

Role of Diffusion Weighted Magnetic Resonance Imaging in the Evaluation of Benign, Atypical and Malignant Intracranial Meningiomas and Comparison with Histopathological Findings

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Abstract

Objective: This cross-sectional study was carried out in Radiology and Imaging department of Bangabandhu Sheikh Mujib Medical University, Dhaka, during January 2014 to December 2016, to evaluate the signal intensity of different types of intracranial meningiomas in DW MRI and to assess the association between signal intensity on DWI and histopathological gradings of intracranial meningiomas to predict the prognosis preoperatively.

Methods: A total of 53 patients underwent MR imaging and admitted in hospitals and enrolled for surgical management were included in this study. MRI and DWI were done in all these patients and they were followed up from the admission upto the post operative tissue diagnosis for histopathological correlation.

Results: More than one third (34.0%) of the patients were in 4th decade and male female ratio was 1:3.1. The mean duration of symptoms was found 10.8±8.8 months. Regarding the chief complaints all patients had headache followed by 52(98.1%) had vomiting, 28(52.8%), convulsion, 23(43.4%) were other predominant symptoms. Among distribution of MRI features almost three fourths 38 (71.7%) patients had supra tentorial and 15(28.3%) had infratentorial position and others are less in number. Regarding signal intensity on T1WI, isointense was found in 23(43.75%), about signal intensity on T2WI, Iso to hyperintense was found in 26(46.1%) and signal intensity on FLAIR, Iso to hyperintense was found in 26(46.1%). Regarding Diffusion Weighted MRI finding, diffusion restriction was found in 14(26.4%) and no diffusion restriction in 39(73.6%). About Diffusion Weighted MRI diagnosis, benign meningioma was found in 39(73.6%) and atypical/malignant meningioma in 14(26.4%). In histopathological diagnosis benign meningioma was found in 40(75.5%), atypical meningioma in 12(22.6%) and malignant meningioma in 1(1.9%). The validity of DW-MRI for diagnosis of benign, atypical and malignant meningioma was correlated by calculating sensitivity 92.3%, specificity 95.0%, accuracy 94.3%, positive predictive values 85.7% and negative predictive values 97.4%.

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Introduction

Meningiomas was named by Harvey Cushing in 1922.¹ Meningiomas are the most common primary nonglial neoplasm of the brain in adults, representing 15-20% of all intracranial tumors.² Their incidence increase with ages, peaks after the fifth decade of life and affects women more commonly than male, having a 2:1 female: male ratio. The annual incidence per 100,000 people ranges from 2 to 7 for females and 1 to 5 for males.³ Meningiomas are rare in children and young adults; they represent 1-3% of all intracranial tumors in individuals up to age 20 years and 13.5% of all intracranial tumors in the 20-34 age group; both significantly lower than the incidence in patient over the age 40. Sex differences are also evident among the age groups; among patients under the age of 20 years, they are more common in males while there is a female predominance in patients over the age of 20 years.⁴

There are three types of meningiomas based on malignant behavior: common benign (grade I), atypical (grade II) and malignant (grades III) (WHO 2000) and within the benign category, there are several subtypes, including syncytial, fibrous and transitional (Grade I).⁵ Meningioma of higher grade include the atypical, chordoid, and clear cell meningioma (Grade II) and the anaplastic, papillary, and rhabdoid meningiomas (Grade III). Most meningiomas are supratentorial and only 8% to 10% are located in the posterior fossa. In general, these lesions come to clinical attention as a result of symptoms including headache, seizure, hemiparesis, or cranial nerve neuropathy such as vision loss.⁶ Patients may also suffer subtle losses of neurological function over time including difficulty with speech such as finding words, changes in ability to concentrate, and weakness in an arm or leg causing problems with writing, gait, or walking.⁵

The aims of the imaging are to attain an accurate preoperative exclusion of other intracranial masses and to assess morphological appearances and relationships to adjacent structures as an aid to surgical resection. On precontrast CT scans, 86% of meningiomas were hyperdense relative to cortex; 3% were hypodense and 9% were isodense to cortex. On postcontrast studies, 98% were hyperdense.⁷ Magnetic resonance imaging has largely replaced CT for delineating the location and soft tissue imaging characteristics of meningiomas.⁸ The accuracy of diagnosis of meningiomas on MRI is estimated to be about 95% in most series.⁹ MR imaging provides improved delineation of dura and sinus involvement, and even information about a tumor's consistency.¹⁰ Bony abnormalities were much more likely to be detected by CT than by MRI, with hyperostosis being most often seen at the convexities and sphenoidal ridge.⁷

MRI characteristics of intracranial meningiomas are different. With regard to signal intensities, intracranial meningiomas on T1WI show isointense and hypointense signals. On T2WI, isointense and hyperintense signal are shown.¹¹ Soft meningiomas were predictably more often hyperintense on T2WI and hypointense on T1WI, whereas firm meningiomas were more often hypointense on T2WI and isointense on T1WI.¹

Most benign meningiomas are isointense on DW images. High signal intensity on DW images suggest malignant meningiomas. Diffusion restriction in malignant meningiomas is probably due to high tumor cellularity.¹² MRI plays a crucial role in the pre-operative assessment of brain meningiomas.¹³ Although meningiomas do have some identifiable imaging features on conventional MR images, no special features have been found to be reliable in the predicting tumor grade.¹⁴ Diffusion weighted magnetic resonance imaging (DW-MRI) is an imaging technique

based on the sensitivity of magnetic resonance (MR) to microscopic mobility of water molecules within tissue, and provides image contrast that is dependent on the molecular motion of water. Both tumor cellularity and the amount of fibrous tissue contribute the signal intensity on DWI.¹⁵ Lesions with diffusion restriction appear bright on DW images. Structures with increased diffusion like CSF will appear dark on DW images.¹⁶

Various theories have been proposed to explain the decreased free diffusion of water in high-grade tumors, including increased tumor cellularity, tumor matrices, fibrous or gliotic tissues, or a combination of these factors.¹⁷ Water diffusion in biologic tissue is highly dependent on the ratio of intracellular to extracellular space, and increased cellularity in high-grade tumors may decrease the fraction of extracellular space, thus restricting net water diffusion.¹⁸ Furthermore, compared with benign meningiomas, atypical and malignant meningiomas have increased mitotic activity, necrosis, prominent nuclei, and small cells with an increased amount of intracellular complex protein molecules and high nucleus-to-cytoplasm ratio, contributing to decreased free diffusion of water.¹⁹ In contrast, DWI is now commonly accepted as part of conventional MR examination in most institutes. For this reason, it is important to investigate the utility of diffusion-weighted (DW) MR imaging to differentiate benign and malignant meningiomas.

Methods

This was a cross-sectional study and carried out in the Department of Radiology and Imaging, BSMMU, Dhaka in collaboration of the Department of Neurosurgery and was conducted from January 2014 to December 2016. This study was carried out on patients with meningioma, who were attended in the Department of Radiology and Imaging for preoperative assessment of meningioma and

attended in the Department of Neurosurgery, BSMMU, Dhaka during the study period. Sample size was determined by power analysis for a single proportion. Purposive sampling was done. Patients who were diagnosed as meningioma by CT scan and coming for MRI including DWI in Radiology and Imaging Department, BSMMU and incidentally patients diagnosed by MRI as having meningioma, and are waiting for surgical intervention were included in the study. Patient who refused surgery, patients having absolute contraindication for MRI (e.g. Cardiac pacemaker, claustrophobia), non availability of histopathological reports not consistent with meningioma were excluded from the study. Data collection sheet was used to collect the necessary information. Voluntary written informed consent was taken from the patients and/or the legal guardian/responsible family members. At presentation a detailed history of illness were taken and general and neurological examination were carried out. MRI of brain was obtained on 1.5 T machine (Avanto Magnetom, Siemens) using T1WI (TR-195, TE-4.8), T2WI (TR-3280, TE-96), FLAIR (TR-8000, TE-93.0) & DWI (TR-3300, TE-118) two dimensional fast spin echo multislice technique. Confirmation of types of meningioma was done by histopathology. Statistical analyses were carried out by using the Statistical Package for Social Sciences version 20.0 for Windows (SPSS Inc., Chicago, Illinois, USA).

Results

This study includes 53 patients. Of them more than one third (34.0%) of the patients were in 4th decade (Table- I), male patients were 40 (75.5%) and patients were 13 (24.5%) with female ratio was 1:3.1. Mean duration of symptoms was found 10.8 ± 8.8 months (Table-II), regarding the chief complaints all patients had headache followed by 52 (98.1%) had vomiting, 28 (52.8%), convulsion 23 (43.4%) were predominant symptoms (Figure-I), almost three fourths 38 (71.7%) patients had supra

tentorial and 15(28.3%) had infratentorial position and others are less in number in MRI features (Table-III), regarding signal intensity on T1WI, isointense was found in 23(43.75%), about signal intensity on T2WI, Iso to hyperintense was found in 26(46.1%) and signal intensity on FLAIR, Iso to hyperintense was found in 26(46.1%) (Table-IV), diffusion Weighted MRI finding, diffusion restriction was found in 14(26.4%) and no diffusion restriction in 39(73.6%) (Table-V), diffusion Weighted MRI diagnosis, benign meningioma was found in 39(73.6%) and atypical/malignant meningioma in 14(26.4%) (Table- VI). In histopathological diagnosis benign meningioma was found in 40(75.5%), atypical meningioma in 12(22.6%) and malignant meningioma in 1(1.9%) (Table-VII). The validity of DW-MRI for diagnosis of benign, atypical and malignant meningioma was correlated by calculating sensitivity 92.3%, specificity 95.0%, accuracy 94.3%, positive predictive values 85.7% and negative predictive values 97.4% (Table-IX).

Table I: Distribution of the study patients by age variable (n=53)

Socio-demographic variable	Number of patients	%
Age (in years)		
21 - 30	8	15.1
31 - 40	10	18.9
41 - 50	18	34.0
51 - 60	13	24.5
61 - 70	3	5.7
71 - 8	1	1.9
Total	53	100

Table II: Distribution of the study patients by duration of symptoms (n=53)

Duration of symptoms (months)	Number of patients	%
≤10	38	71.7
>10	15	28.3
Total	53	100

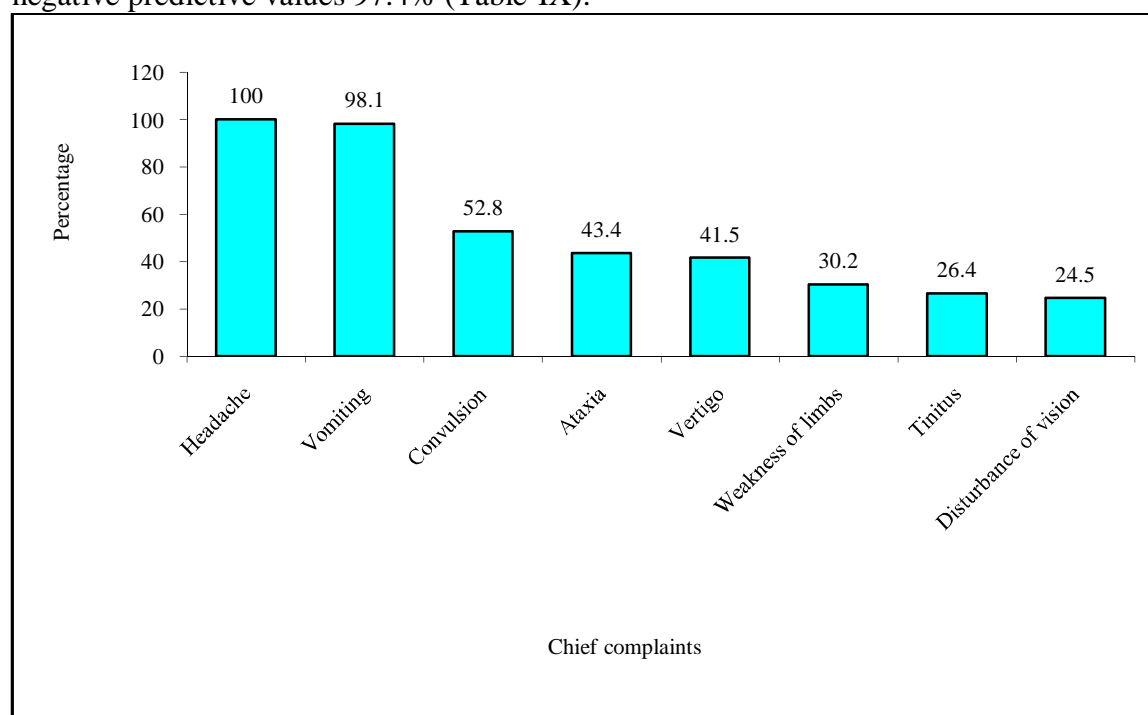


Figure 1. Bar diagram shows chief complaints of the patients

Table III: Distribution of the study patients by MRI features (n=53)

MRI features	Number of patients	%
Position		
Supra tentorial	38	71.7
Infratentorial	15	28.3
Location		
Convexity	9	17.3
Parasagittal	16	30.8
Sphenoid	8	15.4
Middle cranial fossa	4	7.7
Frontal	3	5.8
Posterior fossa	13	25
Shape of the lesion		
Rounded	11	20.8
Oval	17	32.1
Labulated	24	45.3
Others	1	1.9
Number of lesion		
One	51	96.2
Multiple	2	3.8

Table IV: Distribution of the study patients by routine MRI findings (n=53)

Routine MRI findings	Number of patients	%
Signal intensity on T ₁ WI		
Hypointense	14	26.4
Iso to hypointense	15	28.3
Isointense	23	43.4
Hyperintense	1	1.9
Signal intensity on T ₂ WI		
Hypointense	1	1.9
Iso to hypointense	2	3.8
Isointense	3	5.7
Iso to hyperinten	26	49.1
Hyperintense	21	39.6
Signal intensity on FLAIR		
Hypointense	1	1.9
Iso to hypointense	2	3.8
Isointense	3	5.7
Iso to hyperinten	26	49.1
Hyperintense	21	39.6

Table V: Distribution of the study patients by Diffusion Weighted MRI findings (n=53)

Diffusion weighted MRI finding	Number of patients	%
Diffusion restriction	14	26.4
No diffusion restriction	39	73.6
Total	53	

Table VI: Distribution of the study patients by Diffusion Weighted MRI diagnosis (n=53)

Diffusion weighted MRI diagnosis	Number of patients	%
Benign meningioma (WHO-Grade I)	39	73.6
Meningioma (WHO - Grade II or WHO - Grade III)	14	26.4
Total	53	100

Table VII: Distribution of the study patients by histopathological diagnosis (n=53)

Histopathological diagnosis	Number of patients	%
Benign meningioma	40	75.5
Atypical meningioma	12	22.6
Malignant meningioma	1	1.9
Total	53	

Table VIII: Comparison between histopathology and Diffusion Weighted MRI evaluation of meningioma (n=53)

DW-MRI	Histopathology	
	Positive (n=13)	Negative (n=40)
Positive (n=14)	12 (True positive)	2 (False positive)
Negative (n=39)	1 (False negative)	38 (True negative)

Table IX: Sensitivity, specificity, accuracy, positive and negative predictive values of DW-MRI diagnosis evaluation of meningioma

Validity test for DW-MRI	%
Sensitivity	92.3
Specificity	95.0
Accuracy	94.3
Positive predictive value	85.7
Negative predictive value	97.4

Discussion

Meningiomas are rare in children and young adults; they represent 1-3% of all intracranial tumors in individuals up to age 20 years and 13.5% of all intracranial tumors in the 20-34 age group. In this study it was observed that more than one third (34.0%) patients were in 4th decade and the mean age was found 45.3 ± 11.9 years with range from 24 to 80 years. Similarly, Moradi et al. found the mean age of patients with meningiomas was 49.11 ± 12.99 years with range 6–78 years.⁶

In this present study it was observed that meningiomas is predominant in female subject, where more than three fourth (75.5%) patients were female and 24.5% were male. Male female ratio was 1:3.1. Similarly, Stefanovic et al. (2011) found 33.3% and 66.7% patients were male and female respectively and male to female ratio was 1:2.¹¹

In this current study it was observed that almost three fourth (71.7%) patients had duration of

symptoms ≤ 10 months. The mean duration of symptoms was found 10.8 ± 8.8 months with range from 1 to 24 months.

Sanders et al mentioned that signs of increased cranial pressure are found in 50% of the patients. Headache has been reported as the most common single presenting symptom, found in 36.0%, while normal physical examination has been reported in 26.0% of patients. In this series it was observed that all (100.0%) patients had headache followed by 52(98.1%) had vomiting, 28(52.8%) had convulsion.²¹

Most meningiomas are supratentorial and only 8% to 10% are located in the posterior fossa. Convexity meningiomas were most common, followed by meningiomas of the sphenoid ridge and cerebellopontine angle.⁶ In this study it was observed that almost three fourth (71.7%) patients had supra tentorial, 30.8% had parasagittal site, 45.3% had lobulated shape of the lesion, 96.2% patients was found having single lesion.

MRI characteristics of intracranial meningiomas are different. With regard to signal intensities, intracranial meningiomas on T1WI show isointense and hypointense signals. On T2WI, isointense and hyperintense signal are shown.¹¹ Soft meningiomas were predictably more often hyperintense on T2 and hypointense on T1, whereas firm meningiomas were more often hypointense on T2 and isointense on T1.¹ Most benign meningiomas are isointense on DW images. High signal intensity on DW images suggest malignant meningiomas.¹¹ In this present study it was observed that regarding signal intensity on T₁WI, most common is isointense 43.75% and on T₂WI, mostly found Iso to hyperintense 26(46.1%). About the signal intensity on FLAIR, Iso to hyperintense was found in 26(46.1%), hyperintense in 21(39.6%),

isointense in 3(5.7%), iso to hypointense in 1(1.9%) and Iso to hypointense in 2(3.8%).

In this series it was observed that regarding diffusion weighted MRI finding, diffusion restriction was found in 26.4% and no diffusion restriction in 73.6%. Regarding diffusion weighted MRI diagnosis, benign meningioma was found in 39(73.6%) and malignant meningioma in 14(26.4%).

In this study, histopathological diagnosis of the study patients, it was observed that benign meningioma was found in 40(75.5%), atypical meningioma in 12(22.6%) and malignant meningioma in 1(1.9%).

In this current study it was observed that the validity of DW-MRI for diagnosis of meningioma was correlated by calculating sensitivity 92.3%, specificity 95.0%, accuracy 94.3%, positive predictive values 85.7% and negative predictive values 97.4%. Tantawy et al., showed in their study, the validity of advanced MRI (DW-MRI) in distinguishing atypical and malignant meningioma was as follow, sensitivity 83.3%, specificity 95.8%, positive predictive value 83.3%, negative predictive value 95.8%.²² Nagar et al. showed in their study, the accuracy of the DW-MR imaging to diagnosing typical and atypical/malignant meningioma was as follows, with a sensitivity of 96%, specificity of 82.6%, positive predictive value of 85.7%, and negative predictive value of 95%. The above studies findings are comparable with the current study.²³

Conclusion

This study was undertaken to establish the diagnostic usefulness of DW-MRI in evaluation of Benign, Atypical and Malignant intracranial meningiomas. It can be concluded that the Diffusion Weighted Magnetic Resonance Imaging (MRI) is an useful diagnostic modality in pre-operative discrimination of types of

intracranial meningiomas and it should be worthy to note here that DW-MRI can be used as a reliable tool with which we can assess intracranial meningiomas types and can be plan the subsequent appropriate management in majority of cases.

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