Original Article

Correlation of degree and pattern of contrast enhancement on Magnetic Resonance Imaging with histopathological grade of intracranial astrocytoma

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ABSTRACT:

Background/Objective: *Astrocytomas, a type of glioma, require accurate grading to guide treatment. This study evaluates the correlation between MRI contrast enhancement and histopathological grades of astrocytomas.*

Methods: *A cross-sectional study of 37 patients with biopsy-confirmed astrocytomas was conducted. Non-probability or purposive sampling was carried out. MRI scans assessed contrast enhancement characteristics, and tumors were classified radiologically and histopathologically.*

Results: *The age range of the patients was 11 to 74 years and mean age was 40.25±16.04 years. The male to female ratio was 4:1. Headache was the most common presenting symptoms (95%). Most of the tumors were located at the cerebral hemispheres (78%). None or slight contrast enhancement was found in 17 (46%) and the pattern of contrast enhancement was heterogeneous in 24 (65%) patients. Maximum 20 (54%) patients had high grade astrocytoma. In the present study, 85% high grade astrocytoma showed moderate to marked whereas 82.4% low grade astrocytoma showed none or slight contrast enhancement. Sensitivity & specificity of contrast enhanced MRI was 82.4% and 85% respectively. The overall accuracy was 83.78%.*

Conclusion: *MRI is a reliable non-invasive tool for grading astrocytomas, with strong correlation between contrast enhancement and tumor grade, supporting its use in clinical decision-making.*

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Introduction

Astrocytomas are a common type of primary central nervous system tumor, originating from astrocytic glial cells, which are part of the brain's supportive tissue. These tumors represent approximately 50- 80% of all gliomas, which collectively account for 35-50% of intracranial tumors [1]. Astrocytomas are highly heterogeneous in terms of cellularity, vascular proliferation, mitotic activity, and necrosis— characteristics that influence both their classification and clinical behavior [2].

The World Health Organization (WHO) classifies astrocytomas from Grade I to Grade IV, depending on their degree of malignancy. Grade I tumors, such as pilocytic astrocytomas, are typically benign and often found in pediatric populations. In contrast, Grade IV astrocytomas, known as glioblastoma multiforme (GBM), are among the most aggressive and fatal forms of brain tumors [2]. The therapeutic management and prognosis for astrocytoma patients heavily depend on the accurate distinction between high-grade (Grade III-IV) and low-grade (Grade I-II) tumors [3].

Magnetic Resonance Imaging (MRI) has become an essential tool for the non-invasive diagnosis and grading of astrocytomas due to its superior soft tissue contrast and ability to provide detailed images of the tumor's structure and surroundings [4]. Contrast enhancement on MRI is particularly valuable for determining tumor grade, typically indicating disruption of the blood-brain barrier, which is more pronounced in high-grade astrocytomas [5]. Recent studies have shown that advanced MRI techniques, such as dynamic contrast-enhanced MRI, can enhance the reliability of differentiating astrocytoma grades. For example, a study using deep learning to improve the arterial input function during dynamic contrast-enhanced MRI found an increase in diagnostic performance for astrocytoma grading [6].

Moreover, recent evidence suggests that the level of vascular endothelial growth factor (VEGF) expression correlates well with MRI contrast-enhanced imaging findings, providing a useful biomarker for tumor progression. This study found that VEGF expression was significantly related to increased signal intensity and tumor angiogenesis [7]. Another study highlighted the importance of pharmacokinetic parameters obtained from dynamic susceptibility contrast-enhanced MRI as valuable biomarkers for predicting disease progression in anaplastic astrocytoma patients [8].

Despite the utility of MRI, the grading of astrocytomas can still present challenges, particularly when distinguishing between Grade III and Grade IV tumors, which often share overlapping imaging characteristics [9]. Asari et al. developed an MRI scoring system based on nine imaging criteria, including the degree of contrast enhancement and heterogeneity, to improve the accuracy of non- invasive tumor grading [9]. These criteria have been validated by subsequent studies and have shown a consistent correlation between imaging scores and histopathological grades, suggesting their usefulness in clinical practice [9]. The recent advancements in MRI technologies are proving to be a game-changer in the way clinicians can assess tumor severity and prognostic outcomes effectively.

The main objective of the study is to evaluate the relation between the degree & pattern of contrast enhancement on MRI of intracranial astrocytomas and its histopathologic grade.

Methodology

This study was a cross-sectional observational study conducted at Dhaka Medical College Hospital and Bangabandhu Sheikh Mujib Medical University from June 2008 to May 2009. The aim was to evaluate the correlation between MRI contrast enhancement and the histopathological grade of intracranial astrocytomas.

A total of 37 patients with biopsy-confirmed astrocytomas were included in this study. Non-probability or purposive sampling was carried out. Inclusion criteria were patients of all ages diagnosed with intracranial astrocytomas who were eligible for both MRI and subsequent biopsy. Patients with recurrent astrocytomas or previous surgical or radiotherapy treatments were excluded to avoid any influence on the grading accuracy.

The MR studies were performed on 1.5T imager mostly, though in some cases it was done by lower imager (0.3T) also. T1-weighted and T2-weighted and contrast enhanced axial, sagittal and coronal images along with FLAIR images were obtained. The MRI of all cases were reviewed preoperatively in respect to their contrast enhancement characters (degree and pattern of contrast enhancement). The contrast enhancement characters (degree and pattern of contrast enhancement) scored on a scale as described by Asari et al. (1994) and Riemann et al. (2002), is summarized in Table 1. [9,10]

Table 1: Contrast Enhancement Criteria and Score

Contrast Enhancement Character		Score
Degree of Contrast Enhancement	None	0
	Slight	1
	Moderate	2
	Marked	3
Pattern (Heterogeneity) of Contrast Enhancement	None	0
	Homogeneous	1
	Heterogeneous	2

By using the contrast enhancement characters on MRI, the astrocytomas were divided into two-tier grading system: radiologically low- versus high-grade (Table - 2) (Law et al. 2003). The radiological diagnosis (low- versus high-grade) was then compared statistically with the histological diagnosis (low- versus high-grade) [13].

Table 2: Degree of Contrast Enhancement and Radiological Grade

Degree of Contrast Enhancement	Radiological Grade
None or Slight Enhancement	Low Grade
Moderate or Marked Enhancement (Homogeneous or Heterogeneous)	High Grade

Biopsy material was collected during surgery or by endoscopic procedure. The Neoplasms were assigned the tumor grade, ranging from I to IV, according to the criteria of the revised WHO classification. For the purposes of this study, the histological diagnosis was categorized into low-grade (Grade-I & II) and high grade (Grade-III & IV) tumors. The radiological diagnosis (low versus high grade) was then compared statistically with the histological diagnosis (low versus high grade).

Statistical Analysis

Statistical analysis was carried out using the SPSS software package (version 22). The MRI scores were presented as mean ± standard deviation (SD). An unpaired Student t-test was used to evaluate statistical differences between groups. To evaluate the diagnostic performance of MRI in predicting the histopathological grade, sensitivity, specificity, and accuracy were calculated.

Results

The study included a total of 37 patients whose ages ranged from 11 to 74 years, with a mean age of 40.25 ± 16.04 years. The peak incidence was observed in the age group of 31-40 years, accounting for 30% of the patients (11 cases). The male-to-female ratio was approximately 4:1, with 30 males (81%) and 7 females (19%) Table 3 summarizes the demographic and clinical characteristics of the patients, including age, sex, mode of presentation, tumor location, and biopsy technique.

Table 3: Distribution of Patients by Demographic and Clinical Characteristics

Vaiable	Criteria	Frequency	Percentage (%)
Age Group	11-20	5	14
	21-30	6	16
	31-40	11	30
	41-50	4	11
	51-60	7	19
	61-70	3	8
	71-80	1	3
Sex	Male	30	81
	Female	7	19
Mode of Presentation	Headache	35	95
	Vomiting	23	62
	Visual Disturbance	17	46
	Seizure	17	46
	Hemiparesis	14	38
	Dysphasia	5	14
	Mental Dysfunction	8	22
	Cerebellar Dysfunction	4	11
	Long Tract Sign/Cranial Nerve Palsy	3	8
Location of Astrocytoma	Hemispheric/Lobar	29	78
	Diencephalic	4	11
	Cerebellar	4	11

The most common presenting symptom was headache, which was reported by 35 patients (95%). Other common symptoms included vomiting (62%), visual disturbances (46%), and seizures (46%). Hemispheric or lobar tumors were the most common, observed in 29 patients (78%), while the remaining tumors were found in the diencephalon and cerebellum (11% each).

24% patients showed no enhancement whereas 8 (22%) patients showed slight contrast enhancement. Moderate and marked contrast enhancement on MRI was demonstrated in 4 (11%) patients and 16 (43%) patients respectively. Regarding pattern (heterogeneity) of contrast enhancement, homogeneous and heterogeneous contrast enhancement were found in 4 (11%) and 24 (65%) patients respectively (Table-04).

Table 4: The distribution of the pattern (heterogeneity) of contrast enhancement on MRI

Pattern heterogeneity of contrast enhancement	Frequency	Percentage
None	9	24
Heterogeneous	4	11
Heterogeneous	24	65

The tumors were radiologically graded based on their MRI contrast enhancement characteristics as either low-grade or high-grade. Radiologically, 17 tumors (46%) were classified as low-grade due to the absence or slight degree of contrast enhancement, while 20 tumors (54%) were classified as high- grade due to moderate or marked enhancement. Histopathological examination following biopsy confirmed 17 tumors (46%) as low-grade (WHO Grade I and II) and 20 tumors (54%) as high-grade (WHO Grade III and IV). Table 5 provides a summary of the distribution of radiological and histo-pathological grading.

Table 5: Distribution of Radiological and Histopathological Grades

Criteria		Frequency	percent
Radiological Diagnosis (MRI)	No/slight enhancement (Low-grade)	17	46
	Moderate to marked enhancement (High-grade)	20	54
Histopathological Grade	Low Grade (WHO Grade I & II)	17	46
	High Grade (WHO Grade III & IV)	20	54

Histopathological examination further classified the tumors into specific WHO grades (table-6). Among the 37 patients, 7 (19%) had WHO Grade I astrocytomas (pilocytic astrocytomas), 10 (27%) had WHO Grade II astrocytomas, 10 (27%) were diagnosed with WHO Grade III astrocytomas (anaplastic astrocytomas), and another 10 (27%) had WHO Grade IV astrocytomas (glioblastoma multiforme).

Table-6: Histopathological WHO grade of astrocytomas

WHO grade	Frequency	percent
WHO Grade I (pilocytic astrocytomas)	7	19%
WHO Grade II (astrocytomas)	10	27%
WHO Grade III (anaplastic astrocytomas	10	27%
WHO Grade IV (glioblastoma multiforme)	10	27%

The mean MR imaging scores of degree of contrast enhancement showed LGA had a significant lower value than that of high grade astrocytomas (grade III, P .005 and grade IV, P .003). However, there was no significant difference between high grade astrocytomas (grade III & IV, P .051). Same result came out in case of degree and pattern of contrast enhancement (Table 7).

Table 7: Mean MRI Scores of Contrast Enhancement by Pathological Grade

Pathological Grade	Mean MRI Scores of degree of contrast enhancement	Mean MRI scores of pattern of contrast enhancement
WHO Grade I & II (LGA)	0.82 ± 1.01	0.82 ± 0.88
WHO Grade III (AA)	2.10 ± 1.10	1.80 ± 0.63
WHO Grade IV (GBM)	2.90 ± 0.32	2.00 ± 0.00

Statistical analysis using the unpaired Student's t-test revealed significant differences in the mean MRI scores for contrast enhancement between low-grade and high-grade astrocytomas ($p < 0.05$). Specifically, there was a significant difference between low-grade astrocytomas and both WHO Grade III ($p = 0.005$) and Grade IV ($p = 0.003$) astrocytomas. However, no significant difference was observed between WHO Grade III and Grade IV astrocytomas ($p = 0.051$). Similar results were found for the pattern of contrast enhancement, with significant differences between low-grade and high-grade astrocytomas, but no significant difference between Grade III and Grade IV, as shown in Table 8.

Table 8: Statistical Analysis of MRI Scores (Unpaired Student's t-test)

Group Comparison		P value (Degree of Contrast Enhancement)	P value (Pattern of Contrast Enhancement)
LGA	AA	.005	.003
LGA	GBM	.003	.001
AA	GBM	.051	.343

The diagnostic accuracy of MRI in determining tumor grade was assessed by comparing radiological and histo-pathological findings. MRI correctly identified the grade in 14 out of 17 patients with low- grade astrocytomas

(82.4%) and in 17 out of 20 patients with high-grade astrocytomas (85%). The sensitivity of MRI for identifying high-grade astrocytomas was 82.4%, while the specificity for identifying low-grade astrocytomas was 85%. The overall accuracy of MRI in grading astrocytomas was 83.78%. Table 9 provides a cross-tabulation of radiological and histopathological findings, demonstrating that MRI was effective in identifying the correct grade for the majority of tumors.

Table 9: Correlation of Radiological Diagnosis and Histopathological Grade (Cross-tabulation)

Radiological diagnosis (MRI) Count (% within radiological diagnosis)	Histopathological grade		Total
	Low grade	High grade	
Low grade	14 (82.4%)	3 (17.6%)	17 (100.0%)
High grade	3 (15.0%)	17 (85.0%)	20 (100.0%)
Total	17 (45.9%)	20 (54.1%)	37 (100.0%)

Discussion

Gliomas are the most common form of intracranial neoplasm, accounting for between 35-50% of all intracranial tumors, with astrocytomas constituting 50-80% of gliomas [5]. The management and prognosis of astrocytomas heavily depend on distinguishing between high-grade and low-grade varieties. Magnetic Resonance Imaging (MRI) has established itself as a critical non-invasive diagnostic tool for evaluating patients with astrocytomas, helping clinicians make crucial decisions regarding treatment planning [12].

Patient Characteristics and Presentation

In the present study, the patient age ranged from 11 to 74 years, with a mean age of 40.25 ± 16.04 years, which is consistent with the typical presentation of astrocytomas seen in clinical practice. The highest incidence was in the 31-40-year age group (30%), which aligns with the understanding that benign astrocytomas tend to present earlier than malignant ones, with incidence declining after the age of fifty [5]. The male-to-female ratio in this study was 4:1, which is higher compared to the 3:1 ratio noted in standard literature [5]. This finding might be attributed to regional or sample-specific variations.

The clinical presentation of astrocytomas varies based on tumor location and grade. In this study, 95% of patients presented with headache, followed by vomiting (62%), visual disturbances (46%), and seizures (46%). These findings are in line with previous observations that supratentorial gliomas typically present with symptoms of raised intracranial pressure (ICP), seizures, or focal neurological deficits [5]. Most tumors were located in the cerebral hemispheres (78%), with the remainder found in the diencephalon (11%) and cerebellum (11%). This supports the common understanding that supratentorial regions are a prevalent site for high-grade astrocytomas [5].

MRI Contrast Enhancement and Grading

The grading of astrocytomas in this study was conducted using both radiological and histopathological criteria. The World Health Organization (WHO) grading system was used, which classified 19% of the tumors as Grade I (pilocytic astrocytomas) and 27% as Grade II astrocytomas. WHO Grade III (anaplastic astrocytomas) and Grade IV (glioblastoma multiforme, GBM) each accounted for 27% of the cases. These findings are consistent with those from Riemann et al. (2002), where 31.25% of cases were low-grade and 68.75% were high-grade [10].

In this study, MRI-based contrast enhancement characteristics were used to determine tumor grade. The mean MRI score for the degree of contrast enhancement significantly increased with tumor grade. Low- grade astrocytomas had significantly lower enhancement scores compared to high-grade astrocytomas (Grade III, $p < 0.01$; Grade IV, $p < 0.01$). These results align well with previous findings by Asari et al. (1994) and Riemann et al. (2002), who both reported that higher grades of astrocytomas exhibited greater degrees of enhancement [9,10]. Tervonen et al. (1992) also demonstrated a direct correlation between contrast enhancement and tumor grade, further validating the use of MRI as a reliable method for non-invasive tumor grading [11]. Similar to the degree of contrast enhancement, the pattern (heterogeneity) of contrast enhancement also differed significantly between low- and high-grade tumors.

Figure 1a and 1b illustrate a pre-contrast and post-contrast T1-weighted (T1W) image, respectively, showing no visible enhancement. The histopathological analysis confirmed this tumor as WHO Grade I (pilocytic astrocytoma).

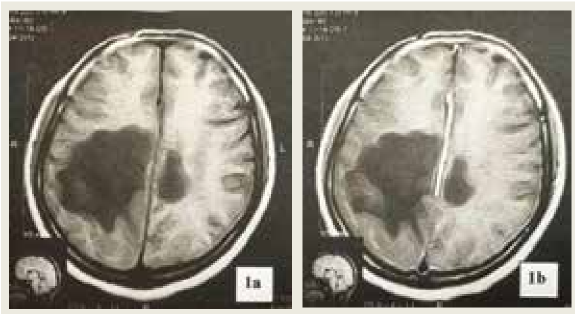

Figure 1a: Pre-contrast T1W image showing no contrast enhancement. Histopathology confirmed WHO Grade I (pilocytic astrocytoma). Figure 1b: Post-contrast T1W image showing no contrast enhancement. Histopathology confirmed WHO Grade I (pilocytic astrocytoma).

Similarly, Figures 2a and 2b represent a pre-contrast and post-contrast T1W image, respectively, demonstrating slight heterogeneous contrast enhancement. The histopathological examination revealed this as a WHO Grade II astrocytoma.

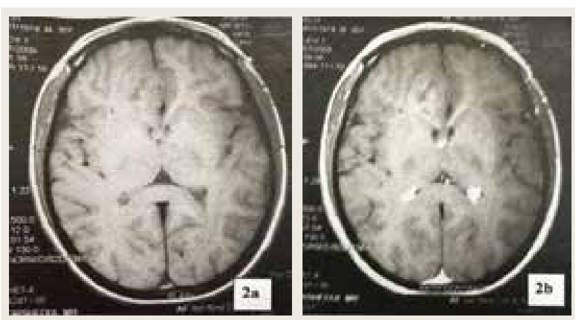

Figure 2a: Pre-contrast T1W image showing slight heterogeneous contrast enhancement. Histopathology revealed WHO Grade II astrocytoma. Figure 2b: Post-contrast T1W image showing slight enhancement. Histopathology revealed WHO Grade II astrocytoma.

Diagnostic Accuracy of MRI

The diagnostic performance of contrast-enhanced MRI in grading astrocytomas was evaluated, revealing a sensitivity of 82.4%, specificity of 85%, and an overall accuracy of 83.78%. These findings indicate that MRI is a valuable tool for preoperative grading, offering significant insights into tumor aggressiveness and guiding treatment decisions. The sensitivity and specificity observed in this study are comparable to those reported by Riemann et al. (2002), who found a sensitivity of 91% and a specificity of 80%, with an accuracy of 88% [10]. This correlation supports the robustness of MRI as a diagnostic modality, though slight variations in findings may be attributed to differences in sample size and imaging quality.

Previous studies have similarly reported high sensitivity and specificity for MRI in determining tumor grade. Hakyemez et al. (2006) found that 88.5% of high-grade gliomas demonstrated moderate to extensive enhancement following contrast administration, while 88.8% of low-grade gliomas exhibited minimal or no enhancement [14]. Shin et al. (2002) reported that 90.9% of high-grade gliomas showed moderate to strong enhancement, whereas 71.4% of low-grade gliomas exhibited mild or no enhancement [15]. These findings are in line with our study, demonstrating the utility of MRI contrast enhancement in accurately predicting tumor grade.

Limitations and Future Directions

Despite the promising findings, there are limitations to this study that should be acknowledged. The sample size was relatively small, limiting the generalizability of the results. Moreover, the study used MRI machines with different field strengths (0.3 Tesla and 1.5 Tesla), potentially introducing variability in image quality and influencing the assessment of contrast enhancement. Additionally, the histopathological examination was not conducted in a single center, which could lead to variability in grading accuracy. Future studies with larger, multicentric cohorts and standardized imaging protocols could provide more definitive evidence of MRI's diagnostic value.

Conclusion

The study highlights that MRI is a reliable tool for the non-invasive grading of astrocytomas, with good agreement between radiological and histopathological findings. The degree and pattern of contrast enhancement are significant predictors of tumor grade, and MRI demonstrates high sensitivity and specificity in distinguishing low-grade from high-grade astrocytomas. Despite limitations such as sample size and variability in MRI quality, the findings support the role of MRI as an integral part of the diagnostic process for astrocytomas.

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