RESEARCH PAPER

Role Of Diffusion-Weighted Mri In Differentiating Benign And Malignant Brain Tumor

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Abstract

Background: Differentiating benign from malignant brain tumors is crucial for appropriate management. Conventional mri has limitations due to overlapping imaging features. Diffusion-weighted imaging (dwi) provides functional insights by assessing water molecule diffusion and tissue cellularity.

Aim: To evaluate the role of diffusion-weighted mri in differentiating benign and malignant brain tumors.

Materials and Methods: This prospective observational study was conducted over 6 months in the department of radiodiagnosis at maharishi markandeshwar institute of medical sciences and research, haryana. A total of 50 patients with suspected brain tumors underwent mri with dwi and adc mapping. Adc values were calculated and correlated with histopathological findings. Statistical analysis was performed to determine significance.

Results: Malignant tumors showed significantly lower mean adc values ($0.82 \pm 0.15 \times 10^{-3}$ mm²/s) compared to benign tumors ($1.32 \pm 0.18 \times 10^{-3}$ mm²/s) ($p < 0.001$). Diffusion restriction was observed in 80.8% of malignant lesions versus 20.8% of benign lesions ($p < 0.001$). Dwi demonstrated a sensitivity of 80.8%, specificity of 79.2%, and overall diagnostic accuracy of 80%. No significant association was found between tumor type and age, gender, or location.

Conclusion: Dwi is a reliable, non-invasive imaging modality for differentiating benign and malignant brain tumors. Adc values serve as an effective quantitative biomarker, enhancing diagnostic accuracy and aiding in clinical decision-making when used alongside conventional mri.

Keywords: Diffusion-Weighted Imaging, Apparent Diffusion Coefficient, Brain Tumors, Magnetic Resonance Imaging, Tumor Characterization, Neuroimaging.

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INTRODUCTION

Brain tumors encompass a heterogeneous group of lesions with varying biological behavior, prognosis, and therapeutic implications. Accurate preoperative differentiation between benign and malignant brain tumors is essential for treatment planning, surgical decision-making, and predicting outcomes. Conventional magnetic resonance imaging (MRI) remains the cornerstone for evaluating intracranial neoplasms due to its excellent soft tissue contrast and multiplanar capabilities. However, morphological MRI sequences alone often fall short in reliably distinguishing benign from malignant lesions, as overlapping imaging features such as edema, necrosis, and contrast enhancement can be present in both categories [1,2].

Diffusion-weighted imaging (DWI), an advanced MRI technique, has emerged as a valuable non-invasive tool that provides insights into the microstructural characteristics of tissues. It measures the random Brownian motion of water molecules within the tissue, which is influenced by cellular density, membrane integrity, and extracellular space. Malignant tumors typically demonstrate increased cellularity and reduced extracellular space, leading to restricted diffusion and lower apparent diffusion coefficient (ADC) values. In contrast, benign lesions usually exhibit less cellular density and relatively

higher ADC values due to increased water mobility [3,4].

The quantitative assessment of ADC values has gained importance in neuro-oncology as it allows objective differentiation between tumor grades and types. Several studies have demonstrated that high-grade malignant tumors, such as glioblastomas, tend to have significantly lower ADC values compared to low-grade gliomas and benign lesions like meningiomas or schwannomas. This inverse relationship between ADC values and tumor cellularity has been widely validated, making DWI a crucial adjunct to conventional MRI protocols [5,6].

Moreover, DWI is particularly useful in cases where contrast administration is contraindicated, such as in patients with renal impairment or allergies to gadolinium-based contrast agents. It also plays a role in identifying tumor components such as cystic or necrotic areas, differentiating abscesses from necrotic tumors, and detecting early tumor recurrence versus post-treatment changes like radiation necrosis [7,8]. These additional advantages enhance its clinical utility beyond simple tumor characterization.

Despite its significant benefits, DWI is not without limitations. Factors such as susceptibility artifacts, tumor heterogeneity, and overlapping ADC values between certain benign and malignant lesions can reduce diagnostic accuracy. Therefore, DWI should be interpreted in conjunction with other advanced imaging techniques such as perfusion-weighted imaging and MR spectroscopy for a more comprehensive evaluation [9].

In recent years, the integration of DWI into routine neuroimaging protocols has improved diagnostic confidence and contributed to more precise tumor characterization. Its ability to non-invasively reflect tumor cellularity and microenvironment makes it a powerful tool in differentiating benign from malignant brain tumors. Continued research and standardization of ADC thresholds are expected to further enhance its diagnostic performance and clinical applicability [10].The study aims to evaluate the role of diffusion-weighted MRI in differentiating benign and malignant brain tumors. Objectives include assessing ADC values, correlating imaging findings with histopathology, and determining the diagnostic accuracy of DWI in improving characterization, guiding treatment planning, and enhancing overall clinical decision-making in neuro-oncology.

MATERIALS AND METHODS

Study Design: Prospective observational study

Study Duration: 6 months

Sample Size: 50 patients

Study Setting: Department of RadioDiagnosis, Maharishi Markandeshwar Institute of Medical Sciences and Research, Mullana, Haryana, India

Study Population: Patients with clinically suspected brain tumors referred for MRI

Inclusion Criteria: Patients with intracranial space-occupying lesions undergoing MRI with DWI

Exclusion Criteria: Patients with contraindications to MRI or poor image quality

Statistical Analysis: We put the data into Microsoft Excel and then used SPSS software version 27.0 (SPSS Inc., Chicago, IL, USA) and GraphPad Prism version 5 to look at it. Mean ± standard deviation was used to show continuous variables, and frequencies and percentages were used to show categorical variables. The unpaired t-test was utilized to examine continuous variables between independent groups, whereas the paired t-test was employed for comparisons within the same group. The Chi-square test or Fisher's exact test was used to look at categorical variables, depending on which one was better. A p-value of less than 0.05 was seen to be statistically important.

RESULT

Table 1. Distribution of Patients by Age Group and Tumor Type

Age Group (years)	Benign (n=24)	Malignant (n=26)	Total (n=50)	P-value
0–20	4 (16.7%)	6 (23.1%)	10 (20%)	**0.642**
21–40	8 (33.3%)	7 (26.9%)	15 (30%)	
41–60	9 (37.5%)	8 (30.8%)	17 (34%)	
>60	3 (12.5%)	5 (19.2%)	8 (16%)	

Table 2. Gender Distribution and Tumor Type

Gender	Benign (n=24)	Malignant (n=26)	Total (n=50)	P-value
Male	13 (54.2%)	15 (57.7%)	28 (56%)	**0.812**
Female	11 (45.8%)	11 (42.3%)	22 (44%)	

Table 3. Tumor Location and Nature

Location	Benign (n=24)	Malignant (n=26)	Total (n=50)	P-value

Supratentorial	15 (62.5%)	21 (80.8%)	36 (72%)	**0.142**
Infratentorial	9 (37.5%)	5 (19.2%)	14 (28%)	

Table 4. Mean ADC Values in Benign vs Malignant Tumors

Tumor Type	Mean ADC (×10⁻³ mm²/s)	SD	P-value
Benign	1.32	0.18	**<0.001**
Malignant	0.82	0.15	

Table 5. DWI Restriction Pattern and Tumor Type

DWI Pattern	Benign (n=24)	Malignant (n=26)	Total (n=50)	P-value
Restricted Diffusion	5 (20.8%)	21 (80.8%)	26 (52%)	**<0.001**
No Restriction	19 (79.2%)	5 (19.2%)	24 (48%)	

Table 6. Diagnostic Accuracy of DWI (Using ADC Cutoff 1.0 ×10⁻³ mm²/s)

Parameter	Value (%)
Sensitivity	80.80%
Specificity	79.20%
Positive Predictive Value (PPV)	80.80%
Negative Predictive Value (NPV)	79.20%
Accuracy	80.00%
P-value	**<0.001**

Figure: 1.Tumor Location and Nature

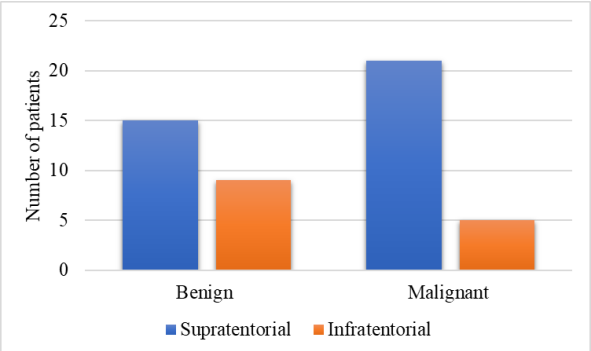

Figure: 2. DWI Restriction Pattern and Tumor Type

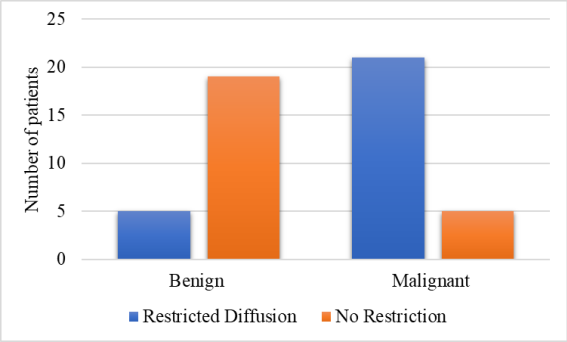

Table 1: Age Distribution and Tumor Type

The distribution of patients across different age groups showed that the majority belonged to the 41–60 years category (34%), followed by 21–40 years (30%). Among benign tumors, most cases were observed in the 41–60 years group (37.5%), whereas malignant tumors were also most frequent in the same age group (30.8%). The association between age group and tumor type was not statistically significant ($p = 0.642$).

Table 2: Gender Distribution and Tumor Type

Out of 50 patients, males constituted 56% (n=28) and females 44% (n=22). Benign tumors were seen in 54.2% of males and 45.8% of females, while malignant tumors were present in 57.7% of males and 42.3% of females. There was no statistically significant association between gender and tumor type ($p = 0.812$).

Table 3: Tumor Location and Nature

Most tumors were located in the supratentorial region (72%), with 62.5% of benign and 80.8% of malignant tumors occurring in this region. Infratentorial tumors accounted for 28% of cases. Although malignant tumors were more common in the supratentorial region, the association between tumor location and nature was not statistically significant ($p = 0.142$).

Table 4: Mean ADC Values in Benign vs Malignant Tumors

The mean ADC value for benign tumors was 1.32 ± 0.18 ×10⁻³ mm²/s, whereas malignant tumors demonstrated significantly lower ADC values of 0.82 ± 0.15 ×10⁻³ mm²/s. This difference was highly statistically significant ($p < 0.001$), indicating restricted diffusion in malignant lesions compared to benign ones.

Table 5: DWI Restriction Pattern and Tumor Type

Restricted diffusion was observed in 52% of cases overall. Among malignant tumors, 80.8% showed restricted diffusion, whereas only 20.8% of benign tumors demonstrated restriction. Conversely, absence of restriction was predominantly seen in benign tumors (79.2%). This association was highly statistically significant ($p < 0.001$).

Table 6: Diagnostic Accuracy of DWI

Using an ADC cutoff value of 1.0 $\times 10^{-3}$ mm²/s, diffusion-weighted imaging showed a sensitivity of 80.8%, specificity of 79.2%, positive predictive value of 80.8%, and negative predictive value of 79.2%. The overall diagnostic accuracy was 80.0%, with a highly significant statistical association ($p < 0.001$), confirming the effectiveness of DWI in differentiating benign and malignant brain tumors.

DISCUSSION

In the present study, the association between age distribution and tumor type was found to be statistically insignificant ($p = 0.642$). A similar observation was reported by El-Shahat et al. [11], who noted no significant correlation between demographic variables and lesion nature, suggesting that age alone is not a reliable discriminator between benign and malignant tumors. Likewise, other diffusion-based studies have emphasized that biological behavior is more dependent on cellular characteristics than demographic factors [12].

Gender distribution in our study also showed no significant association with tumor type ($p = 0.812$). This finding is consistent with studies by Ningappa et al. [13] and other authors, who reported that gender does not significantly influence the diffusion characteristics or biological aggressiveness of brain lesions. These observations reinforce that DWI parameters are independent of patient gender and are more reflective of tumor microstructure.

Regarding tumor location, although malignant tumors were more frequently supratentorial, the association was not statistically significant ($p = 0.142$). Comparable findings have been reported in neuroimaging literature, where tumor location alone was not a definitive predictor of malignancy [14]. Nagar et al. demonstrated that while certain tumors have predilections for specific locations, diffusion characteristics provide more reliable differentiation than anatomical distribution [12].

A key finding of our study was the significantly lower mean ADC values in malignant tumors ($0.82 \pm 0.15 \times 10^{-3}$ mm²/s) compared to benign tumors ($1.32 \pm 0.18 \times 10^{-3}$ mm²/s), which was highly significant ($p < 0.001$). This is in strong agreement with multiple studies. For instance, studies have shown malignant lesions to have ADC values ranging from 0.46–0.99 $\times 10^{-3}$ mm²/s, while benign lesions show higher values (1.1–2.2 $\times 10^{-3}$ mm²/s) [15]. Similarly, Vermoolen et al. reported significantly lower ADC values in malignant lesions ($p < 0.01$) [16]. This difference is attributed to increased cellularity and reduced extracellular space in malignant tumors, restricting water diffusion [20].

In terms of diffusion restriction patterns, our study demonstrated that 80.8% of malignant tumors exhibited restricted diffusion compared to only 20.8% of benign lesions ($p < 0.001$). This finding aligns with previous studies where diffusion restriction strongly favored malignancy [17]. However, some overlap has been documented, as certain benign lesions may also show restriction, leading to false positives [19]. Despite this limitation, DWI remains a highly sensitive indicator of tumor aggressiveness.

The diagnostic performance of DWI in our study showed an overall accuracy of 80%, with sensitivity of 80.8% and specificity of 79.2%. These findings are comparable to earlier studies reporting high diagnostic efficacy. For example, diffusion MRI demonstrated sensitivity up to 100% and specificity around 80% in differentiating benign from malignant lesions [15]. Meta-analyses have also shown strong diagnostic performance with area under the curve (AUC) values exceeding 0.80, indicating good accuracy [18]. Furthermore, combining DWI with conventional MRI has been shown to further improve diagnostic confidence and accuracy [20].

Overall, the findings of the present study are consistent with existing literature, confirming that diffusion-weighted imaging and ADC values are reliable, non-invasive biomarkers for differentiating benign and malignant brain tumors. While some overlap exists, especially in certain tumor subtypes, the addition of DWI significantly enhances diagnostic precision when used alongside conventional MRI.

CONCLUSION

The present study demonstrates that diffusion-weighted MRI (DWI) plays a significant role in differentiating benign and malignant brain tumors. Malignant lesions showed significantly lower ADC values compared to benign tumors, reflecting higher cellularity and restricted diffusion. The strong statistical association between ADC values and tumor nature ($p < 0.001$) highlights the reliability of DWI as a non-invasive diagnostic tool. Additionally, diffusion restriction patterns were found to be highly indicative of malignancy, further supporting its clinical utility. Although demographic factors such as age, gender, and tumor location did not show significant correlation with tumor type, DWI provided objective and reproducible parameters for differentiation. The overall diagnostic accuracy of 80% reinforces its effectiveness in routine neuroimaging. However,

minor overlap in ADC values suggests that DWI should be interpreted alongside conventional MRI. Thus, DWI serves as a valuable adjunct, improving diagnostic confidence and aiding in appropriate treatment planning.

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