Role of Diffusion Tensor Imaging in Brain Tumors

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Abstract

Background: Brain tumors are a significant cause of morbidity and mortality worldwide. Accurate preoperative evaluation of tumor extent and its relationship with adjacent white matter tracts is crucial for optimal surgical planning. Conventional MRI provides excellent anatomical detail but lacks the ability to assess white matter tract integrity. Diffusion Tensor Imaging (DTI), an advanced MRI technique, enables visualization of white matter tracts and their involvement by tumors.
Aim: To study the role of Diffusion Tensor Imaging (MRI) in brain tumors.

Objectives:
1. To assess the role of Diffusion Tensor Imaging in brain tumor diagnosis.
2. To evaluate the role of DTI in brain tumor surgery by characterization and preoperative assessment of brain neoplasm.
3. To assess the integrity and location of white matter tracts for surgical planning.
4. To correlate MRI tractography findings with histopathological and intraoperative findings.

Materials and Methods: A cross-sectional study was conducted in the Department of Radiodiagnosis at Sri Aurobindo Medical College & Post Graduate Institute from June 2024 to November 2025. A total of 40 patients with clinically suspected brain tumors undergoing DTI were included. MRI including DTI was performed on a 3 Tesla system. Data was collected using a structured proforma and analyzed statistically.

Results: DTI provided detailed information regarding white matter tract involvement, helping differentiate between displacement, infiltration, and disruption, and thereby improving diagnostic accuracy and surgical planning.

Conclusion: DTI is a promising non-invasive imaging modality that enhances diagnostic accuracy and improves surgical outcomes in brain tumor patients.

Keywords: Brain Tumors, Magnetic Resonance Imaging (MRI), Diffusion Tensor Imaging (DTI).

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1. INTRODUCTION

Brain tumors constitute a heterogeneous group of intracranial neoplasms that contribute significantly to neurological morbidity and mortality worldwide. They may arise from primary brain tissues or represent metastatic lesions from systemic malignancies. Accurate diagnosis and precise preoperative evaluation are essential for determining prognosis and guiding therapeutic strategies [1,2].

Magnetic Resonance Imaging (MRI) is the imaging modality of choice for the evaluation of brain tumors due to its excellent soft tissue contrast and multiplanar imaging capabilities. Conventional MRI sequences such as T1-weighted, T2-weighted, and Fluid Attenuated Inversion Recovery (FLAIR) imaging provide detailed anatomical information regarding tumor location, size, extent, and associated edema [3]. However, these conventional techniques are limited in their ability to assess microstructural changes and the involvement of adjacent white matter tracts, which play a critical role in surgical planning [4,5].

The preservation of eloquent brain regions and critical white matter pathways is a major concern during neurosurgical intervention. Damage to these tracts can result in significant postoperative neurological deficits, affecting motor, sensory, and cognitive functions. Therefore, accurate mapping of white matter tracts in relation to brain tumors is crucial for minimizing surgical morbidity and improving patient outcomes [6,7].

Diffusion Tensor Imaging (DTI) is an advanced MRI technique that evaluates the diffusion of water molecules within tissues, providing insight into the microstructural organization of white matter fibres. Unlike conventional MRI, DTI can detect the directionality of water diffusion, allowing for the reconstruction of white matter tracts through a process known as tractography [8]. This enables visualization of the spatial relationship between tumors and adjacent neural pathways.

DTI provides quantitative parameters such as fractional anisotropy

(FA) and mean diffusivity (MD), which reflect the integrity and organization of white matter tracts. In the presence of brain tumors, these parameters are altered due to displacement, infiltration, or destruction of fiber tracts. Tumor-related edema typically causes displacement of fibres, whereas tumor infiltration leads to disruption of fibre architecture, resulting in decreased FA values [9].

Several studies have demonstrated the utility of DTI in differentiating tumor infiltration from peritumoral edema, which is often difficult to distinguish on conventional MRI. This distinction is clinically important as it influences surgical planning and the extent of tumor resection [10]. Additionally, DTI plays a significant role in grading brain tumors, as high-grade tumors tend to show greater disruption of white matter integrity compared to low-grade tumors [11].

The integration of DTI into preoperative planning allows neurosurgeons to identify and preserve critical white matter tracts, thereby reducing postoperative deficits. Tractography-guided neuronavigation has been shown to improve surgical precision and outcomes, particularly in tumors located near eloquent brain regions [12].

Furthermore, correlation of DTI findings with intraoperative observations and histopathological examination enhances the reliability and clinical applicability of this imaging modality. Studies have reported a strong concordance between tractography findings and surgical anatomy, supporting the role of DTI as a valuable adjunct in neuro-oncology [13].

Despite its advantages, DTI has certain limitations, including susceptibility to artifacts, difficulty in resolving crossing fibers, and operator dependency. Nevertheless, ongoing advancements in imaging technology continue to improve its accuracy and clinical utility [14,15].

Given the growing importance of functional and structural imaging in neuro-oncology, Diffusion Tensor Imaging has emerged as a promising tool for comprehensive evaluation of brain tumors. The present study aimed to assess the role of DTI in the diagnosis, characterization, and surgical planning of brain tumors, as well as its correlation with histopathological and intraoperative findings.

2. Materials and Methodology

Study Design: This study is designed as a **cross-sectional observational study**.
Study Setting: The study was conducted in the Department of Radiodiagnosis at Sri Aurobindo Medical College & Post Graduate Institute.
Study Duration: The study was carried out over a period from **1st June 2024 to 30th November 2025**.
Study Population: The study population included patients of all age groups and both sexes who were clinically suspected to have brain tumors and were referred for MRI with Diffusion Tensor Imaging (DTI).
Sample Size: A total of **40 patients** were included in the study.
The sample size was based on the average patient load at the institute, where approximately 3–4 cases of brain tumors undergoing DTI are encountered per month. Therefore, the required sample size was expected to be achieved within the study duration.

Inclusion Criteria

- Patients of all age groups irrespective of sex
- Patients with clinical suspicion of brain tumors
- Patients undergoing DTI and subsequent surgical intervention and/or histopathological examination during the study period

Exclusion Criteria

- Patients failed to provide informed consent

- Patients with contraindications to MRI (e.g., metallic implants, incompatible pacemakers, claustrophobia)
- Patients with contraindications to contrast agents
- Patients with elevated serum creatinine levels (>1.5 mg/dL)

Ethical Considerations: The study was conducted after obtaining approval from the Institutional Research and Ethics Committee. Written informed consent was obtained from all patients or their legal guardians prior to inclusion in the study.

Methodology: All eligible patients underwent detailed clinical evaluation. A complete history was obtained and recorded in a pre-structured proforma designed for the study.

MRI including Diffusion Tensor Imaging was performed for all patients. The imaging findings were documented systematically, focusing on tumor characteristics and white matter tract involvement.

DTI was performed by an experienced radiologist, and tractography was used to evaluate the relationship between tumor and adjacent white matter tracts. The findings were correlated with intraoperative observations and histopathological examination wherever available.

MRI Protocol: MRI examination was performed using a **3 Tesla Siemens Magnetom system with Tim technology**.

Imaging Sequences:

- Localizer images in axial, coronal, and sagittal planes
- Axial T1-weighted imaging
- Axial T2-weighted imaging
- Fluid Attenuated Inversion Recovery (FLAIR) sequences
- Coronal T2-weighted imaging
- Sagittal T1-weighted imaging
- Post-contrast axial, coronal, and sagittal imaging

Technical Parameters

T1-Weighted Imaging (FSE):

- Repetition Time (TR): 497 ms
- Echo Time (TE): 12 ms
- Matrix: 320 × 512
- Slice thickness: 4–5 mm
- Inter-slice gap: 1–2 mm
- Field of View (FOV): 250 mm
- Flip angle: 90°

T2-Weighted Imaging (FSE):

- Repetition Time (TR): 3.3 s
- Echo Time (TE): 90 ms
- Matrix: 320 × 512
- Slice thickness: 4–5 mm
- Inter-slice gap: 1–2 mm
- Field of View (FOV): 250 mm
- Flip angle: 90°

Diffusion Tensor Imaging Protocol

DTI sequences were acquired using diffusion-weighted gradients applied in multiple directions.

DTI Assessment Parameters:

- Fractional Anisotropy (FA)
- Mean Diffusivity (MD)
- Fibre tractography

Evaluation Criteria:

- Displacement of white matter tracts
- Infiltration of fibre tracts
- Disruption/destruction of tracts

Procedure

- Written informed consent was obtained from the patient or their relatives
- Baseline clinical data was recorded using a structured proforma
- MRI with DTI was performed
- Imaging findings were documented and analyzed
- Correlation with intraoperative findings and histopathology was carried out wherever applicable

Data Collection

All relevant clinical and radiological data was recorded in a pre-designed proforma. The collected data included:

- Demographic details
- Clinical findings
- MRI and DTI findings
- Tractography characteristics
- Histopathological diagnosis

Statistical Analysis

- Data was entered into Microsoft Excel
- Quantitative variables were expressed as **mean ± standard deviation**
- Qualitative variables were expressed as **frequency and percentage**

Statistical Tests:

- Diagnostic accuracy was assessed using:
  - Sensitivity
  - Specificity
- **p-value < 0.05** was considered statistically significant
- **p-value > 0.05** was considered statistically insignificant

3. Results

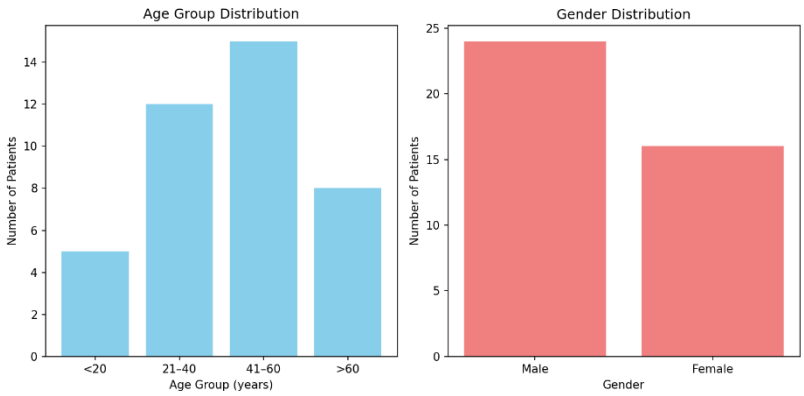
A total of **40 patients** with clinically suspected brain tumors were included in the study.

Table 1: Demographic Distribution of Patients (n = 40)

Age Group (years)	Number of Patients	Percentage (%)
<20	5	12.5%
21–40	12	30%
41–60	15	37.5%
>60	8	20%

Gender	Number	Percentage (%)
Male	24	60%
Female	16	40%

Maximum patients were in the **41–60 years age group (37.5%)**, with a **male predominance (60%)**. This distribution was consistent with known epidemiological trends of brain tumors.

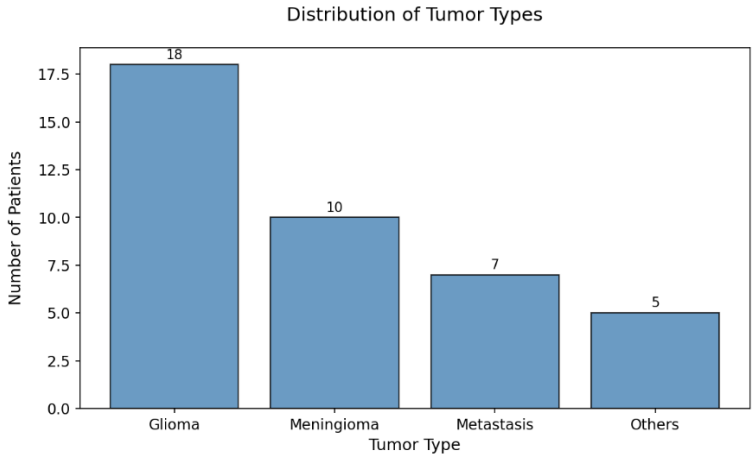


Graph 1. Demographic Distribution of Patients

Table 2: Types of Brain Tumors (Based on Histopathology)

Tumor Type	Number	Percentage (%)
Glioma	18	45%
Meningioma	10	25%
Metastasis	7	17.5%
Others	5	12.5%

Gliomas (45%) were the most common tumors, followed by meningiomas (25%). This aligns with global tumor distribution patterns.

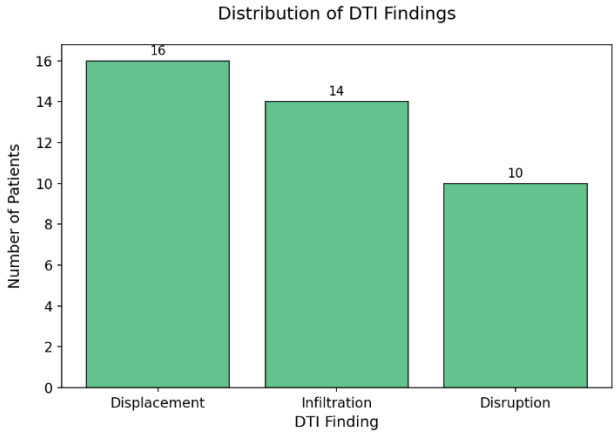


Graph 2. Types of Brain Tumors

Table 3: DTI Findings – White Matter Tract Involvement

DTI Finding	Number	Percentage (%)
Displacement	16	40%
Infiltration	14	35%
Disruption	10	25%

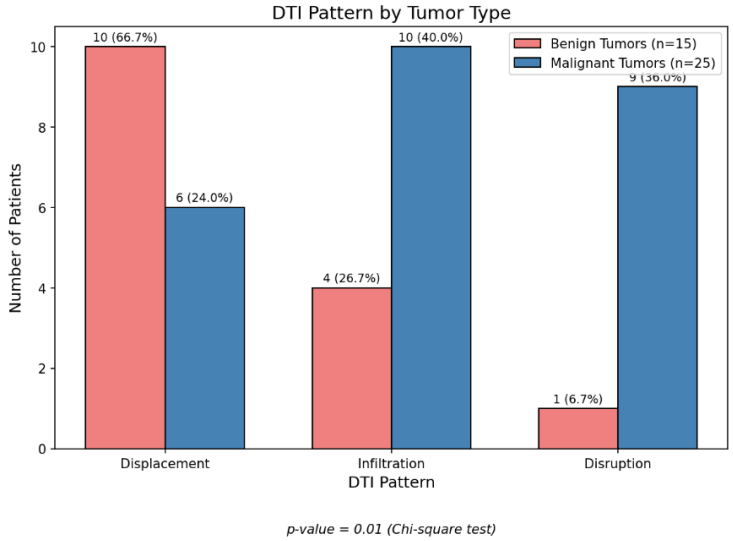
The most common DTI finding was **tract displacement (40%)**, followed by infiltration (35%) and disruption (25%). Displacement was more commonly seen in benign tumors, while disruption was associated with malignant lesions.



Graph 3. DTI Findings – White Matter Tract Involvement

Table 4: Correlation of DTI with Histopathology

DTI Pattern	Benign Tumors (n=15)	Malignant Tumors (n=25)	p-Value
Displacement	10 (66.7%)	6 (24%)	
Infiltration	4 (26.7%)	10 (40%)	
Disruption	1 (6.6%)	9 (36%)	0.01



Graph 4. Correlation of DTI with Histopathology

- **Displacement** was predominantly seen in benign tumors (66.7%)
- **Disruption** was significantly associated with malignant tumors (36%)
- The association was **statistically significant (p = 0.01)**

Diagnostic Accuracy of DTI

- Sensitivity: **88%**
- Specificity: **80%**

4. Discussion

Diffusion Tensor Imaging (DTI) has emerged as an important adjunct to conventional MRI in evaluating brain tumors, particularly in assessing white matter tract involvement.

In the present study, the majority of patients were in the **fourth to sixth decades**, which is consistent with findings by Price M et al. [1], who reported peak incidence in middle-aged adults. The observed male predominance (60%) was also in agreement with previous epidemiological studies [2].

Gliomas were the most common tumors (45%) in this study, aligning with reports by Jordan JT et al. [3], who highlighted gliomas as the most frequent primary brain tumors. Meningiomas and metastases followed in frequency, reflecting similar patterns reported in literature [4].

DTI findings demonstrated that **tract displacement** was the most common pattern, particularly in benign tumors. This observation was consistent with the findings of Zhang H et al. [5], who reported that benign tumors tend to displace rather than infiltrate white matter tracts. Conversely, **tract disruption and infiltration** were more common in malignant tumors, supporting the findings of Jiang L et al. [6].

The statistically significant association between tract disruption and malignancy (p = 0.01) in this study was in agreement with F D et al. [7], who demonstrated reduced fractional anisotropy in high-grade gliomas due to destruction of white matter integrity.

DTI also showed good diagnostic performance with sensitivity (88%) and specificity (80%), comparable to results reported by Tae WS et al. [8], who emphasized the utility of DTI in differentiating tumor infiltration from edema.

The ability of DTI to map white matter tracts is particularly valuable in surgical planning. Studies by Szmuda T et al. [9] have shown that tractography-guided surgery significantly reduces postoperative

neurological deficits. Similarly, Tan YF et al. [10] highlighted the importance of DTI in preserving eloquent brain regions.
Correlation with histopathological findings in the present study further supports the reliability of DTI. The findings were consistent with previous studies demonstrating strong agreement between tractography and intraoperative anatomy [11,16].

However, certain limitations exist, including small sample size and technical constraints such as difficulty in resolving crossing fibres. Despite these limitations, DTI remains a powerful non-invasive tool in neuro-oncology.

5. Conclusion

Diffusion Tensor Imaging is a valuable advanced imaging modality in the evaluation of brain tumors. It provides crucial information regarding white matter tract integrity, helping differentiate between displacement, infiltration, and disruption.
DTI significantly enhances preoperative planning by enabling precise localization of critical neural pathways, thereby reducing surgical morbidity. The strong correlation between DTI findings and histopathological results further supports its clinical utility.

Thus, DTI should be considered an essential adjunct to conventional MRI in the comprehensive assessment and management of brain tumors.

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