SAS Journal of Surgery
Abbreviated Key Title: SAS J Surg
ISSN 2454-5104
Journal homepage: https://www.saspublishers.com

OPEN ACCESS

Neurosurgery

Correlation between Magnetic Resonance Imaging (MRI) Grading with Histopathological Grading of Supratentorial Meningiomas

Dr. Md. Nasir Uddin[1*], Dr. Dipankar Ghosh[2], Dr. Saiful Hoque[3], Prof. Dr. Asit Chandra Sarker[4]

[1]Assistant Professor, Department of Neurosurgery, Bangladesh Institute of Health Science (BIHS) General Hospital, Dhaka, Bangladesh
[2]Registrar, Department of Neurosurgery, Khulna Medical College Hospital, Khulna, Bangladesh
[3]Assistant Professor, Department of Neurosurgery, Comilla Medical College, Comilla, Bangladesh
[4]Professor & Head (Ex), Department of Neurosurgery, Dhaka Medical College, Dhaka, Bangladesh

DOI: 10.36347/sasjs.2023.v09i11.009 | **Received:** 24.09.2023 | **Accepted:** 28.10.2023 | **Published:** 15.11.2023

***Corresponding author:** Dr. Md. Nasir Uddin
Assistant Professor, Department of Neurosurgery, Bangladesh Institute of Health Science (BIHS) General Hospital, Dhaka, Bangladesh

Abstract **Original Research Article**

Background: Meningiomas, common intracranial tumors originating from meningeal cells, critically impact patient outcomes. Their histologic grade influences recurrence risk and treatment decisions, including radiation therapy. Identifying advanced-grade meningiomas via pre-operative MRI is vital for surgical planning, reducing complications, and guiding adjuvant therapies. ***Objective:*** To investigate the correlation between pre-operative MRI features and histopathological grade 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 and were analyzed in terms of neuroimaging features of pre-operative MRI. The relationships between MRI features and WHO histopathological grade were analyzed and scored quantitatively. ***Results:*** The mean age of the study population was 37±11.86 (SD) years. Male female ratio was 1:2.7. Main clinical presentation was headache (90.7%). The most common location was convexity meningioma (37.2%). Out of all patients, high, grade and low-grade meningioma were diagnosed by MRI, 9 (20.93%) and 34 (79.09%), respectively; on the other hand, high, grade and low-grade meningiomas diagnosed by histopathology 7 (16.3%) and 36 (83.7%) respectively. A positive correlation was found between MRI grading and histopathological grading of supratentorial meningiomas and statistical significance (Spearman rho-0.547, p-value <0.001). A significant association was also observed between MRI grading and histopathological grading of supratentorial meningiomas (p-value 0.002). Unclear tumor brain interface, capsular enhancement, and irregular tumor margin in the MRI were identified factors in predicting advanced histopathological grade of meningiomas as p-values 0.002, 0.008, and 0.001, respectively. ***Conclusion:*** This scoring approach may be useful for neurosurgeons in determining therapeutic strategy, surgical planning, and patient counseling preoperatively.
Keywords: Meningiomas, Histopathological grading, MRI, Surgical planning, Adjuvant therapy.

INTRODUCTION

Meningiomas, tumors originating from the meningeal (dural) coverings of the brain, were first described by Harvey Cushing in 1922. These tumors arise from arachnoidal cap cells, specifically meningothelial cells within the arachnoidal membrane [1]. They represent a significant proportion of primary intracranial tumors, with approximately 90% being located intracranially; of those, 90% are supratentorial [2]. Age and gender differences are notable in the epidemiology of meningiomas. They typically manifest in individuals between their fourth and sixth decades of life, with an average age of diagnosis around 45 years. Additionally, there is a clear gender disparity, with females being affected more frequently than males, at a ratio of 2:1.

Interestingly, the gender difference in incidence varies with age. Among patients under 20 years of age, meningiomas are more common in males, whereas there is a female predominance in patients over 20 years of age. Although meningiomas are relatively rare in children and young adults, they constitute a notable portion of intracranial tumors, accounting for 1-3% of cases in those under 20 years and 13.5% in the 20-34 age group, although still lower compared to the incidence in individuals over 40 years of age [3]. Meningiomas typically exhibit slow growth and have an insidious onset of symptoms. Many are incidentally discovered during brain imaging. The clinical presentation of meningiomas is diverse, lacking pathognomonic features. Symptoms often result from increased intracranial pressure and mass effect, encompassing headaches, focal neurological deficits (including cranial nerve involvement), and partial seizures.

In some cases, personality changes, confusion, and altered consciousness levels may occur, particularly with anterior or parasagittal meningiomas, occasionally mimicking conditions like dementia or depression [4]. The majority of meningiomas exhibit slow growth and are asymptomatic or minimally symptomatic, making them frequently incidental findings on neuroimaging. The World Health Organization (WHO) classification system categorizes meningiomas into three histological grades and fifteen subtypes, offering a valuable tool for prognosis prediction [5]. Over time, patients may experience subtle neurological decline, including speech difficulties, concentration issues, and limb weakness, affecting activities such as writing and walking [6]. Medical imaging plays a pivotal role in diagnosing and planning the treatment of CNS (central nervous system) neoplasms, with magnetic resonance imaging (MRI) being a crucial tool for neurosurgeons managing intracranial meningiomas. Identifying meningiomas with advanced histopathological grades through pre-operative MRI is of paramount importance. Specific MRI features have been identified as associated with high proliferative potential and aggressive biological behavior [7]. MRI allows for improved delineation of dura and sinus involvement and provides insights into a tumor's consistency [8].

Consequently, MRI has largely replaced computed tomography (CT) for visualizing meningiomas' location and soft tissue characteristics [9]. The MRI accuracy of meningioma diagnosis is estimated to be approximately 95%. Meningiomas are classified based on their signal intensity relative to cortical gray matter on T1- and T2-weighted images and their contrast enhancement patterns following Gadolinium-DTPA administration [10].

Moreover, WHO has classified meningiomas into three grades, with grade I representing slow-growing, well- circumscribed tumors with benign histopathological features and grades II and III indicating more aggressive behavior and clinical recurrence [7]. The primary treatment approach for symptomatic meningiomas involves maximal surgical resection, sometimes supplemented with adjuvant radiation therapy, depending on the histological grading. While the majority of meningiomas fall into the WHO grade I category, atypical (grade II, 5-7%) and anaplastic (grade III, 1-2%) meningiomas, though less common, tend to behave more aggressively and have a higher risk of recurrence even after gross total resection. As a result, adjuvant radiation therapy has been employed for atypical and anaplastic meningiomas, leading to improved outcomes compared to surgery alone [11]. The mechanical and histological properties of meningiomas play a crucial role in patient management and risk assessment. Non-invasive techniques that enable pre-operative assessment of these properties could enhance surgical planning and dura substitution strategies for advanced meningiomas [12].

Furthermore, advanced MRI techniques have contributed to the improved prediction of malignancy in meningiomas, providing a more accurate assessment of these tumors [13]. In the study, meningiomas are a significant subset of intracranial tumors with distinct epidemiological and clinical characteristics. The role of MRI in diagnosing and managing these tumors is paramount, particularly in identifying advanced histopathological grades and guiding treatment decisions. Understanding the specific MRI features associated with meningiomas and their grading is essential for optimizing patient care and surgical outcomes.

OBJECTIVES

General Objective

- To identify the correlation between Magnetic Resonance Imaging (MRI) grading with histopathological grading of supratentorial meningiomas.

Specific Objectives

- To assess the imaging (MRI) nature of the meningiomas before surgery.
- To evaluate the MRI grading of meningioma preoperatively
- To evaluate the histopathological grading of supratentorial meningioma after surgery
- To correlate the MRI grading with histopathological grading of supratenorial meningiomas

MATERIALS AND METHODS

Study Design

This cross-sectional study included 43 patients and was conducted at the Department of Neurosurgery, Dhaka Medical College and Hospital (DMCH), Dhaka, Bangladesh, from July 2019 to December 2020.

Inclusion Criteria

- Diagnosed with supratentorial meningioma via MRI with contrast before surgery.
- Age ≥ 18 years.
- Admitted to the neurosurgery department at DMCH for surgical intervention.
- Confirmed as meningioma cases through post-operative histopathological reports.
- Willing to provide informed consent.

Exclusion Criteria

- Diagnosed with lesions other than supratentorial meningioma via MRI with contrast before surgery.
- Age less than 18 years.
- Refused surgery.
- Histopathology reports are not consistent with meningioma.
- Refused to provide consent to participate in the study.

Data Collection

Data collection occurred at DMCH's Neurosurgery Department during the study period. Eligible patients diagnosed with supratentorial meningioma through pre-operative MRI with contrast were included. Informed consent was sought from patients or their legal guardians, with a comprehensive explanation of the study's objectives. Detailed medical histories were recorded, followed by general and neurological examinations. Meningioma diagnoses via MRI relied on criteria including lesion morphology, signal intensity, and contrast enhancement patterns. Tumor characteristics were categorized, and pre-operative MRI grading followed criteria outlined by [7], with specific attention to age, tumor-brain interface, tumor enhancement, and capsular enhancement, each criterion receiving a weighting of 1 or 0.

Data Analysis

Data were processed and analyzed using SPSS (Statistical Package for the Social Sciences) version 25. Descriptive statistics were used to present categorical data as frequencies and percentages, while continuous data were summarized as mean and standard deviation (SD). The pre-operative MRI grading was compared with post-operative histopathological grading using statistical tests such as the Chi-square test, Fisher's exact test, and Spearman's rank correlation coefficient test. A significance level of 'p' value < 0.05 was considered statistically significant.

Ethical Consideration

This study adhered to ethical guidelines and obtained ethical clearance from the Ethical Review Committee (ERC) of DMCH. It ensured minimal physical, psychological, social, and legal risks during data collection. Patient confidentiality and data privacy were strictly maintained, with only the researcher accessing the collected data. Informed written consent was obtained from all participants or their legal guardians, and participants were fully informed about the study's design and their right to withdraw at any time, as per the Helsinki Declaration for Medical Research Involving Human Subjects (1964). Proper safety measures were implemented throughout the study.

RESULTS

The age of the patients was distributed in 6 categories. The highest 21 (48.8%) patients were between 41 - 50 years. The second highest 7 (16.3%) patients were between 21 – 30 and 31 – 40 years in each group followed by 4 (9.3%) patients from 61 – 70 years, 3 (7.0%) patients from 51 – 60 years, and the lowest 01 (2.3%) patient came from 11 -20 years. The mean age of the patients was 37 (± 11.86) years (Table 1).

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

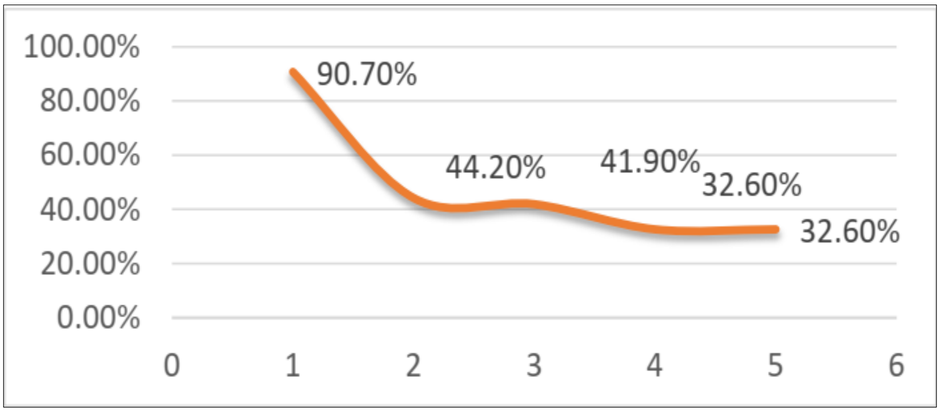

Figure 1: Distribution of Patients by Clinical Presentations (n = 43)

The main clinical presentations of the patients were headache in 39 (90.7%) followed by vomiting in 19 (44.2%), visual disturbance in 18 (41.9%), convulsion in 14 (32.6%) and weakness of limbs in 14 (32.6%). (Figure 1).

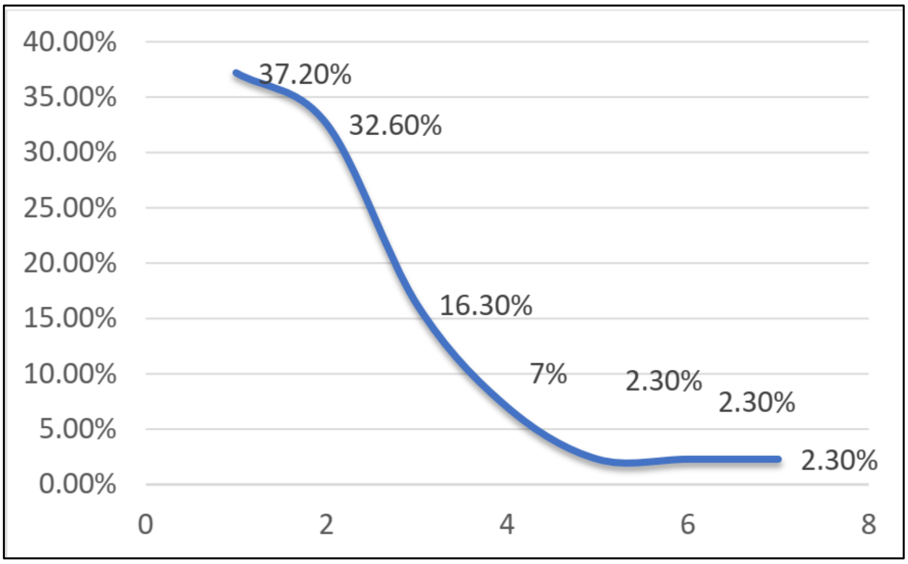

Figure 2: Distribution of Patients According to Anatomical Location (n = 43)

The most common location was convexity meningioma in 16 (37.2%), followed by sphenoidal wing in 14 (32.6%) and parasagital in 7 (16.3%) cases. Only a few patients, i.e., 3 (7.0%) in the olfactory groove and 1 (2.3%) in falcine, tentorial, and lateral ventricular each case (Figure 2).

Table 2: Distribution of Patients According to Score with Grading of Meningioma by Features of MRI (n = 43)

Meningioma grading on MRI	Frequency	Percentage
Low grade (Score < 4)	34	79.07
High grade (Score ≥ 4)	09	20.93
Total	43	100.0

According to the score of meningioma by WHO grading of meningiomas by features MRI, 34 (79.09%) were low grade, and 09 (20.93%) were high grade.

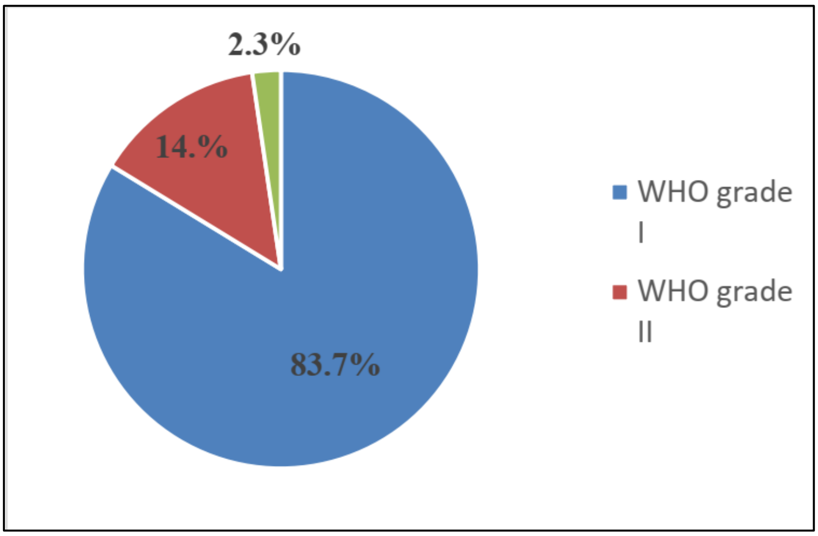

Figure 3: Distribution of Patients According to WHO Grading of Meningioma by Histopathological Findings (n = 43)

Patients according to WHO grading of meningioma by histopathology, 36 (83.7 %) patients with meningiomas were confirmed as WHO grade I, followed by 6 (14.0 %) patients with WHO grade II and 1 (2.3 %) patients were grade III (Figure 3).

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

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

Table 3 shows the association between signal findings in MRI and histopathological grading; among a total 36 low-grade meningiomas, hyperintensity shows 19 (52.78%) in T1WI and 2 (5.56%) in T2WI, Isointense shows 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, Hyperintense shows 3 (42.86%) in T1WI and 0 (00%) in T2WI, Isointense 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 harmful brain edema in 19 (52.78%), as 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 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 4).

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

Correlations				
Variable			**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).				

The correlation of pre-operative 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 5).

DISCUSSION

Meningiomas represent a significant proportion of intracranial tumors, accounting for about 15% of such cases [14]. These tumors arise from arachnoid cap cells of the leptomeninges. They are most commonly diagnosed in individuals between their fourth and sixth decades of life, with an average age of diagnosis around 45 years [2]. Accurately predicting the histopathological grade of meningiomas before surgery is crucial for guiding optimal treatment strategies. Clinical practice often encounters multiple radiological features within meningiomas, leading to confusion about their relative importance. This study aims to integrate various radiological findings into an exclusive and comprehensive prediction model for identifying high-grade meningiomas. The results highlight tumor-brain interface, tumor enhancement, capsular enhancement, and tumor margin as the most influential variables.

A total of 43 male and female adult patients with supratentorial meningiomas admitted to the Department of Neurosurgery at DMCH from July 2019 to December 2020 were included. Patients with lesions other than supratentorial meningioma, those under 18 years of age, those with histopathological reports inconsistent with meningioma, and those who refused consent were excluded from the study. Regarding age distribution, this study found the highest incidence of supratentorial meningioma (48.8%) in the 41–50 age group, followed by 16.3% in the 21–30 and 31–40 age groups, with a mean age of 37 (± 11.86) years and a median age of 40 years. These findings align with Moradi *et al*., (2008), who reported a mean age of 49.11 ± 12.99 years for meningioma patients. Additionally, Bhat *et al*., (2014) noted that nearly 47.32% of meningioma patients were in the 41–50 age group.

Regarding gender distribution, this study observed that meningioma was more predominant in female patients (74.4%) than in male patients (25.6%), with a male-to-female ratio of 1:2.7. These findings are consistent with [2], who reported that 67% of their meningioma patients were female, and Bhat *et al*., (2014), who found a female-to-male ratio of 1.82:1.

This study identified specific factors on MR imaging that were useful for predicting high-grade meningiomas. Tumor-brain interface (TBI) was assessed as an important indicator, where a clear TBI suggested the presence of physiological barriers between the tumor and adjacent brain tissue. At the same time, an unclear TBI indicated their absence, signifying tight adhesion between the tumor and brain or tumor invasion of the brain—a characteristic feature of high-grade meningiomas. The study demonstrated that unclear TBI was the most significant predictor of malignancy [13]. High-grade meningiomas exhibited unclear TBI in approximately 72% of cases, which was statistically significant (p-value = 0.002). In contrast, 89% of low-grade meningiomas displayed a clear tumor-brain interface.

Meningiomas typically develop connective tissue around the tumor, which takes time to form. This connective tissue was explored was explored, recognized as an enhanced layer at the tumor-brain interface on T1Gd MR i Positive capsular enhancement was seen in approximately 57% of high-grade meningiomas, and this finding was statistically significant (p- value = 0.008), while 92% of low-grade meningiomas exhibited negative capsular enhancement. Heterogeneous tumor enhancement on MR imaging was associated with high-grade meningiomas, reflecting non-uniform pathological features like intertumoral necrosis—a hallmark of high-grade meningiomas. Approximately 71% of high-grade meningiomas displayed heterogeneous enhancement, though it did not reach statistical significance (p-value = 0.093). In contrast, 67% of low-grade meningiomas exhibited homogeneous contrast enhancement.

Histological heterogeneity within high-grade meningiomas, characterized by the irregular distribution of proliferating cells, was associated with an irregular tumor margin on MR imaging. In this study, approximately 86% of high-grade meningiomas displayed irregular tumor margins, which was statistically significant (p-value = 0.001). Conversely, approximately 83% of low-grade meningiomas exhibited regular tumor margins. Although a has been associated with meningioma malignancy due to blood-brain barrier disruption, this study did not find peritumoral edema to be a predictive factor for high-grade meningioma (p-value = 0.412).

Tumor intensity in T1-weighted and T2-weighted images did not emerge as predictive factors for high-grade meningioma in this study (p-values of 0.741 and 0.554, respectively). A similar study [7], and [13], have reported similar findings, highlighting the significance of factors like unclear tumor-brain interface, positive capsular enhancement, and heterogeneous enhancement in predicting high-grade meningiomas. Additionally, it was noted that age above 75 years was a significant predictor. Peritumoral edema, unclear tumor-brain interface, heterogeneous contrast enhancement, and the absence of a subarachnoid rim are important indicators of high-grade meningiomas with aggressive growth tendencies and higher recurrence risk. However, no association was found between MRI signal intensities and histological subtypes of meningioma [5].

The current study found distinct MRI features associated with low-grade and high-grade meningiomas. Low-grade meningiomas typically exhibited homogeneous contrast enhancement, a clear tumor-brain interface, no capsular enhancement on MRI, and regular tumor margins. In contrast, high-grade meningiomas were characterized by heterogeneous contrast enhancement, an unclear tumor-brain interface, positive capsular enhancement on MRI, and irregular tumor margins.

Out of the study population, 09 (20.93%) cases were diagnosed as high-grade meningiomas on MRI, with 71.43% confirmed as high grade on histopathology. Additionally, 04 (11.11%) cases initially diagnosed as low-grade meningiomas on MRI were identified as high-grade on histopathology, resulting in false positives. Conversely, 34 (79.07%) cases were diagnosed as low-grade meningiomas on MRI, with 88.89% confirmed as low-grade on histopathology. Two (28.57%) cases initially diagnosed as low grade on MRI were identified as high grade on histopathology, resulting in false negatives.

Histopathological analysis revealed that the majority of tumors were WHO grade I (83.7%), followed by WHO grade II (14.0%) and WHO grade III (2.3%). These findings align with prior studies [2], which reported similar distributions of WHO grades in meningiomas. Statistical analysis using the Chi-square (X2) test and Fisher's exact test demonstrated a significant correlation between pre-operative MRI grading and histopathological grading of supratentorial meningiomas, with a p-value of 0.002. The correlation was further supported by Spearman's rank correlation coefficient of 0.547, indicating a statistically significant and moderately positive correlation between pre-operative MRI and histopathological grading.

The diagnostic accuracy of clinical diagnosis in assessing tumor grade was evaluated, revealing a sensitivity of 71.43%, specificity of 88.88%, positive predictive value of 55.56%, negative predictive value of 94.1%, and an overall accuracy of 86.05%. These findings highlight the potential of pre-operative MRI in predicting the histopathological grade of supratentorial meningiomas, aiding in treatment planning and patient management.

CONCLUSION

Pre-operative MRI grading correlates significantly with post-operative histopathological grading of supratentorial meningiomas in adults. Unclear tumor brain interface, capsular enhancement, heterogeneous tumor enhancement, and irregular tumor margin in the MRI are the most important parameters in predicting high-grade meningiomas preoperatively. By this analysis, the MRI parameters can be very good tools to clinically predict the post-operative grading of the meningiomas before surgery.

RECOMMENDATIONS

- MRI with contrast in all patients with meningiomas should be studied carefully to make pre-operative surgical planning and proper counseling
- Post-operative immunohistochemistry should be done to get better results
- Representative tissue should be sent to the laboratory with the standard protocol
- Further study should be carried out for a long time and a large number of patients for a better conclusion

ACKNOWLEDGMENT

I am pleased to express profound gratitude and indebtedness to my respected teachers, all staff, and research assistants with the Department of Neurosurgery of Dhaka Medical College and Hospital, Dhaka, for the valuable suggestions that make this study possible.

FUNDING: No funding sources
CONFLICT OF INTEREST: None declared

REFERENCES

1. Alalade, A. F., & Kitchen, N. D. (2018). Convexity and Parasagittal Versus Skull Base Meningiomas. In *Principles of Neurological Surgery* (pp. 593-601). Elsevier.
2. Shah, S., Gonsai, R. N., & Makwana, R. (2013). Histopathological study of meningioma in civil hospital, ahmedabad. *International Journal of Current Research and Review*, *5*(3), 76.
3. Prabhu, V. C., Perry, E. C., Melian, E., Barton, K., Guo, R., & Anderson, D. E. (2014). Intracranial meningiomas in individuals under the age of 30; Analysis of risk factors, histopathology, and recurrence rate. *Neuroscience Discovery*, *2*(1), 1-14.
4. Buerki, R. A., Horbinski, C. M., Kruser, T., Horowitz, P. M., James, C. D., & Lukas, R. V. (2018). An overview of meningiomas. *Future Oncology*, *14*(21), 2161-2177.
5. Schob, S., Frydrychowicz, C., Gawlitza, M., Bure, L., Preuß, M., Hoffmann, K. T., & Surov, A. (2016). Signal intensities in preoperative MRI do not reflect proliferative activity in meningioma. *Translational oncology*, *9*(4), 274-279.
6. Wiemels, J., Wrensch, M., & Claus, E. B. (2010). Epidemiology and etiology of meningioma. *Journal of neuro-oncology*, *99*, 307-314.
7. Lin, B. J., Chou, K. N., Kao, H. W., Lin, C., Tsai, W. C., Feng, S. W., ... & Hueng, D. Y. (2014). Correlation between magnetic resonance imaging grading and pathological grading in meningioma. *Journal of neurosurgery*, *121*(5), 1201-1208.
8. Engelhard, H. H. (2001). Progress in the diagnosis and treatment of patients with meningiomas: Part I: Diagnostic imaging, preoperative embolization. *Surgical neurology*, *55*(2), 89-101.
9. D'Ambrosio, A. L., & Bruce, J. N. (2003). Treatment of meningioma: an update. *Current Neurology and Neuroscience Reports*, *3*(3), 206-214.
10. Maiuri, F., İaconetta, G., De Divitiis, O., Cirillo, S., Di Salle, F., & De Caro, M. L. (1999). Intracranial meningiomas: correlations between MR imaging

and histology. *European journal of radiology*, *31*(1), 69-75.
11. Tan, L. A., Boco, T., Johnson, A. K., Rivas, F. F., Ahmed, S., Byrd, S. E., & Byrne, R. W. (2015). Magnetic resonance imaging characteristics of typical and atypical/anaplastic meningiomas–Case series and literature review. *British journal of neurosurgery*, *29*(1), 77-81.
12. Yogi, A., Koga, T., Azama, K., Higa, D., Ogawa, K., Watanabe, T., ... & Murayama, S. (2014). Usefulness of the apparent diffusion coefficient (ADC) for predicting the consistency of intracranial meningiomas. *Clinical Imaging*, *38*(6), 802-807.
13. Kawahara, Y., Nakada, M., Hayashi, Y., Kai, Y., Hayashi, Y., Uchiyama, N., ... & Hamada, J. I. (2012). Prediction of high-grade meningioma by preoperative MRI assessment. *Journal of neuro-oncology*, *108*, 147-152.
14. Dharmajaya, R. (2020). Review of Intracranial Meningioma in North Sumatera. *Pituitary*, *21*, 5-6.