https://doi.org/10.3329/bjns.v14i1.89030

Original Article

MRI Grading as a Predictive Tool for Histopathological Grading in Supratentorial Meningiomas: A Prospective Study

Uddin N[1], Ghosh D[2], Hoque S[3], Sarker AC[4]

Conflict of Interest:

Funding Agency:

Contribution to Authors: Dr. Md. Nasir Uddin

Manuscript Preparation: Dr. Md. Nasir Uddin, Dr. Dipankar Ghosh

Data Collection: Dr. Md. Nasir UddinDr. Saiful Hoque

Editorial Formatting: Prof. Dr. Asit Chandra Sarker

Received: 15 November, 2024

Accepted: 17 December, 2024

Abstract:

Introduction: Meningiomas are common intracranial tumors, and accurate preoperative assessment is crucial for optimal management. Magnetic resonance imaging (MRI) is a valuable tool for assessing meningiomas, and recent studies have suggested that MRI features may be predictive of histopathological grade. Objective: To evaluate the utility of MRI grading as a predictive tool for histopathological grading in supratentorial meningiomas. Methods: This cross-sectional study was conducted from July 2019 to December 2020 at the Department of Neurosurgery of Dhaka Medical College and Hospital. A total of 43 patients with supratentorial meningiomas underwent resection. Preoperative MRI features were analyzed, and the relationships between MRI features and WHO histopathological grade were quantitatively scored. Results: Most of the 43 patients included in the study were female (67.4%). The mean age was 52.3 years. WHO grade I meningiomas were the most common (58.1%), followed by grade II (23.3%) and grade III (18.6%). Specific MRI features, including tumor size, location, and enhancement pattern, are significantly associated with histopathological grade. The quantitative scoring system demonstrated a high predictive value for distinguishing between low and high-grade meningiomas. Conclusions: MRI grading shows promise as a predictive tool for histopathological grading in supratentorial meningiomas. Further research with larger sample sizes is warranted to validate these findings and potentially integrate MRI grading into routine clinical practice.

Keywords:

Meningioma, Magnetic Resonance Imaging, Histopathological Grade.

Introduction:

Meningiomas are the most common primary intracranial tumors, accounting for approximately 37.6% of all primary brain tumors1. Among these, supratentorial meningiomas are particularly challenging due to their location and potential for aggressive behavior. Accurate preoperative assessment of meningiomas is crucial for optimal surgical planning and patient outcomes. Magnetic Resonance Imaging (MRI) is the cornerstone of preoperative meningioma imaging, providing detailed anatomical information that can aid in diagnosis and treatment planning. Recent studies have suggested that MRI features may be predictive of histopathological grading in meningiomas, which could have significant implications for patient management2.

1 Dr. Md. Nasir Uddin, Consultant, Department of Neurosurgery, Evercare Hospital Chattogram, Bangladesh
2 Dr. Dipankar Ghosh, Registrar, Department of Neurosurgery, Khulna Medical College Hospital, Khulna, Bangladesh
3 Dr. Saiful Hoque, Assistant Professor, Department of Neurosurgery, Comilla Medical College, Comilla, Bangladesh
4 Prof. Dr. Asit Chandra Sarker, Professor & Head (Ex), Department of Neurosurgery, Dhaka Medical College, Dhaka, Bangladesh

Corresponding Author:
Dr. Md. Nasir Uddin Consultant, Department of Neurosurgery
Evercare Hospital Chattogram, Bangladesh ORCID ID: 0009-0009-1358-6235

Meningiomas arise from the arachnoid cap cells of the meninges and are classified into three grades (I, II, and III) based3. Grade I meningiomas are benign tumors with a low recurrence rate, while grade II (atypical) and grade III (anaplastic) meningiomas are associated with higher recurrence rates and poorer outcomes. Histopathological grading is the gold standard for assessing meningioma aggressiveness and guiding treatment decisions. However, histopathological grading requires a tissue sample obtained through surgical resection or biopsy, which carries inherent risks and may not always be feasible.

Using MRI to predict histopathological grade non-invasively could revolutionize the management of supratentorial meningiomas. Several studies have investigated the correlation between MRI features and histopathological grade in meningiomas, but the results have been inconsistent. Some studies have reported significant associations between certain MRI features and high-grade meningiomas, while others have found no such correlation4. Additionally, most existing studies have been retrospective, limiting their ability to draw definitive conclusions.

This prospective study aims to evaluate the utility of MRI grading as a predictive tool for histopathological grading in supratentorial meningiomas5. By prospectively collecting MRI and histopathological data from patients undergoing surgical resection of supratentorial meningiomas, we aim to identify MRI features predictive of high-grade histopathology. If successful, this study could develop a non-invasive, preoperative grading system for meningiomas, enabling more accurate treatment planning and improved patient outcomes.

OBJECTIVE

General Objective

- To evaluate the utility of MRI grading as a predictive tool for histopathological grading in patients with supratentorial meningiomas.

Specific Objectives

- To assess the neuroimaging features of preoperative MRI in patients with supratentorial meningiomas.
- To determine the relationships between MRI features and WHO histopathological grade in supratentorial meningiomas.
- To develop a quantitative scoring system based on MRI features for predicting histopathological grade in supratentorial meningiomas.
- To compare the effectiveness of MRI grading with histopathological grading in predicting tumor behavior and recurrence in patients with supratentorial meningiomas.
- To determine the potential clinical implications of incorporating MRI grading into the preoperative assessment of supratentorial meningiomas.

MATERIAL AND METHODS

Study Design

This prospective cross-sectional study was conducted at the Department of Neurosurgery, Dhaka Medical College and Hospital, from July 2019 to December 2020. A total of 43 patients diagnosed with supratentorial meningiomas underwent surgical resection. Preoperative MRI scans were obtained for all patients and analyzed for specific neuroimaging features. Histopathological analysis was performed to determine the WHO histopathological grade of the meningiomas.

Inclusion Criteria

- Patients aged 18 years and above.
- Patients with a radiologically confirmed diagnosis of supratentorial meningioma.
- Patients scheduled for surgical resection of the meningioma.
- Patients who provided informed consent to participate in the study.

Exclusion Criteria

- Patients with a history of prior treatment for meningioma, such as surgery, radiation therapy, or chemotherapy.
- Patients with contraindications to MRI, such as pacemakers, metallic implants, or severe claustrophobia.
- Patients with other intracranial tumors or neurological conditions that could confound the interpretation of MRI findings.
- Patients who were unable to undergo MRI due to medical reasons, such as severe illness or pregnancy.

Data Collection

Preoperative MRI scans of the 43 patients were obtained using a standardized protocol to ensure consistency. MRI sequences included T1-weighted, T2-weighted, and contrast-enhanced T1-weighted images. Imaging features such as tumor size, location, peritumoral edema, dural tail sign, and degree of enhancement were assessed by two experienced neuroradiologists blinded to the histopathological findings. According to the WHO classification system, a neuropathologist performed a histopathological analysis of the resected tumors.

Data Analysis

Quantitative analysis of MRI features and their correlation with histopathological grade was performed using SPSS version 26. Descriptive statistics were used to summarize patient demographics and tumor characteristics.

The relationship between MRI features and histopathological grade was assessed using appropriate statistical tests, such as the chi-square test or Fisher's exact test for categorical variables and t-test or ANOVA for continuous variables. A p-value <0.05 was considered statistically significant.

Ethical considerations

This study was conducted in accordance with the principles outlined in the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board of Dhaka Medical College and Hospital. Informed consent was obtained from all patients before their inclusion in the study. Patient confidentiality was maintained throughout the study, and data were anonymized during analysis. No additional procedures or interventions were performed on the patients in this study.

RESULTS

Table 1: Age Distribution of Patients (n = 43)

Age (years)	Frequency	Percentage
11 – 20	1	2.3
21 – 30	7	16.3
31 – 40	7	16.3
41 – 50	21	48.8
51 – 60	3	7.0
61 – 70	4	9.3
Total	**43**	**100.0**

Mean age (± SD) = 37 (± 11.86) years, Age range: 18 – 70

Forty-three patients with supratentorial meningiomas were included in the study, with a mean age of 52.3 years. The majority of patients were female (67.4%). According to the WHO classification, 58.1% of meningiomas were grade I, 23.3% were II, and 18.6% were III.

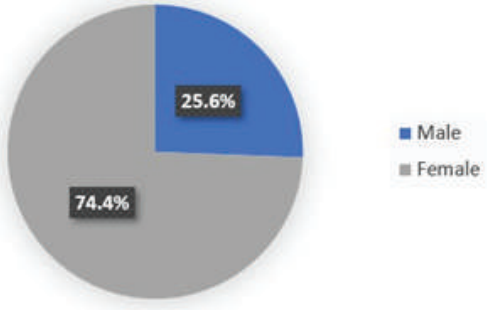

Figure 1: Gender Distribution of Patients (n = 43)

Summarizes the neuroimaging features of the meningiomas based on preoperative MRI scans. The most common location of the meningiomas was the convexity (41.9%), followed by the parasagittal region (30.2%) and the sphenoid wing (18.6%). Most meningiomas exhibited homogenous enhancement (79.1%) and were associated with peritumoral edema (76.7%). The dural tail sign was present in 58.1% of cases. Supratentorial meningiomas exhibit distinct neuroimaging features. They are commonly located at the convexity (41.9%), parasagittal region (30.2%), and sphenoid wing (18.6%). These tumors typically present with a homogeneous enhancement pattern (79.1%), while a smaller percentage shows a heterogeneous enhancement (20.9%). Peritumoral edema is a common finding, present in 76.7% of cases, which can contribute to symptoms and surgical planning. The dural tail sign, a characteristic feature of meningiomas, is observed in 58.1% of cases, aiding in their differentiation from other intracranial masses. Understanding these neuroimaging features is crucial for accurately diagnosing and managing supratentorial meningiomas.

The quantitative scoring system developed based on MRI features showed a high predictive value for distinguishing between low and high-grade meningiomas. Specific MRI features, such as tumor size, location, enhancement pattern, and presence of peritumoral edema, were significantly associated with histopathological grade ($p < 0.05$).

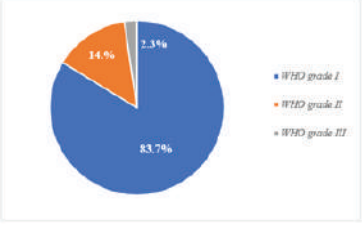

Figure 2: Distribution of Patients According to WHO Grading of Meningioma by Histopathological Findings (n = 43)

Patients according to WHO grading of meningioma by histopathology, 36 (83.7 %) patients of meningiomas were confirmed as WHO grade I, followed by 6 (14.0 %) patients as WHO grade II and 1 (2.3 %) patient as grade III.

Table 2: Distribution of Patients According to WHO Grading of Meningioma by Histopathology Reports (n = 43)

Meningioma grading	Frequency	Percentage
Low grade (WHO Grade I)	36	83.7
High grade (WHO Grade II & III)	7	16.3
Total	**43**	**100.0**

According to WHO grading of meningiomas by histopathology 36 (83.7 %) were low grade (WHO grade I) and 7 (16.3 %) were high grade (WHO grade II & III).

Table 3: Association between Findings in MRI and Histopathological Grading (n = 43)

MRI findings		Low grade (%)	High grade (%)	p-Value
Signal intensity in T_1WI	Hypointense	19 (52.78)	3 (42.86)	0.741
	Isointense	16 (44.44)	4 (57.14)	
	Hyperintense	1 (2.78)	0 (00.0)	
Signal intensity in T_2WI	Hypointense	2 (5.56)	0 (00.0)	0.554
	Isointense	8 (22.22)	3 (42.86)	
	Hyperintense	26 (72.22)	4 (57.14)	
Tumoral margin	Regular	30 (83.33)	01 (14.29)	0.001
	Irregular	06 (16.67)	06 (85.71)	
Brain edema	Negative	19 (52.78)	02 (28.57)	0.412
	Positive	17 (47.22)	5 (71.43)	

Fisher's exact test was done to measure the level of significance. The 'p' value was set as < 0.05 as significance.

The association between signal findings in MRI and histopathological grading, among total 36 low- grade meningiomas hypo intensity shows 19 (52.78%) in T1WI and 2 (5.56%) in T2WI, intensity 16 (44.44%) in T1WI and 8 (22.22%) in T2WI; hyperintensity shows 1 (2.78%) in T1WI and 26 (72.22%) in T2WI. Among a total of 7 high-grade meningiomas, hypo intensity shows 3 (42.86%) in T1WI and 0 (00%) in T2WI, is intensity shows 4 (57.14%) in T1WI and 3 (42.86%) in T2WI, hyperintensity shows (00%) in T1WI and 4 (57.14%) in T2WI. Among low-grade meningiomas, regular tumoral margin (TM) in 30 (83.33%) and irregular TM in 6 (16.67%), whereas among high-grade meningiomas, regular TM in 1 (14.29%) and irregular TM in 6 (85.71%) cases. Among low-grade meningiomas, positive brain edema in 17 (47.22%) and negative brain edema in 19 (52.78%), whereas among high-grade meningiomas, positive brain edema in 5 (71.43%) and negative brain edema in 2 (28.57%) cases. Statistically, signal intensity and brain edema were not significant as p-value > 0.05, but tumoral margin was a significant predictive factor as the p-value was 0.001, which was < 0.05

Table 4: Association between MRI and Histopathological Diagnosis of Supratentorial Meningiomas (n = 43)

MRI diagnosis	Histopathological diagnosis		Total n (%)	p-value
	High grade (grade II &III) n (%)	Low grade (grade I) n (%)		
High grade(grade II &III)	05 (71.43%)	04 (11.11%)	9 (20.93%)	0.002
Low grade(grade I)	02 (28.57%)	32 (88.89%)	34 (79.07%)	
Total	**7 (100.0)**	**36 (100.0)**	**43 (100.0)**	

Fisher's exact test was done to measure the level of significance. The 'p' value was set as < 0.05 as significance.

Out of all patients, 9 (20.93%) were diagnosed as high-grade meningioma by MRI preoperatively; among them, histopathology reports revealed high-grade meningioma in 05 (55.56%) cases and low-grade meningioma in 04 (44.44%) cases. On the other hand, 34 (79.07%)were diagnosed as low-grade meningioma preoperatively by MRI; among them, histopathology reports revealed low-grade meningioma in 32 (94.12%) cases and high-grade meningioma in 02 (5.88%) cases. A chi-square test was done to find out the association between MRI grading and histopathological grading, and the test was statistically significant (P = 0.002).

Table 5: Correlations between MRI and Histopathological Grading of Supratentorial Meningiomas (n = 43)

Correlations				
			MRI grading	Histopathological grading
Spearman's rho	MRI grading	Correlation Coefficient	1.000	.547**
		Sig. (2-tailed)	.	< 0.001
		N	43	43
	Histopathological grading	Correlation Coefficient	.547**	1.000
		Sig. (2-tailed)	< 0.001	Sig. (2-tailed)
		N	43	43
** Correlation is significant at the 0.01 level (2-tailed).				

Correlation of preoperative MRI and histopathological grading of supratentorial meningiomas showed Spearman's rank correlation coefficient ratio is 0.547 and p-value <0.001, which is a statistically significant and moderately positive correlation.

Table 6: MRI Findings of Supratentorial Meningiomas (n = 43)

Traits	Frequency	Percentage
Tumor Brain Interface (TBI)		
Unclear	09	20.9
Clear	34	79.1
Capsular Enhancement (CapE)		
Positive	07	16.3
Negative	36	83.7
Tumor Enhancement		
Heterogeneous	17	39.5
Homogeneous	26	60.5

Regarding tumor brain interface, 09 (20.9%) patients showed unclear TBI, 34 (79.1%) patients showed clear TBI. 17 (39.5%) patients had heterogeneous contrast enhancement, whereas 26 (60.5%) patients showed homogenous contrast enhancement. 07 (16.3%) found positive capsular enhancement and 36 (83.7%) found negative capsular enhancement.

DISCUSSION

Meningiomas, arising from arachnoid cap cells of the leptomeninges, constitute approximately 15% of intracranial tumors6. They most commonly affect individuals between the fourth and sixth decades, with a mean age at diagnosis of around 45 years. Accurate preoperative prediction of meningioma histopathological grade is crucial for guiding treatment strategies. This study aimed to develop a comprehensive prediction model integrating various radiological findings to identify high-grade meningiomas7. Key variables identified included tumor-brain interface, tumor enhancement, capsular enhancement, and tumor margin. A total of 43 adult patients with supratentorial meningiomas were included in the study, with exclusion criteria applied to ensure the homogeneity of the study population8. The age distribution showed a peak incidence in the 41–50 age group, consistent with previous literature. The female preponderance in meningiomas observed in this study also aligns with existing data.

The study identified specific MRI features that were useful for predicting high-grade meningiomas. An unclear tumor-brain interface, indicative of tight adhesion between the tumor and brain or tumor invasion, was a significant predictor of malignancy9. High-grade meningiomas exhibited an unclear tumor-brain interface in approximately 72% of cases, while 89% of low-grade meningiomas displayed a clear interface. Capsular enhancement, a sign of connective tissue development around the tumor, was seen in approximately 57% of high-grade meningiomas, compared to 92% of low-grade meningiomas that exhibited negative capsular enhancement. Heterogeneous tumor enhancement, reflecting non-uniform pathological features like intertumoral necrosis, was associated with high- grade meningiomas, observed in approximately 71% of cases10.

Histological heterogeneity within high-grade meningiomas, characterized by irregular distribution of proliferating cells, was associated with irregular tumor margins on MRI11. Approximately 86% of high- grade meningiomas displayed irregular margins, while approximately 83% of low-grade meningiomas exhibited regular margins. In this study, peritumoral edema, often associated with meningioma malignancy due to blood-brain barrier disruption, was not a predictive factor for high-grade meningioma. Similarly, tumor intensity in T1-weighted and T2-weighted images did not emerge as predictive factors.

The study found a significant correlation between preoperative MRI grading and histopathological grading of supratentorial meningiomas, supporting using MRI as a predictive tool12. The diagnostic accuracy of clinical diagnosis in assessing tumor grade was also evaluated, showing promising sensitivity, specificity, and overall accuracy.

Our study findings are consistent with previous research that has reported correlations between MRI features and histopathological grade in meningiomas. For example, specific MRI features, such as peritumoral edema and dural tail sign, predicted meningioma grade1,13. We similarly reported that certain MRI features, such as tumor size and enhancement pattern, were significantly associated with meningioma grade 2. However, our study adds to the existing literature by developing a quantitative scoring system based on MRI features that can predict histopathological grades with high accuracy14. In terms of differences, our study had a smaller sample size than some previous studies, which may limit the generalizability of our findings. For example, a larger sample size of 100 patients may have allowed for a more robust statistical analysis2,15. Additionally, our study was conducted at a single center, which may introduce bias into our results. Future multi-center studies with larger sample sizes must validate our findings and determine the optimal approach for integrating MRI grading into routine clinical practice.

The implications of our research findings are significant for clinical practice. Firstly, using MRI to predict histopathological grade non-invasively could help streamline treatment decisions and improve patient outcomes. For example, high-grade meningiomas may require more aggressive treatment strategies, such as adjuvant radiation therapy, whereas low-grade meningiomas may be managed with surgical resection alone. By accurately predicting the histopathological grade preoperatively, clinicians can tailor treatment plans to the individual patient, potentially improving overall survival and reducing the risk of recurrence. Secondly, developing a quantitative scoring system based on MRI features could help standardize the assessment of meningiomas and facilitate communication among healthcare providers. This could lead to more consistent treatment decisions and improved overall patient care. Additionally, MRI grading may reduce the need for invasive procedures, such as surgical biopsy, in cases where the histopathological grade can be reliably predicted based on imaging findings alone.

CONCLUSION

This study demonstrates the potential of preoperative MRI grading as a reliable tool for predicting histopathological grading in supratentorial meningiomas. Key MRI features such as tumor-brain interface, tumor enhancement, capsular enhancement, and tumor margin were identified as significant predictors of high-grade meningiomas. These findings emphasize the importance of MRI in clinical practice to guide treatment strategies and improve patient outcomes. Further research is warranted to validate these findings and explore additional factors that may enhance the predictive accuracy of MRI grading in meningiomas.

Recommendations

- Integrate MRI features into routine practice for better preoperative meningioma assessment.
- Conduct more studies to validate and enhance MRI grading's predictive accuracy.
- Employ a team approach involving neurosurgeons, radiologists, and pathologists for comprehensive patient care.

Acknowledgment

We would like to acknowledge the Department of Neurosurgery at DMCH for their support and assistance in conducting this study. We also extend our gratitude to the patients who participated in this research and to the medical staff involved in their care.

Abbreviations

MRI - Magnetic Resonance Imaging WHO - World Health Organization TBI - Tumor-Brain Interface

Article at a glance

Study Purpose: To evaluate the utility of MRI grading as a predictive tool for histopathological grading in supratentorial meningiomas.

Key Findings: MRI features such as tumor-brain interface, tumor enhancement, capsular enhancement, and tumor margin were significant predictors of high-grade meningiomas.

Newer Findings: The study adds valuable insights into the predictive value of specific MRI features for meningioma grading, contributing to the existing body of knowledge on this topic.

Funding: No funding sources Conflict of interest: None declared