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“Magnetic Resonance Imaging in the differential diagnosis of benign and malignant brain Tumors”

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Abstract: Radiological diagnostic methods play a crucial role in every stage of managing patients with brain tumors. From the initial diagnosis to treatment planning and monitoring the effectiveness of therapy, accurate and detailed imaging is essential for optimal care. By leveraging advanced imaging techniques like magnetic resonance imaging (MRI), clinicians can precisely identify the location, size, and characteristics of brain tumors without invasive procedures. This information is invaluable for developing personalized treatment plans and assessing the response to therapy over time.

MRI has indeed become a cornerstone of contemporary neurovisualization methods due to its unparalleled capabilities in assessing structural transformations in the brain and exploring various features of tumors. Despite the emergence of novel methodologies, traditional structural MRI remains indispensable in neuro-oncology practice due to its high resolution and the reliability of its results.

The field of neuroradiology continues to advance, with ongoing efforts focused on the development of new scanning protocols, enhancement of image quality, and integration of functional MRI methods. These advancements aim to provide clinicians with more detailed and accurate information for treatment planning and outcome evaluation, ultimately improving patient care in neuro-oncology.

Keywords: brain tumors, magnetic resonance imaging, benign neoplasm, malignant neoplasm.

Relevance: Gliomas of various malignancy grades, meningiomas, and malignant extracranial tumor metastases represent a significant portion of adult brain tumors and pose unique challenges in terms of diagnosis, treatment, and prognosis. The incidence of brain tumors represents a significant medical challenge, and the increasing number of cases worldwide and in the Republic of Uzbekistan warrants attention and preventive measures. The fact that brain tumors rank fifth in the overall oncological morbidity structure in the Republic of Uzbekistan, as well as their high prevalence among both men and women, underscores the need for improved prevention, diagnosis, and treatment measures for this type of tumor. Early detection and timely treatment can significantly increase the chances of recovery and optimization of the patient's quality of life.

Despite significant breakthroughs in neurosurgical practice and radiological diagnostics, differentiating between various brain formations with similar signal characteristics remains a challenging task. This can pose challenges in selecting optimal treatment and planning surgical interventions.

One of the arguments for the difficulty is that many types of tumors or other formations may exhibit similar signal characteristics on various imaging modalities. This can hinder accurate diagnosis and assessment of tumor extent.

Furthermore, delineating tumor boundaries preoperatively may be challenging due to signal inhomogeneity in surrounding tissues and the limited resolution of some diagnostic methods.

To overcome these challenges, it is important to develop new image processing methods, utilize combined diagnostic approaches, and improve collaboration among healthcare professionals from different specialties, such as neurosurgeons and radiologists.

Materials and Methods:

This study is founded upon the comprehensive examination findings of 60 patients with histologically confirmed diagnoses who underwent assessment and treatment at the Republican Scientific Center of Neurosurgery of the Republic of Uzbekistan between 2022 and 2023.

The diagnosis and assessment of brain tumors involved utilizing magnetic resonance imaging (MRI) with contrast enhancement. The examinations were conducted using a 1.5 Tesla magnetic field strength scanner and included standard sequences such as T1-weighted imaging (T1), T2-weighted imaging (T2), T2-fluid-attenuated inversion recovery (FLAIR), diffusion-weighted imaging (DWI), and T1-weighted imaging with post-contrast administration (T1-post contrast).

Clinical data were analyzed based on the patient's medical histories, with the evaluation of histological examination results of tumor tissue.

Statistical data analysis was conducted using the Excel (2007) software application, where parameters such as mean (M), mean standard error (m), standard

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deviation, and the probability of result reliability according to the t-Student criterion were determined.

The chosen threshold for statistical significance was established at $p > 0.005$.

Results and Discussion:

The research involved MRI data analysis from a cohort of 60 patients diagnosed with brain tumors. Within this group, 31 patients were identified as having malignant tumor types (glioma or metastasis), while 29 patients presented with benign tumors (meningioma). The patients' ages ranged from 3 to 70 years, with a mean age of 44 ± 2.14 years. Among the 60 patients, 21 were male and 39 were female. Detailed distributions of patients categorized by age and gender within both tumor groups are provided in Tables 1 and 2.

The results indicate a diverse representation of brain tumor types among the study cohort, with both malignant and benign forms observed. The predominance of female patients in both groups is noteworthy and may reflect underlying epidemiological trends or differential healthcare-seeking behaviors. The age distribution highlights the occurrence of brain tumors across a wide range of ages, emphasizing the importance of comprehensive diagnostic and treatment strategies across age groups. Further analysis of imaging data and clinical parameters will provide valuable insights into the characteristics and management of brain tumors in this population.

Table 1: Representation of the distribution of malignat brain tumors by gender and age

	<20 year		21-30		31-40		41-50		51-60		61-70	
Gliomas	4	4	3		1	5	2	5	1			2
Metastasis			1		2			1				1

Table 2: Representation of the distribution of benign brain tumors by gender and age

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	<20 year		21-30		31-40		41-50		51-60		61-70	
Meningiomas		1	1		1		2	8		5	6	4

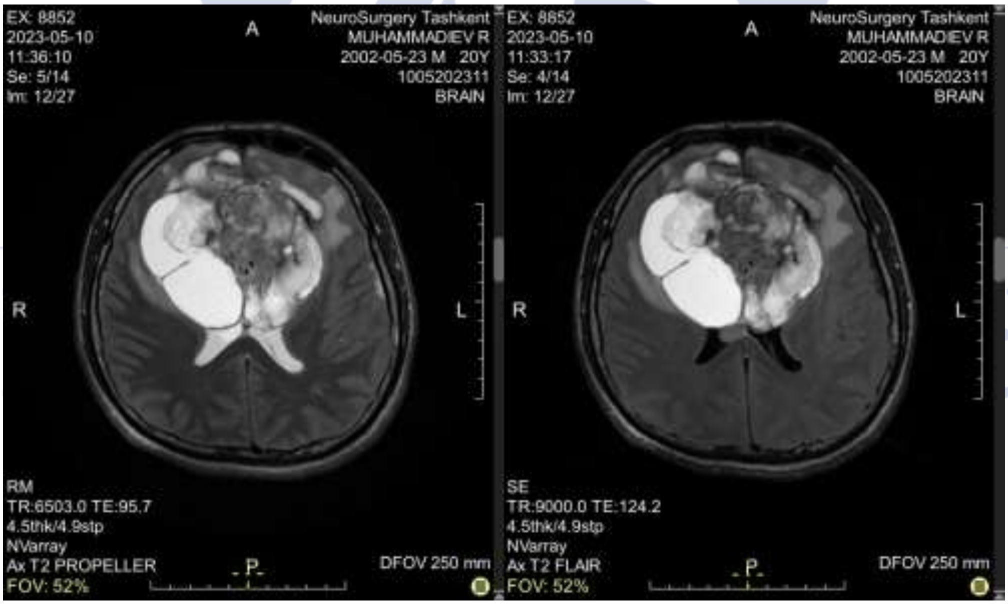
In retrospect, malignant brain neoplasms were further categorized into subgroups based on the histological characteristics of the tumors, following the classification criteria outlined by the World Health Organization (WHO), as presented in Table 3.

Table 3: Distribution of gliomas by hystotype

Histological type	WHO grade of malignancy			
	G = I	G = II	G = III	G = IV
	Piloid astrocytoma (n = 5)	oligodendroglioma (n = 4)	Anaplastic astrocytoma (n = 12)	Glioblastoma (n = 5)

Gliomas were diagnosed in 26 patients, with an average age of 35 ± 2.8 years. Among these patients, 11 were male and 15 were female.

Clinical example of an MRI scan of an anaplastic astrocytoma (Figure 1).



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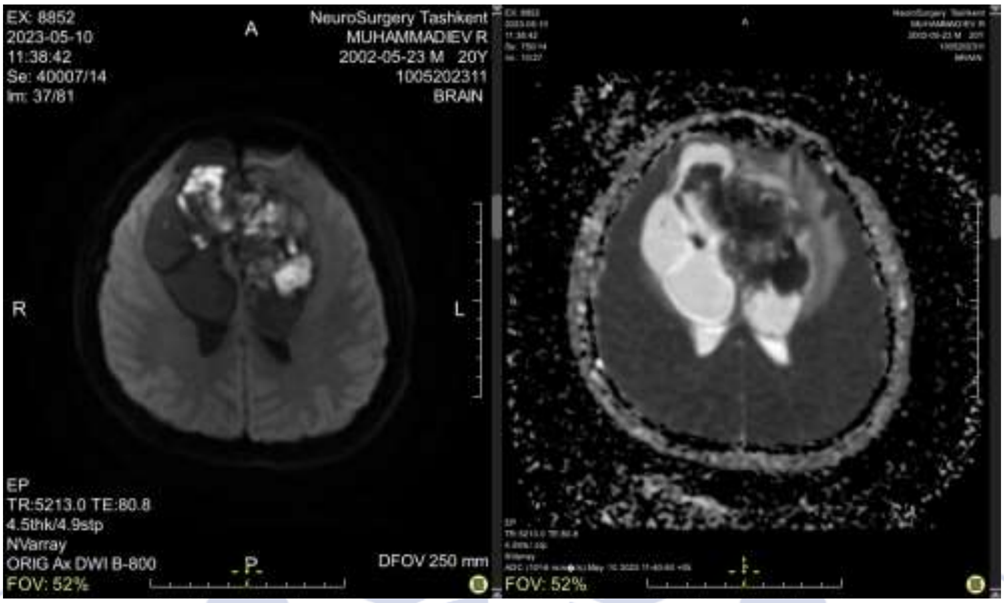

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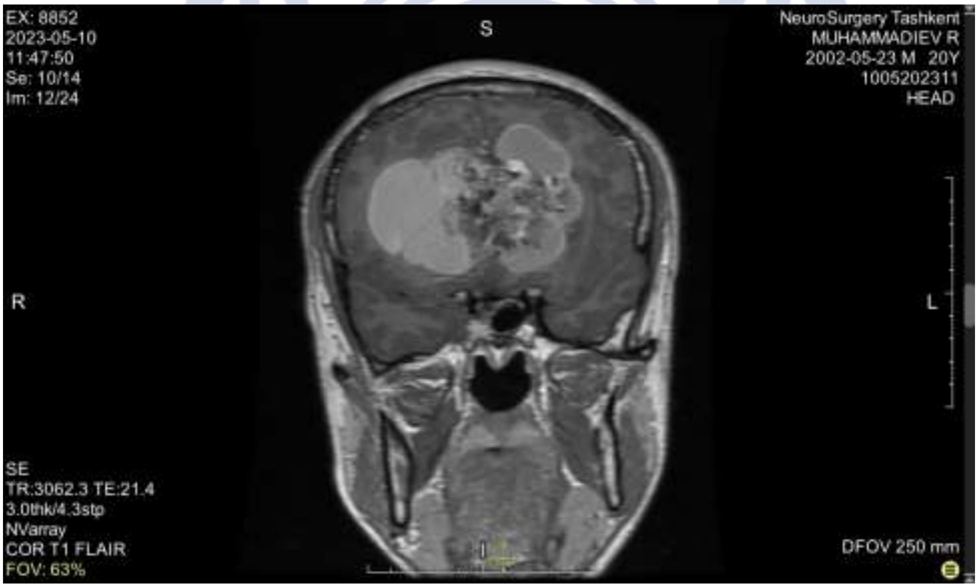

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Figure 1 illustrating MRI images of a frontal lobe anaplastic astrocytoma in a 65-year-old patient:

a) T2-weighted image

b) T2-FLAIR image

c) Diffusion-weighted image (DWI)

d) Apparent diffusion coefficient (ADC) map

e) T1-weighted image after contrast administration

The images reveal an irregularly shaped intracranial volumetric formation measuring 9.2x5.7x9.4 cm in the frontal lobes. It exhibits clear irregular contours and a heterogeneous cystic-solid structure. The components of the tumor demonstrate various signal characteristics: the solid component is hyperintense on T2 and FLAIR, weakly hyperintense on T1, while the cystic component has mixed signal characteristics. Restricted diffusion areas are observed within the solid component, along with compression of adjacent lateral ventricles, corpus callosum, and temporal lobes, accompanied by a perifocal edema zone. Both anterior cerebral arteries pass through the solid component of the tumor. Following contrast administration, heterogeneous intense enhancement of the solid component and tumor walls is noted.

Glioblastomas (GBMs) are recognized as the most aggressive type of primary brain tumors. They are characterized by their rapid growth and invasive nature, which pose considerable challenges in treatment and are associated with a poor prognosis for patients.

Despite considerable advancements in modern micro-neurosurgery, chemotherapy, radiotherapy, and the emergence of molecularly targeted treatment approaches, managing GBMs remains a complex task. These tumors frequently recur after surgical resection, and they tend to exhibit poor responsiveness to standard treatment methods.

The aggressive behavior of GBMs, coupled with their ability to infiltrate surrounding brain tissue, often makes complete surgical removal challenging. Additionally, the blood-brain barrier limits the effectiveness of systemic chemotherapy, and radiation therapy may only provide temporary relief.

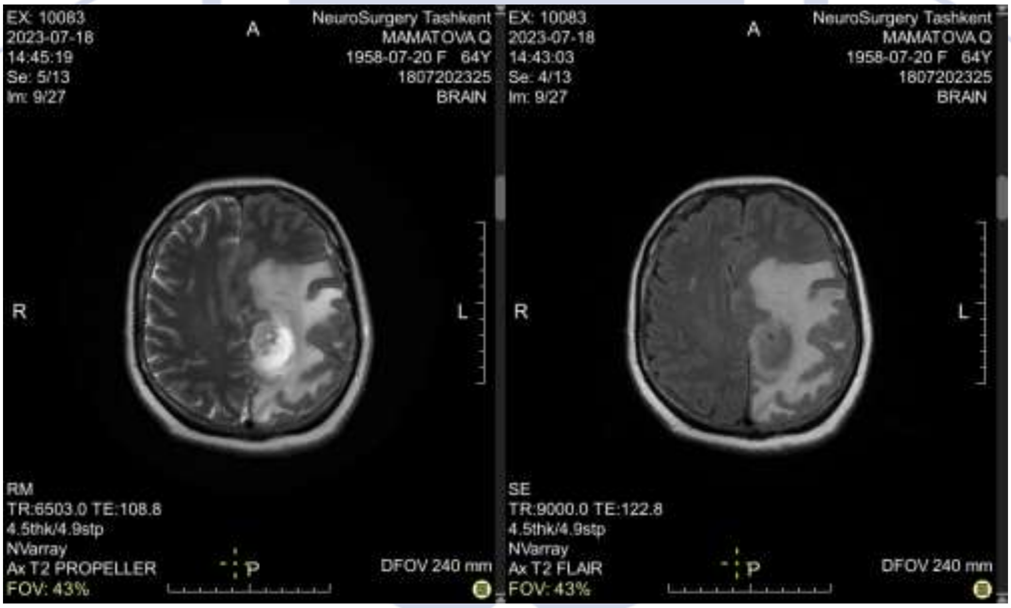
While researchers continue to explore novel treatment modalities and therapeutic targets, the management of GBMs remains a significant clinical challenge, highlighting the urgent need for innovative approaches to improve patient outcomes.

Despite significant advancements in modern micro-neurosurgery, chemotherapy, radiotherapy, and the development of molecularly targeted treatment methods, managing GBMs remains a complex task. These tumors often recur after surgical resection and typically respond poorly to standard treatment methods.

Research in the field of molecular biology and genetics of GBMs helps to understand the biological mechanisms and factors underlying their aggressive behavior. This could result in the emergence of novel treatment strategies, including molecularly targeted therapies directed at precise molecular targets within tumor cells.

However, despite these research efforts and the endeavors of specialists, the prognosis for patients with GBMs remains unfavorable, and further research and innovations in treatment continue to be critically important.

A clinical example of a patient with GBM is presented in Figure 2.



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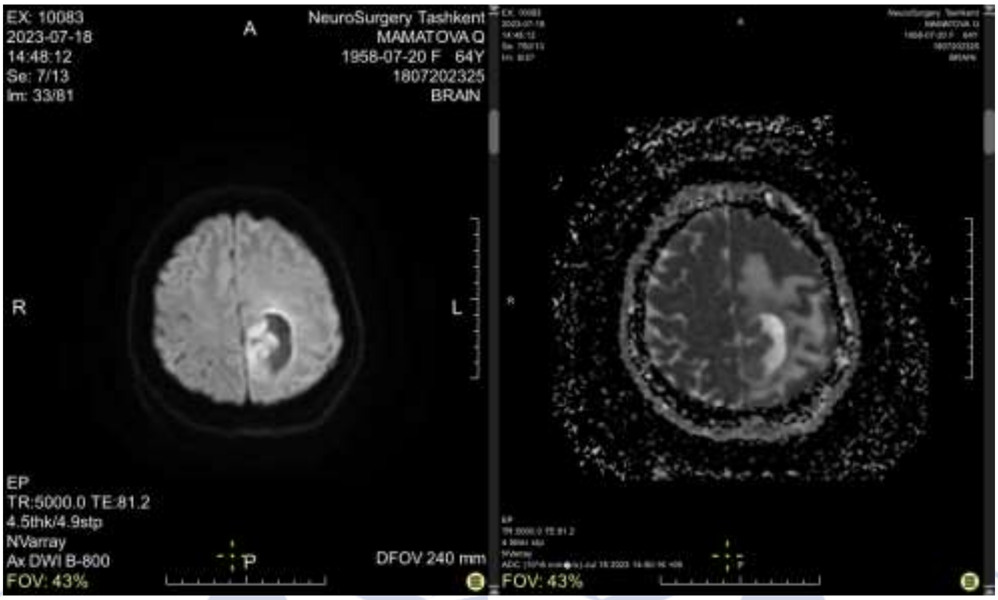

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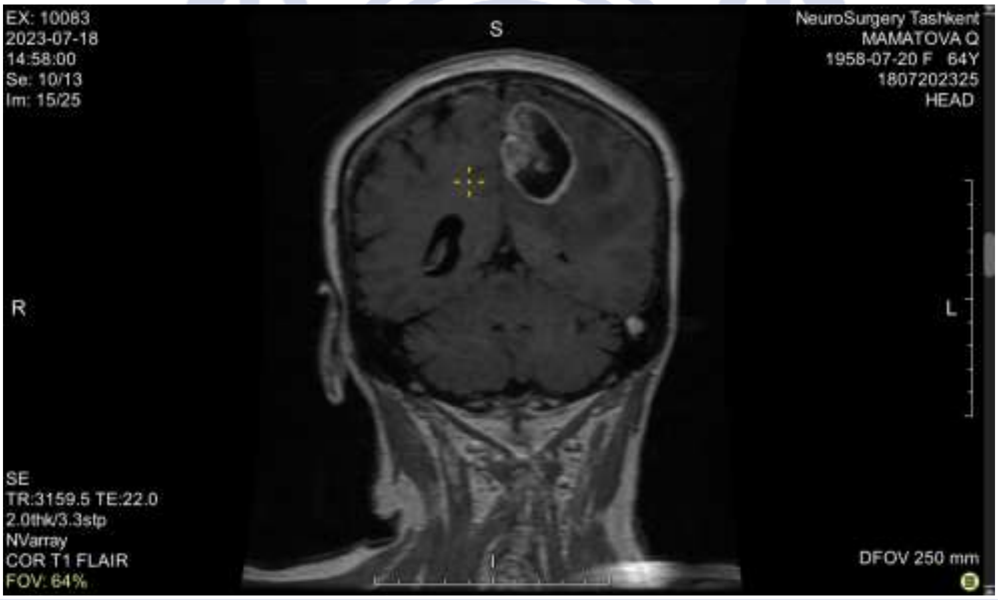

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Figure 2 illustrating MRI images of a glioblastoma in the left temporal lobe in a 21-year-old patient:

a) T2-weighted image

b) T2-FLAIR image

c) Diffusion-weighted image (DWI)

d) Apparent diffusion coefficient (ADC) map

e) T1-weighted image after contrast administration

An irregular shaped volumetric formation measuring 4.9x4.2x3.2 cm is visualized parasagittally in the left temporal region. It exhibits clear irregular contours and a heterogeneous cystic-solid structure, along with an extensive perifocal edema zone. Midline structures are displaced to the right. Restricted diffusion areas are observed on DWI. Following contrast administration of 10 ml of Magnevist (469 mg gadopentetate dimeglumine), intense contrast enhancement of the solid component and peripheral regions of the aforementioned formation is noted.

Maximizing tumor resection while minimizing harm to surrounding brain tissue is crucial for determining surgical outcomes in patients with high-grade gliomas (HGGs). This underscores the importance of advancing surgical techniques and tools to achieve optimal tumor removal, which remains a central focus in modern neuro-oncology.

Assessing the extent of tumor resection primarily relies on data from contrast-enhanced magnetic resonance imaging (MRI). Diffusion tensor imaging (DTI), conducted in specialized centers, is used additionally to exclude motor areas from the planned surgical volume. This helps surgeons accurately delineate tumor boundaries and minimize damage to functionally important brain regions during surgery.

Diffusion-weighted magnetic resonance imaging (DW-MRI) serves a pivotal role not only in distinguishing between lesions and evaluating their progression but also in forecasting the efficacy of surgical interventions. By offering insights into tissue microstructure, this technique assists surgeons in meticulously planning procedures and forecasting their results with greater precision.

Thus, the utilization of modern imaging modalities such as contrast-enhanced MRI and DW-MRI plays a decisive role in improving the outcomes of surgical treatment for patients with high-grade gliomas.

In our investigation, MRI data from 29 patients who underwent surgical treatment for brain meningiomas were analyzed. Among these patients, 10 were male and 16 were female, out of a total of 26 patients. The age of the patients varied from 18 to 70 years, with an average age of 53 ± 2.3 years.

Regarding the localization of meningiomas:

Parasagittal localization was observed in 13 patients.

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Convexital localization was observed in 15 patients.

Skull base was the site of localization in 1 patient.

Upon analysis of the malignancy grade of meningiomas, the following data were identified:

Grade I meningiomas (typical, MI) were found in 37.8% of patients.

Grade II meningiomas (atypical, MII) were found in 56.7% of patients.

Malignant forms of meningiomas (anaplastic, MIII) were verified in 5.5% of patients.

These data provide a more detailed understanding of the characteristics of brain meningiomas and their prevalence in the patient sample. Such analysis can be useful for determining optimal treatment strategies and predicting outcomes for patients with various forms and grades of meningiomas.

A clinical example of a patient with a meningioma is presented in Figure 3.

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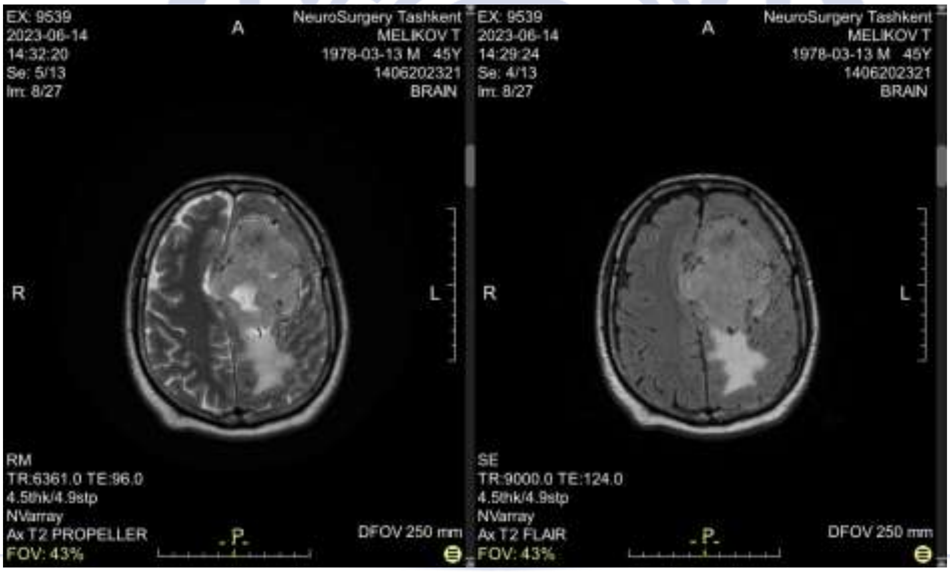

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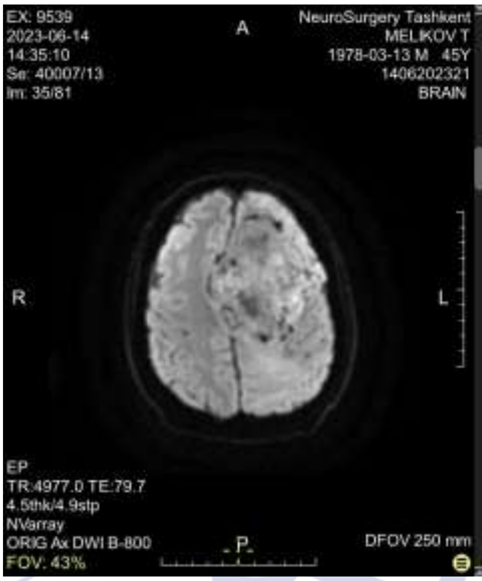

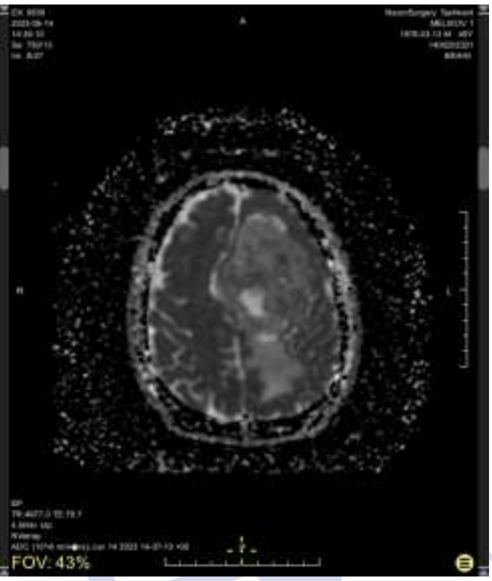

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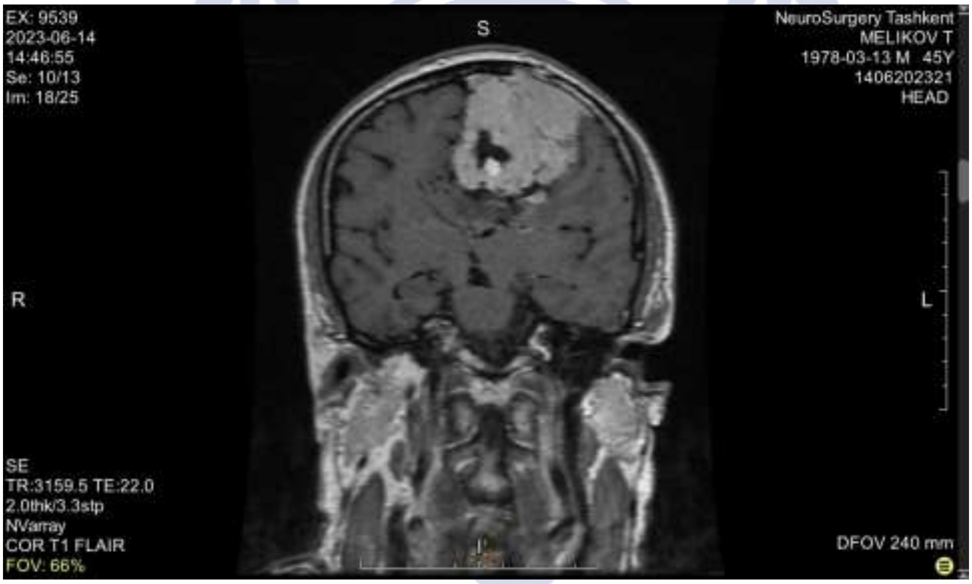

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Certainly, here is Figure 3 illustrating MRI images of a left frontal-temporal convexital meningioma in a 45-year-old patient:

a) T2-weighted image

b) T2-FLAIR image

c) Diffusion-weighted image (DWI)

d) Apparent diffusion coefficient (ADC) map

e) T1-weighted image after contrast administration

In the left frontal-temporal regions, adjacent and closely adherent to the meninges, an irregularly shaped extra-axial volumetric formation measuring 8.4x4.8x5.9 cm is visualized. It exhibits clear irregular contours, a heterogeneous solid structure, and weakly hyperintense signal characteristics on T2 and FLAIR, with isointense signal characteristics on T1, compressing adjacent brain structures, accompanied by a perifocal edema zone. Multiple pathological tortuous vessels of varying calibers are visualized caudally and peritumorally. Following intravenous administration of 10 ml of Magnevist (469 mg gadopentetate dimeglumine), intense contrast enhancement of the aforementioned formation is noted.

Comparatively favorable prognosis for benign meningiomas stands in stark contrast with the more aggressive nature of atypical meningiomas, which progress more rapidly. This distinction between different types of meningiomas is crucial information for surgeons, as treatment planning and prognosis will depend on the pathological type of the tumor.

The standard treatment method for benign meningiomas is their complete surgical removal. However, with atypical meningiomas, despite radical surgery including subsequent radiotherapy, local recurrences are often observed, and the optimal approach to treating atypical meningiomas remains undetermined.

Our study involved MRI scans with diffusion-weighted imaging (DWI) from 5 patients who underwent surgery for solitary brain metastases. Among these patients, there were 2 females and 3 males, with ages ranging from 29 to 74 years (mean age 54.7 ± 11.3 years). The histological types of tumors are detailed in Table 4.

The histological types of tumors, as presented in Table 4 of our study, are crucial data points, as the histological type of metastasis can significantly impact treatment decisions and prognosis for patients. For instance, certain types of metastases may exhibit varying sensitivities to specific treatment modalities, such as chemotherapy or radiotherapy.

Table 4 - Histological Types of Brain Metastases

Histological Types	Number of cases, n	Source of metastasis
Small cell cancer	3	lungs
Tubular adenocarcinoma	1	breast
Stromal sarcoma	1	ovaries

Conclusion

Indeed, the study results underscore the importance of using magnetic resonance imaging (MRI) in differentiating benign and malignant brain tumors. MRI, as a modern and powerful diagnostic method, plays a key role in oncology by providing specialists with detailed information about the structural characteristics of tumors.

With its high spatial resolution and the ability to obtain images in various planes, MRI enables more precise determination of tumor size and extent, as well as the identification of characteristics that may be important in choosing a treatment strategy.

Furthermore, MRI allows for obtaining information about the textural and functional features of the tumor, such as the proliferation of vascular structures, the presence of necrosis, or areas of high vascularity. This data can be crucial in making decisions about surgical intervention, radiotherapy, or chemotherapy.

Thus, the use of MRI in oncological practice is an indispensable tool, providing specialists with all the necessary information for optimal management of patients with brain tumors.

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