imaging findings were compared with the final clinical or histopathological diagnosis. **Results:** Tumor recurrence was confirmed in 62% of patients and radiation necrosis in 38%. Recurrent tumors showed significantly higher relative cerebral blood volume and elevated Cho/NAA and Cho/Cr ratios, whereas radiation necrosis demonstrated reduced perfusion and prominent lipid-lactate peaks ($p<0.001$). Combined perfusion MRI and MRS achieved 94.0% diagnostic accuracy, with 95.2% sensitivity and 92.1% specificity. **Conclusion:** Combined perfusion MRI and MRS reliably differentiate tumor recurrence from radiation necrosis and enhance post-treatment neuroimaging assessment.

Keywords: Perfusion MRI; Magnetic resonance spectroscopy; Tumor recurrence; Radiation necrosis; Brain tumors; Diagnostic accuracy.

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Introduction

Brain tumors, particularly high-grade gliomas and metastatic brain lesions, frequently require multimodal treatment including surgery, radiotherapy, and chemotherapy. Despite advances in treatment, distinguishing true tumor recurrence from radiation necrosis remains a major diagnostic challenge during post-treatment follow-up. Both conditions often present with similar clinical symptoms and conventional magnetic resonance imaging (MRI) findings, including contrast-enhancing lesions and surrounding edema, making accurate diagnosis difficult. However, differentiating these entities is crucial because recurrent tumors generally require additional oncologic treatment, whereas radiation necrosis is often managed conservatively or with corticosteroids, bevacizumab, or surgical intervention when necessary.[1,2]

Conventional contrast-enhanced MRI has limited specificity in differentiating these post-treatment changes because both recurrent tumors and radiation-induced necrosis disrupt the blood–brain barrier. Advanced MRI techniques, particularly perfusion-weighted imaging (PWI) and magnetic resonance spectroscopy (MRS), have emerged as valuable non-invasive tools to improve diagnostic confidence. Perfusion MRI evaluates tumor vascularity by measuring parameters such as relative cerebral blood volume (rCBV), which is typically elevated in recurrent tumors due to neoangiogenesis, while radiation necrosis usually demonstrates reduced perfusion because of vascular destruction and tissue necrosis.[3,4]

Magnetic resonance spectroscopy complements perfusion imaging by assessing tissue metabolism. Recurrent tumors generally demonstrate elevated choline-containing compounds reflecting increased cellular proliferation, whereas radiation necrosis is characterized by reduced choline levels and increased lipid-lactate peaks associated with tissue breakdown. Metabolite ratios such as choline/N-acetylaspartate (Cho/NAA) and choline/creatine (Cho/Cr) have shown promising diagnostic performance in differentiating these entities.[4,5]

Recent evidence suggests that combining perfusion MRI with MR spectroscopy provides higher diagnostic accuracy than either technique alone, reducing the need for invasive biopsy and facilitating timely therapeutic decisions. As advanced neuroimaging becomes increasingly available, evaluating the combined diagnostic performance of these modalities in routine clinical practice is essential. Therefore, the present study aims to assess the diagnostic accuracy of perfusion MRI and MR spectroscopy in differentiating tumor recurrence from radiation necrosis in patients treated for intracranial neoplasms.[5,6]

The aim of this study is to evaluate the diagnostic accuracy of perfusion MRI and magnetic resonance spectroscopy in differentiating tumor recurrence from radiation necrosis in

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patients previously treated for intracranial tumors. The objectives are to assess the individual diagnostic performance of each modality, compare their imaging characteristics, determine the added value of their combined use, and correlate imaging findings with the final clinical or histopathological diagnosis where available.

Materials and Methods

Study Design: This was a hospital-based, prospective observational diagnostic accuracy study conducted to evaluate the role of perfusion magnetic resonance imaging (MRI) and magnetic resonance spectroscopy (MRS) in differentiating tumor recurrence from radiation necrosis in patients with previously treated intracranial tumors.

Study Population: The study population consisted of patients with previously treated primary or secondary intracranial tumors who presented with new or enlarging contrast-enhancing lesions on follow-up conventional MRI and were clinically suspected to have either tumor recurrence or radiation necrosis. All eligible patients referred for advanced MRI evaluation during the study period were considered for inclusion.

Sample Size: A total of 100 patients fulfilling the eligibility criteria were included in the study.

Study Duration: The study was conducted over a period of one year, from January 2025 to July 2025.

Study Setting/Location: The study was carried out in the Department of Radiodiagnosis, Chauhan Medicity Hospital, using advanced MRI facilities equipped with perfusion imaging and magnetic resonance spectroscopy protocols. Clinical information, imaging findings, and follow-up data were collected prospectively and analyzed systematically.

Inclusion Criteria

- Patients aged 18 years or older.
- Patients with previously treated intracranial tumors (primary or metastatic) who had undergone surgery, radiotherapy, chemotherapy, or a combination of these treatments.
- Presence of a new or enlarging contrast-enhancing lesion on follow-up conventional MRI suggestive of either tumor recurrence or radiation necrosis.
- Patients who underwent both perfusion MRI and MR spectroscopy as part of the imaging evaluation.
- Patients who provided written informed consent to participate in the study.

Exclusion Criteria

- Patients with contraindications to MRI, such as non-MRI-compatible pacemakers, cochlear implants, or ferromagnetic metallic implants.
- Patients with severe claustrophobia or inability to complete the MRI examination.
- Patients with poor-quality or non-diagnostic perfusion MRI or MR spectroscopy images due to motion or technical artifacts.
- Patients with untreated intracranial tumors who had not received prior radiotherapy.
- Patients with incomplete clinical records, inadequate follow-up, or refusal to provide informed consent.

Statistical Analysis: The collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 27.0. Categorical variables were expressed as frequencies and percentages, while continuous variables were presented as mean ± standard deviation (SD). Comparisons between tumor recurrence and radiation necrosis groups were performed using the Chi-square test or Fisher's exact test for categorical variables and the independent Student's t-test for continuous variables. Diagnostic performance was evaluated by calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy. A p-value of <0.05 was considered statistically significant.

Results

Table 1: Baseline Demographic Characteristics of the Study Population

Variable		Frequency (n)	Percentage (%)	p-value
Age Group (years)	<40	12	12	0.028
	41–50	24	24	
	51–60	36	36	
	61–70	20	20	
	>70	8	8	
	Total	100	100	
Gender	Male	58	58	0.214
	Female	42	42	
	Total	100	100	

Table 2: Final Diagnosis and Conventional MRI Findings

Variable		Frequency (n)	Percentage (%)	p-value
Final Diagnosis	Tumor Recurrence	62	62	<0.001
	Radiation Necrosis	38	38	
	Total	100	100	
Primary Tumor Type	High-grade Glioma	54	54	0.041
	Brain Metastasis	28	28	
	Low-grade Glioma	10	10	
	Other Intracranial Tumors	8	8	
	Total	100	100	

Table 3: Comparison of Perfusion MRI and MR Spectroscopy Findings According to Final Diagnosis

Imaging Parameter	Tumor Recurrence (n=62)	Radiation Necrosis (n=38)	p-value
Mean rCBV >2.0	54 (87.1%)	6 (15.8%)	<0.001
Mean rCBV ≤2.0	8 (12.9%)	32 (84.2%)	
Elevated Cho/NAA Ratio	52 (83.9%)	8 (21.1%)	<0.001
Elevated Cho/Cr Ratio	50 (80.6%)	10 (26.3%)	<0.001
Prominent Lipid-Lactate Peak	10 (16.1%)	30 (78.9%)	<0.001

Table 4: Diagnostic Performance of Perfusion MRI and MR Spectroscopy

Diagnostic Parameter	Perfusion MRI (%)	MR Spectroscopy (%)	Combined MRI + MRS (%)	p-value
Sensitivity	90.3	87.1	95.2	0.021
Specificity	84.2	81.6	92.1	0.017
Positive Predictive Value	90.3	88.5	95.2	
Negative Predictive Value	84.2	79.5	92.1	
Overall Diagnostic Accuracy	88	85	94	0.009

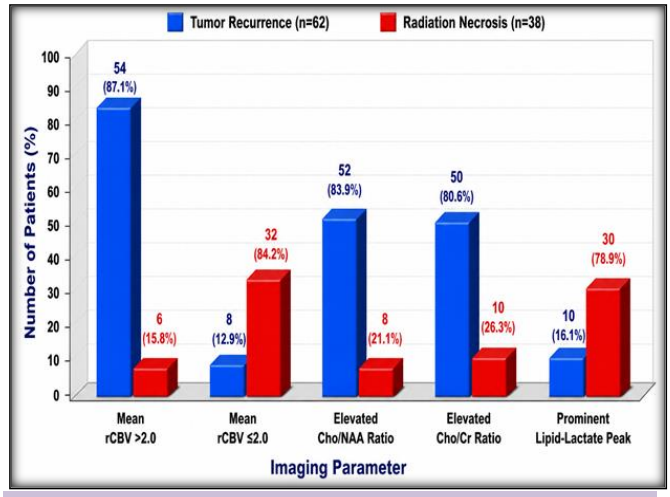

Figure 1: Comparison of Imaging Parameters in Tumor Recurrence and Radiation Necrosis

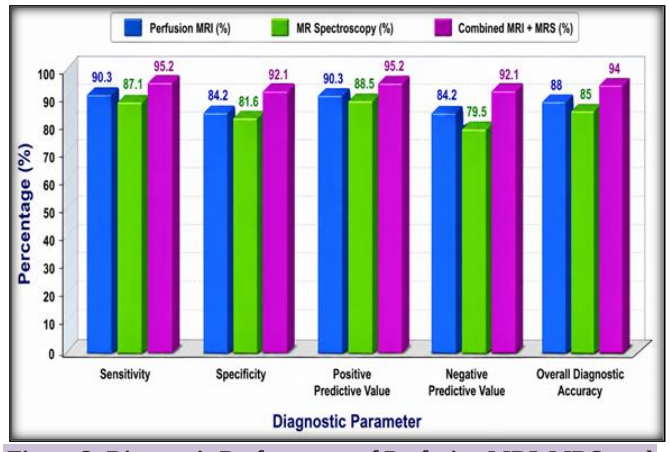

Figure 2: Diagnostic Performance of Perfusion MRI, MRS, and Combined MRI

A total of 100 patients were included in the study. Patients aged 51–60 years constituted the largest group (36.0%), followed by those aged 41–50 years (24.0%), 61–70 years (20.0%), <40 years (12.0%), and >70 years (8.0%). The age distribution was statistically significant (p = 0.028), whereas the male predominance (58.0% vs. 42.0% females) was not statistically significant (p = 0.214).

Tumor recurrence was confirmed in 62.0% of patients, while 38.0% had radiation necrosis (p < 0.001). High-grade gliomas were the most common primary tumor (54.0%), followed by brain metastases (28.0%), low-grade gliomas (10.0%), and other intracranial tumors (8.0%) (p = 0.041).

Advanced MRI parameters differed significantly between the two groups. Elevated rCBV (>2.0), increased Cho/NAA ratio, and increased Cho/Cr ratio were significantly more frequent in tumor recurrence (87.1%, 83.9%, and 80.6%, respectively), whereas low rCBV and prominent lipid-lactate peaks predominated in radiation necrosis (84.2% and 78.9%, respectively; all p < 0.001).

Perfusion MRI alone achieved 90.3% sensitivity, 84.2% specificity, and 88.0% diagnostic accuracy, while MR spectroscopy showed 87.1% sensitivity, 81.6% specificity, and 85.0% accuracy. The combined use of both modalities significantly improved diagnostic performance, yielding 95.2% sensitivity, 92.1% specificity, and 94.0% overall accuracy (p = 0.009), demonstrating the complementary value of multiparametric MRI in differentiating tumor recurrence from radiation necrosis.

Discussion

The present study found that patients aged 51–60 years (36.0%) constituted the largest proportion of the study population, with a slight male predominance (58.0%). These findings are consistent with the epidemiological profile of primary high-grade gliomas and treated metastatic brain tumors, which are more common in middle-aged and older adults. Similar demographic patterns have been reported in previous neuro-oncology studies, where most patients undergoing post-treatment MRI surveillance were in the fifth and sixth decades of life, with a slight male predominance.[7,8]

Tumor recurrence was identified in 62.0% of patients, while 38.0% had radiation necrosis. High-grade gliomas were the most common primary tumors (54.0%), followed by brain metastases (28.0%). These findings agree with previous studies showing that recurrent disease is more common than radiation necrosis during follow-up, particularly in patients with high-grade gliomas, and that differentiating these entities remains a major diagnostic challenge on conventional MRI.[9,10]

A key finding was the significant difference in advanced MRI parameters between the two groups. Tumor recurrence showed a higher frequency of elevated rCBV (87.1%), increased Cho/NAA ratio (83.9%), and increased Cho/Cr ratio (80.6%),

whereas radiation necrosis was characterized by low rCBV and prominent lipid-lactate peaks (78.9%). These observations are consistent with previous studies identifying perfusion and metabolic parameters as reliable biomarkers for distinguishing recurrent tumor from radiation necrosis.[11,12]

The combined use of perfusion MRI and MR spectroscopy achieved the highest diagnostic accuracy (94.0%), outperforming perfusion MRI (88.0%) and MR spectroscopy (85.0%) alone. This finding supports the complementary role of vascular and metabolic imaging and agrees with recent evidence recommending multiparametric MRI for improving diagnostic confidence and guiding appropriate patient management.[13,14]

Conclusion

The present study demonstrated that perfusion MRI and magnetic resonance spectroscopy (MRS) are valuable tools for differentiating tumor recurrence from radiation necrosis after treatment of intracranial tumors. Perfusion MRI identified recurrent tumors through increased cerebral blood volume, while MRS detected characteristic metabolic changes. Their combined use provided higher diagnostic accuracy than either modality alone, improving diagnostic confidence and supporting timely treatment decisions. Incorporating multiparametric MRI into routine follow-up may reduce unnecessary invasive procedures and enhance patient management and clinical outcomes.

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Conflicts of interest

There are no conflicts of interest.

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