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Original Research Article

Role of advanced magnetic resonance imaging techniques in the evaluation of glioblastoma multiforme

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ABSTRACT

Background: Glioblastoma multiforme (GBM) is the most common and aggressive primary brain tumor in adults, often presenting with nonspecific clinical and radiological features that complicate early diagnosis. Advanced magnetic resonance imaging (MRI) techniques, including diffusion-weighted imaging (DWI), gradient-echo (GRE) sequences and magnetic resonance spectroscopy (MRS), may enhance diagnostic accuracy beyond conventional MRI.
Methods: This cross-sectional study was conducted in the Department of Radiology and Imaging, Sir Salimullah Medical College and Mitford Hospital, Dhaka, in collaboration with Neurosurgery and Pathology departments, from January 2018 to December 2019. A total of 31 patients with clinically suspected GBM were enrolled using purposive sampling. All patients underwent advanced MRI protocols, including DWI, GRE and MRS. MRI findings were compared with histopathological diagnoses, considered the gold standard.
Results: The mean patient age was 52.1±11.2 years, with most cases (41.9%) in the 51–60-year group. On DWI, partially restricted diffusion was observed in 51.6% of lesions, particularly among GBM cases (54.1%). Blooming artifacts on GRE were seen in 41.9% overall, including 37.5% of GBM. MRS consistently showed elevated choline, lactate and choline/creatinine ratio with reduced NAA and creatinine. A choline/creatinine ratio >2.5 distinguished GBM and anaplastic astrocytoma, while metastases showed ratios <2.5. Compared with histopathology, MRI achieved a sensitivity of 95.6%, specificity 75.0%, accuracy 90.3%, PPV 91.6% and NPV 85.7%.
Conclusion: Advanced MRI techniques provide significant diagnostic value in differentiating GBM from other intracranial tumors, with high sensitivity and accuracy when correlated with histopathology.

Keywords: Glioblastoma multiforme, Advanced MRI, DWI, GRE, MRS, Histopathology

INTRODUCTION

GBM is the most aggressive and most common primary malignant brain tumor in adults, accounting for approximately 15–20% of all intracranial neoplasms. Despite advances in neurosurgery, radiotherapy and chemotherapy, the prognosis remains poor, with a median survival of only 12–15 months following standard treatment.[1,2] The aggressive biological behavior, infiltrative nature and tendency for recurrence make early and accurate diagnosis crucial for optimal management and prognostication.[3] Conventional magnetic resonance imaging (MRI) plays a pivotal role in the initial evaluation of GBM, providing information about tumor morphology, size and location. Standard sequences such as T1-weighted, T2-weighted, FLAIR and post-contrast T1 images help to identify mass effect, necrosis, peritumoral

edema and contrast enhancement.[4] However, conventional MRI has limitations, particularly in differentiating GBM from other high-grade gliomas, metastases, abscesses, or treatment-related changes such as pseudo progression and radiation necrosis.[5] As a result, reliance solely on morphological imaging may lead to diagnostic uncertainty.

Advanced MRI techniques have emerged as valuable tools to overcome these challenges by offering insights into the biological and functional characteristics of tumors.[6] DWI provides information about tumor cellularity and integrity of white matter tracts. Perfusion imaging evaluates tumor vascularity and angiogenesis, which are hallmarks of GBM.[7] MRS allows metabolic profiling, detecting alterations in choline, N-acetylaspartate and lactate that distinguish neoplastic tissue from normal brain. GRE and SWI highlight intratumoral hemorrhage, calcification and microvascular proliferation.[8] Together, these modalities enhance diagnostic accuracy, assist in treatment planning and facilitate monitoring of disease progression and therapeutic response.[9]

Histopathology remains the gold standard for definitive diagnosis, yet it is invasive and limited by sampling error due to tumor heterogeneity.[10] Advanced MRI, on the other hand, provides a non-invasive and repeatable means of evaluating the entire tumor and its microenvironment. Moreover, by correlating MRI findings with histopathology, clinicians can better understand the diagnostic performance of these imaging tools and refine their application in routine practice.[11]

The present study was undertaken to assess the diagnostic utility of advanced MRI sequences, including diffusion-weighted imaging, gradient-echo and magnetic resonance spectroscopy, in patients with suspected GBM, with histopathology as the reference standard. Furthermore, the study aimed to determine the sensitivity, specificity, predictive values and overall accuracy of MRI in diagnosing GBM.

METHODS

This cross-sectional study was conducted in the Department of Radiology and Imaging, Sir Salimullah Medical College and Mitford Hospital, Dhaka, in collaboration with the Departments of Neurosurgery and Pathology, over a period from January 2018 to December 2019. A total of 31 patients with clinically suspected glioblastoma multiforme (GBM) were included using purposive sampling. Patients who were unfit for MRI or surgery, unwilling to undergo surgery, or claustrophobic were excluded. All patients underwent MRI on a 1.5 Tesla machine (Philips Injenia) with 5 mm slice thickness and 4 mm gap, using standard sequences including T1W, T2W (axial, sagittal, coronal), FLAIR, GRE, DWI and post-contrast T1W images after administration of intravenous gadodiamide (0.1 mmol/kg). Imaging parameters such as lesion location, shape, margin, signal intensity, necrosis, peritumoral edema, contrast enhancement pattern and degree and presence of hemorrhage, calcification, or cystic changes were assessed. Following MRI, patients underwent surgical intervention and tissue specimens were processed for histopathological examination using haematoxylin and eosin staining, which was considered the gold standard for diagnosis. Demographic variables (age, sex), clinical presentations (headache, seizures, cognitive impairment, behavioral changes, focal neurological deficits) and imaging features were recorded using a semi-structured questionnaire.

Data were analyzed using SPSS version 22.0 and diagnostic performance of MRI was evaluated in terms of sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy, with histopathology as the reference standard. Ethical approval was obtained from the Institutional Review Board of SSMC & MH and informed written consent was taken from all participants with assurance of confidentiality and explanation of study objectives, potential risks and benefits.

RESULTS

Table 1 shows age of the study patients, it was observed that majority (41.93%) of the patients belonged to the age between 51-60 years followed by 08 (25.81%) having the age between 30-40 years, 06 (19.35%) patients had age between 41- 50 years and 04 (12.90%) patients had age 61-70 years. The mean age was 52.12±11.23 years with age range from 30 to 70 years. Table 2 shows distribution of the study patients by DW Images. It was observed that majority of the patients had partially restricted diffusion (51.6%), followed by no restricted diffusion lesions (25.8%), 22.6% lesions had restricted diffusion on DWI. Table 3 showing distribution of the study patients on DW Images by MRI diagnosis. It was observed that majority of the patients with GBM had partially restricted diffusion (54.1%), followed by no restricted diffusion (29.2%).

Table 4 showing distribution of the study patients by GRE. It was observed that 13 (41.9%) patients had bloom artifact. Among 24 patients of GBM, 09 (37.5%) had blooming artifact on GRE. 60.0% of AA had blooming artifact and 02 (40%) had no blooming artifact. Among two patients of metastasis 50.0% lesions had blooming artifact and 50% of metastasis had no blooming artifact on GRE.

Table 5 shows MRS parameters of lesions. It was observed that choline, lactate and choline/ creatinine ratio were increased in all lesions, Creatinine & NAA were decreased in all lesions, All GBM and AA had Choline/Creatinine ratio >2.5 whereas all metastasis had <2.5. Lipid was increased in 23 patients and decreased in 08 patients. Among 23 patients of increased lipid, 20 (83.4%) lesions were GBM, 01 (20%) lesion was AA and 2 (100%) lesion was metastasis. Among 08 patients of decreased lipid levels, 04 (16.6%) lesions were GBM, 04 (80%) lesions were AA.

Table 1: Distribution of the study patients by age (n=31).

Age (in year)	Number of patients	%
30-40	08	25.81
41-50	06	19.35
51-60	13	41.93
61-70	04	12.90
Mean±SD	52.12±11.23	
Range (min-max)	30–70	

Table 2: Distribution of the study patients by DW Images (n=31).

Characteristics	Frequency	%
Restricted	07	22.6
No restricted	08	25.8
Partially restricted	16	51.6

Table 3: Distribution of study patients by characterization of lesions on DWI by MRI diagnosis.

Tumor	Characteristics	Frequency	%
GBM (n=24)	Restricted	04	16.7
	No restricted	07	29.2
	Partially restricted	13	54.1
AA (n=5)	Restricted	02	40.0
	No restricted	01	20.0
	Partially restricted	02	40.0
Metastasis (n=2)	Restricted	01	50.0
	No restricted	00	00.0
	Partially restricted	01	50.0

Table 4: Distribution of the study patients by GRE (n=31).

Tumor	Characteristics	Frequency	%	Total	
				Blooming	**No blooming**
GBM (n=24)	Blooming	9	37.5	13 (41.9%)	18 (58.1%)
	No blooming	15	62.5		
AA (n=05)	Blooming	3	60		
	No blooming	2	40		
Metastasis (n=02)	Blooming	1	50		
	No blooming	1	50		

Table 5: Distribution of the study patients by MRS parameters (n=31).

MRS parameters		Tumors						Total	
		GBM (n=24) (n=23)		AA(n=5) (n=06)		Metastasis(n=2) (n=02)		N	%
		N	%	N	%	N	%		
Choline	↑	24	100.0	05	100.0	02	100.0	31	100.0
NAA	↓	24	100.0	05	100.0	02	100.0	31	100.0
Creatinine	↓	24	100.0	05	100.0	02	100.0	31	100.0
Choline/Creatinine	↑ (>2.5)	24	100.0	05	100.0	00	00.0	29	93.5
	↑ (<2.5)	00	0.0	00	0.0	02	100.0	02	6.5
Choline/NAA	↑	24	100.0	05	100.0	02	100.0	31	100.00
Lactate	↑	24	100.0	05	100.0	02	100.0	31	100.0
Lipids	↑	20	83.4	01	20.0	02	100.0	23	74.2
	↓	04	16.6	04	80.0	00	00.0	08	25.8

**Choline/creatinine= Choline/creatinine ratio, **Choline/NAA= Choline/NAA ratio

Table 6: Analysis of MRI findings and histopathological findings of GBM (n=31).

MRI diagnosis	Histopathological diagnosis		Total
	GBM positive	GBM negative	
GBM positive	22 (true positive)	02 (false positive)	24
GBM negative	01 (False negative)	06 (true negative)	07
Total	23	08	31

Table 6 showing analysis of MRI findings and histopathological findings of GBM (n=31). Out of all 31 cases, 24cases were diagnosed as GBM by MRI. Among them 22 cases were confirmed by histopathology to have GBM (TP). 7 cases were diagnosed by MRI as having other tumors than GBM. Among them 6 cases were confirmed by histopathology as having another tumor (TN) and 1 case was found to be GBM (FN). The bar diagram shows sensitivity of MRI in diagnosis of GBM was 95.6%, specificity75.0 accuracy 90.3%, positive predictive value 91.6% and negative predictive value 85.7% (Figure 1).

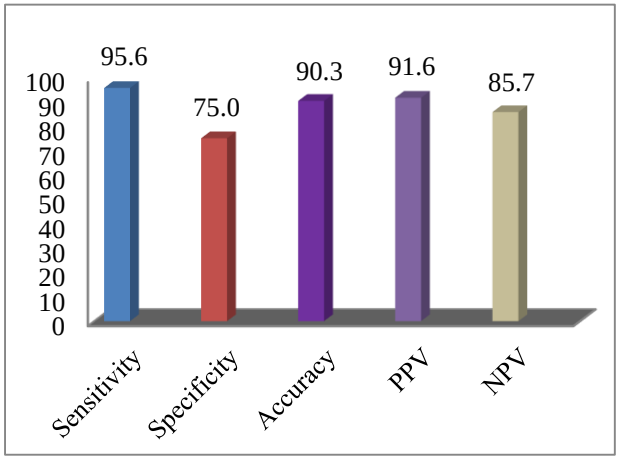

Figure 1: Sensitivity, specificity, accuracy, positive predictive value and negative predictive value of MRI in the diagnosis of GBM.

DISCUSSION

In this study, advanced MRI techniques including DWI, GRE and MRS were evaluated for their role in diagnosing GBM, with histopathology as the reference standard. The findings demonstrated that the majority of GBM lesions exhibited partially restricted diffusion, blooming on GRE in over one-third of cases and a consistent elevation of choline and lactate with reduced NAA on spectroscopy. These features collectively enhanced diagnostic accuracy, with MRI showing a sensitivity of 95.6% and accuracy of 90.3% for GBM.

The results are in line with previous reports that highlight the typical imaging profile of GBM. Abd-Elghany et al described that most GBM cases present with heterogeneous MRI features, including necrosis, edema and irregular margins, which are often correlated with restricted or partially restricted diffusion.[12] Similarly, Bohman et al., emphasized that DWI is helpful in differentiating highly cellular GBM from less aggressive gliomas, though partial restriction is more common due to intratumoral heterogeneity.[13] In the series, more than half of GBM patients showed partial restriction, consistent with these observations.

GRE findings also supported the presence of intratumoral hemorrhage and vascular proliferation. Colonnese and Romanelli noted that susceptibility-weighted sequences are useful in detecting microhaemorrhages and neovascular changes in GBM, which correlate with histopathological aggressiveness.[14] The study found blooming artifacts in 37.5% of GBM cases, similar to the rates reported by Scarabino et al., who suggested that GRE improves diagnostic confidence in distinguishing GBM from lower-grade gliomas and other mimics.[15] Spectroscopy findings in our cohort also mirrored published evidence. Authors observed universal elevation of choline and reduction of NAA, with a choline/creatinine ratio >2.5 in all GBM and AA cases.

This is consistent with Villoria et al who demonstrated that choline elevation reflects membrane turnover and proliferation, while reduced NAA indicates neuronal loss.[16] Ahmed et al further highlighted that lipid and lactate peaks are strongly associated with necrosis, which is a hallmark of GBM.[17] The study found lipid elevation in 83.4% of GBM cases, confirming the diagnostic utility of this parameter. When comparing advanced MRI to histopathology, our diagnostic accuracy was 90.3%, which aligns with international data. Henssen et al emphasized that while histopathology remains the gold standard, advanced MRI modalities substantially improve preoperative diagnosis, treatment planning and follow-up.[18] Wei et al also reported that emerging MR sequences, including DWI and spectroscopy, can achieve diagnostic accuracies above 85%, especially when used in combination.[19]

The integration of advanced MRI into clinical decision-making has been widely advocated. Castellano et al stressed that advanced imaging improves radiotherapy planning by accurately defining tumor margins and infiltrative components.[20] Similarly, Dhermain et al highlighted the role of functional imaging techniques in assessing treatment response and differentiating true progression from pseudoprogression.[21] These insights

suggest that the techniques used in our study are not only valuable for initial diagnosis but also for long-term disease monitoring.

The findings also reinforce the broader applicability of advanced MRI in differentiating GBM from other lesions. Mehrabian et al., demonstrated the utility of DWI and MRS in distinguishing GBM from brain metastases, which often share overlapping features on conventional imaging.[22] In the study, metastatic lesions consistently showed choline/creatinine ratios <2.5, contrasting with the elevated ratios seen in GBM and AA, thereby supporting this distinction.

Limitations

Despite these strengths, some limitations exist. The sample size was relatively small and the study was conducted at a single center, which may limit generalizability. Additionally, perfusion-weighted imaging, another advanced MRI modality with high utility in GBM, was not included. Nevertheless, the consistency of our findings with published literature supports the robustness of our results.

CONCLUSION

In conclusion, the study confirms that advanced MRI techniques including DWI, GRE and MRS significantly enhance the diagnostic accuracy of GBM when correlated with histopathology. These modalities provide essential insights into tumor biology, improve preoperative planning and can guide therapeutic strategies. Future research with larger cohorts and incorporation of perfusion and radiomics-based approaches may further refine the role of MRI in GBM management.

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