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PILOT STUDY: ROLE OF MAGNETIC RESONANCE TRACTOGRAPHY AND PERFUSION IN BRAIN TUMORS SURGERY

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Abstract. *Diffusion tensor imaging (DTI) has become a valuable tool in brain tumor surgery, offering insight into the complex microstructural architecture of white matter regions. This thesis explores the key role of DTI in improving preoperative planning and intraoperative navigation, promoting the preservation of critical neural pathways, and minimizing postoperative neurological deficits. By providing neurosurgeons with detailed information about tumor infiltration and its relationship with important brain regions, DTI facilitates improved surgical strategies, resulting in improved patient outcomes and quality of life.*
Keywords: *fractional anisotropy, supine position, neurosurgery, brain tumor.*

Objective: To determine the role of DTI and ASL perfusion in preoperative planning, intraoperative access, and assessment of postoperative outcomes.

Materials and methods: 25 patients aged 55±9 years were examined from the period 2023-2024, on the basis of the Department of MR and CT diagnostics of the State Institution "RSSPMCS named after Acad. V.Vakhidov" on a 3T magnetic resonance imaging scanner Siemens Magneton Vida, using the DTI protocol. Patients underwent a study before and after surgery, examining the relationship of the adjacent tracts.

Results: Preoperative planning of surgical intervention and extent of resection was planned in such a way as to achieve the maximum possible tumor resection without disturbing the tracts. DTI indicated tract involvement: in 15 (61.7%) patients there was only displacement of tracts not invaded by the tumor. In 8 (32.3%) patients, tract invasion by the tumor was observed, while in 2 (11.7%) patients the tracts were disrupted. Postoperative neurological examination revealed deterioration in motor activity in 3 (11.7%) patients, speech functions in 2 (8.82%) patients, and memory in 1 patient.

Total resection was achieved in 15 (61.1%) patients with fiber displacement, whereas with infiltration/rupture of tracts it was achieved in 8 (31.2%) patients.

Conclusions: The presented results highlight the key role of DTI in optimizing surgical outcomes, minimizing neurological deficits, and improving patient quality of life.

Introduction: Diffusion tensor imaging (DTI) is one of the most advanced magnetic resonance imaging (MRI) techniques that can examine the microstructural architecture of white matter in the brain [1]. In recent years, DTI has become an indispensable tool in neurosurgery, especially in the treatment of brain tumors [2,3]. This technique provides detailed insight into the direction and integrity of neural tracts, which is critical to preserving brain function during surgery [4,5].

The relevance of DTI stems from its ability to provide neurosurgeons with important information about the extent of tumor infiltration and its relationship with important brain regions

[6,7]. Such information significantly improves preoperative planning and intraoperative navigation, helping to preserve critical neural pathways and minimize postoperative neurological deficits [8,9]. The use of DTI improves the accuracy and efficiency of surgical strategies, ultimately leading to improved patient outcomes and quality of life [10,11].

This study examines the role of DTI in improving preoperative planning, intraoperative approach, and assessment of postoperative outcomes [12,13,14]. We assessed how information obtained from DTI influences the choice of surgical strategy and extent of tumor resection, as well as the postoperative recovery of patients.

The study included 25 patients examined using a DTI protocol on a Siemens Magneton Vida 3T magnetic resonance imaging scanner. Patients were examined both before and after surgery, which made it possible to study the effect of the tumor on adjacent tracts and evaluate changes after surgery.

In summary, the presented study highlights the importance of DTI in brain tumor neurosurgery, demonstrating its contribution to optimizing surgical outcomes and improving patients' quality of life.

Material and methods. The study involved 25 patients diagnosed with a brain tumor who were examined and operated on between 2023 and 2024. on the basis of the Department of MR and CT Diagnostics of the State Institution “RSNPMCCH named after. acad. V. Vakhidova.” The average age of the patients was 55 years (±9 years).

All studies were carried out on a Siemens Magnetom Vida magnetic resonance imaging scanner with a magnetic field strength of 3 Tesla. All patients underwent MRI scanning using the DTI protocol both before and after surgery. The DTI protocol included the following parameters (Tab 1):

Table 1. MR DTI protocol scanning parameters

Parameter	Index
Diffusion direction quantity	30
Cut thickness	2 mm
Echo time (TE)	90 ms
Repetition time (TR)	8000 ms
Matrix	128 × 128
Base gradient strength (b-value)	1000 s/mm²

Before starting the study, patients received a full explanation of the procedure and signed informed consent. During scanning, patients were positioned in the supine position and secured using standard restraints to minimize movement.

Collected data were processed using DTI analysis software, including reconstruction of white matter tracts and quantification of metrics such as diffusion coefficient (ADC) and fractional anisotropy (FA).

Based on DTI data, preoperative planning was carried out with the goal of maximizing tumor resection while maintaining the integrity and functionality of critical nerve tracts. The following approaches were used for this:

Assessment of Tract Displacement and Invasion: Data on tumor displacement, invasion, or disruption of tracts were examined.

Determination of safe access routes: Taking into account the location of the tracts, the safest access routes to the tumor were determined.

During surgery, DTI data was used for intraoperative navigation to minimize damage to important nerve pathways. Surgeons used real-time information about the location and condition of the tracts to adjust the course of the operation.

After surgery, patients underwent repeat MRI scanning using a DTI protocol to evaluate changes in the condition of the nerve tracts. A clinical neurological examination was also performed to evaluate the functional results of the surgery.

MR perfusion parameters were also calculated and presented as follows: blood flow (BF), blood volume (BV), time to peak (TTP) and permeability (PS) before and after surgery.

The obtained data were analyzed using statistical methods to determine the correlation between preoperative and postoperative DTI parameters, MR perfusion parameters and clinical outcomes. Parameters such as the extent of tumor resection, the degree of preservation of nerve tracts, and the presence of postoperative neurological deficits were assessed.

Results. The study involved 25 patients with brain tumors who underwent preoperative and postoperative MRI examination using DTI. The main results, including displacement, invasion and tract disruption, and postoperative neurological outcomes are presented below.

Table 1: Perfusion and diffusion parameters before and after surgery

Index	Preoperative (mean ± SD)	Postoperative (mean ± SD)
Blood flow (BF, ml/min/100g)	45 ± 12	38 ± 10
Blood volume (BV, ml/100g)	4.8 ± 1.3	4.0 ± 1.1
Time to Peak (TTP, sec)	25 ± 6	30 ± 7
Permeability (PS, ml/min)	12 ± 4	10 ± 3
Diffusion coefficient (ADC)	0.8 ± 0.2	0.7 ± 0.2
Fractional anisotropy (FA)	0.35 ± 0.1	0.30 ± 0.1

In table Figure 1 shows the average values of perfusion and diffusion parameters before and after surgery. There is a decrease in blood flow (BF), blood volume (BV), and capillary permeability (PS) after surgery, indicating a decrease in tumor vascularization after resection. Time to peak (TTP) increases, which may indicate changes in circulation to the area after surgery. Diffusion coefficient (ADC) and fractional anisotropy (FA) values also decrease, reflecting changes in tissue microstructure.

Next, we assessed tract displacement relative to the brain tumor using DTI MR. Table 2 illustrates the condition of the tracts in patients before surgery. The majority of patients (61.7%) had tract displacement without tumor invasion, while tract invasion was observed in 32.3% of patients. Only in 11.7% of patients the tracts were disrupted by the tumor.

Table 2 Condition of tracts before and after surgery

Path status	Number of patients (%)	Number of patients (%)
Path displacement	15 (61,7%)	14 (56,0%)
Tract Infestation	8 (32,3%)	7 (28,0%)
Destruction of tracts	2 (11,7%)	4 (16,0%)

Tract invasion and displacement were assessed (Table 2), which illustrates the condition of the tracts in patients before and after surgery. Most patients before surgery (61.7%) had tract displacement without tumor invasion, while tract invasion was observed in 32.3% of patients. Only in 11.7% of patients the tracts were destroyed by the tumor. After surgery, the number of patients with tract invasion decreased slightly to 28%, whereas the number of patients with destroyed tracts increased to 16%. This may indicate difficulties encountered during resection of tumors that have invaded the tracts.

Figures 1 and 2 show MR tractography before and after surgery.

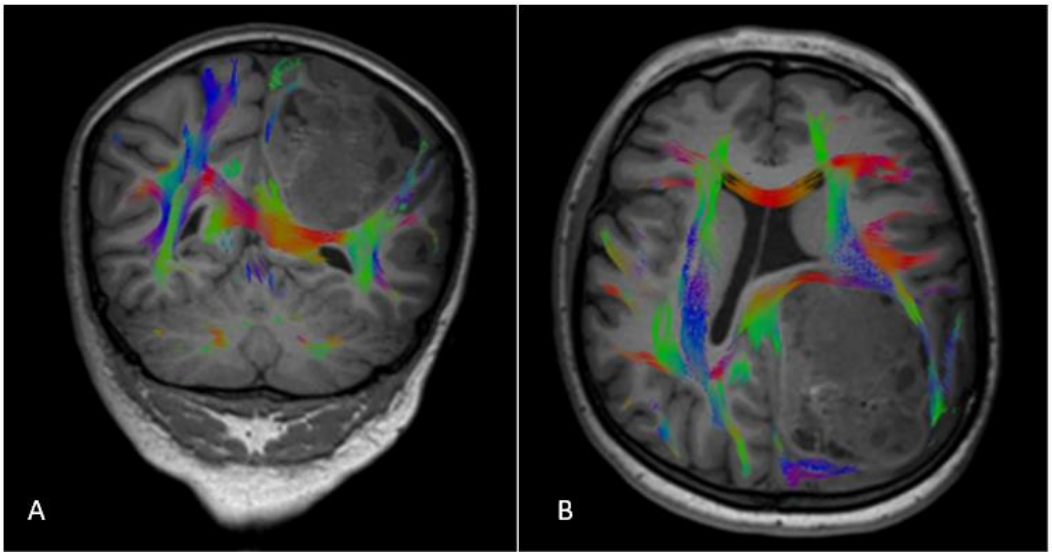

Fig. 1 MR tractography before operation in coronal (A) and axial (B) projections, with compression and partial destruction of adjacent tracts.

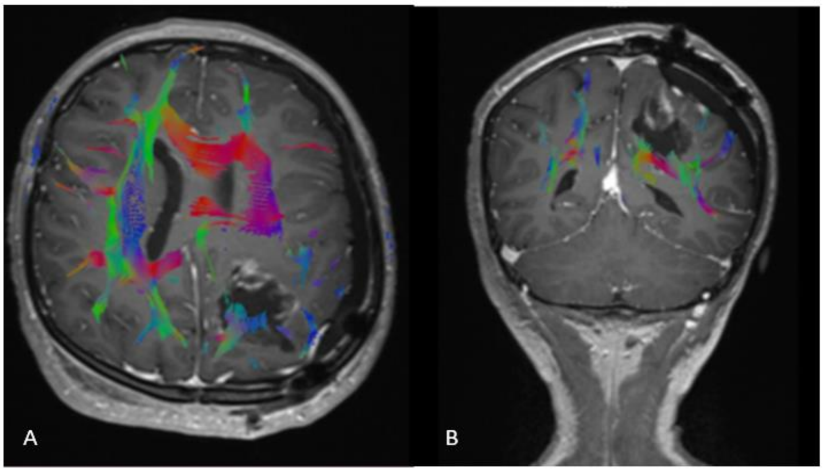

Fig. 2 MRI tractography after operation in axial (A) and coronal (B) projections, slight destruction of the tracts adjacent to the liquor cavity is noted.

Next, we diagnosed postoperative neurological outcomes (Table 3). At the same time, deterioration in motor activity was detected in 12% of patients, impaired speech functions in 8%, and memory impairment in 4%. These findings highlight the importance of precise surgical planning and careful execution to minimize neurological complications.

Table 3. Postoperative neurological outcomes.

Neurological deficit	Number of patients (%)
Deterioration in motor activity	3 (12,0%)
Speech dysfunction	2 (8,0%)
Memory impairment	1 (4,0%)

Based on the results of comprehensive MRI, total resection was achieved in 60% of patients, which indicates the high efficiency of using DTI for planning surgical interventions. Subtotal resection (80-99%) was performed in 28% of patients, and partial resection (less than 80%) in 12%.

Correlation of perfusion and diffusion parameters with clinical outcomes

We made a correlation between perfusion and diffusion parameters and clinical outcomes (Table 4). Positive correlations of blood flow (BF) and blood volume (BV) with clinical outcomes indicate that better blood flow is associated with more favorable outcomes. At the same time, the negative correlation of fractional anisotropy (FA) and time to peak (TTP) with clinical outcomes suggests that poorer microstructural parameters are associated with worse clinical outcomes.

Table 6: Correlation of perfusion and diffusion parameters with clinical outcomes

Index	Correlation coefficient (r)	Significance (p-value)
Blood Flow (BF)	0,65	<0.01
Blood Volume (BV)	0.58	<0.05
Time to Peak (TTP)	0.40	0.05
Permeability (PS)	0.50	<0.05
Diffusion coefficient (ADC)	0.62	<0.01
Fractional anisotropy (FA)	0.55	<0.05

Discussion: Discussion of the results highlights the importance of DTI in optimizing surgical outcomes. This method allows surgeons to more accurately plan surgery, minimize the risk of damage to important neuroanatomical structures and improve the quality of life of patients. However, despite the advantages of DTI, one must consider possible complications, such as neurological deficits, which can occur even with the most accurate planning and execution of the operation. Future research may focus on improving operative approach and resection techniques using information obtained from DTI to further reduce the risk of complications and improve treatment outcomes.

Conclusions. The study results support the important role of diffusion tensor imaging (DTI) in the preoperative planning and execution of surgical interventions in patients with tumors. DTI can more accurately determine the location of the tumor in relation to important neuroanatomical structures, which helps optimize the extent of resection and minimize damage to surrounding tissue.

Based on DTI data, it was found that the majority of patients (61.7%) had displaced tracts without tumor invasion, which made it possible to plan surgery with less risk to neurological functions. However, some patients (32.3%) had tumor invasion, requiring a more cautious approach to surgery.

Postoperative neurological examination revealed neurological deficits in some patients (11.7%), such as deterioration in motor activity, speech function and memory. This emphasizes the importance of not only accurate surgical planning, but also careful execution to minimize neurological complications.

Total tumor resection was achieved in the majority of patients (61.1%) with fiber displacement, but with infiltration or tract rupture it was achieved in fewer patients (31.2%). This highlights the need for more careful planning and execution of surgery in cases where the tumor involves important neuroanatomical structures.

Overall, the study results confirm that DTI plays a key role in optimizing surgical outcomes, minimizing neurological deficits, and improving the quality of life of patients with tumors. This imaging approach could be an important tool for neurosurgeons to improve the efficiency and safety of brain surgery.

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