Int. J Med. Pharm. Res. (P-ISSN: 2958-3675 | E-ISSN: 2958-3683)
Available on: https://ijmpr.in/

International Journal **of Medical and Pharmaceutical Research**

ORIGINAL ARTICLE **OPEN ACCESS**

Evaluating the Diagnostic Efficacy of Diffusion Weighted Imaging and MR Spectroscopy in Brain Tumor Classification

Dr. Samineni Nandini[1], Dr. Parthasarathy K R[2], Dr Akhilesh Shanbhough[1], Dr. M Sirisha[1], Dr. Chirag A Thakker[1], Dr Kewin Raj[1]
[1]Department of Radiodiagnosis, Junior Resident, SSIMS and RC; RGUHS, INDIA
[2]Department of Radiodiagnosis, Professor and Head of department, SSIMS and RC/ RGUHS, INDIA

OPEN ACCESS

***Corresponding Author**
Dr. Samineni Nandini
Department of Radiodiagnosis, Junior Resident, SSIMS and RC; RGUHS, INDIA

Received: 10-11-2024
Accepted: 20-12-2024
Available online: 30-12-2024

ABSTRACT

Introduction: The objective is to evaluate efficacy of DWI and MR spectroscopy with conventional MRI in differentiation and grading of brain tumors.
Material and Methods: A total number of 60 patients with brain tumours who were referred to Department of Radiodiagnosis, SSIMS&RC, Davanagere over a period of 2 years.
Results: Study group consists of 39 male and 21 female patients, majority of the age group is 40.0%. Accordingly, the mean ADC value was 0.81 with a standard deviation of around ±0.216. However, the proportion of each diagnosis was found to be quite different from the actual diagnosis based on HPE, thereby suggesting the possibility of false reports from the DWI procedure.
MRS was performed and ratios between choline and creatinine, NAA and creatinine, and choline and NAA to diagnose the condition.
Conclusion: On performing both DWI and MRS among patients with history of headache and focal neurological deficits, the study observed the following;
DWI was in correlation with ADC values which helped in diagnosing the condition appropriately in most of the cases.
MR spectroscopy was successful in imaging and grading the brain tumors using the ratios between choline and creatinine, N-acetyl aspartate and creatinine, and choline and N-acetyl aspartate.
MR spectroscopy proven to be more sensitive than diffusion weighted imaging in all the cases.

Key words: DWI, ADC, MR spectroscopy, HPE.

INTRODUCTION

Tumors of the central nervous system (CNS) constitute approximately 2% of all malignancies. The incidence of central nervous system (CNS) tumors in India ranges from 5 to 10 per 100,000 population[1].

Astrocytomas (38.7%) were the most common primary tumors in adults with the majority being high-grade gliomas (59.5%)[2]. The most common tumor in pediatric age group were astrocytoma (34.7%) followed by medulloblastoma and supratentorial PNETs (22.4%) and craniopharyngioma[3].

The primary roles of structural MRI in the initial brain tumor evaluation include determining the lesion location, extent of tissue involvement, and resultant mass effect upon the brain, ventricular system, and vasculature[4].
MRI offers superior soft tissue contrast over other cross-sectional imaging techniques allowing for better visualization of subtly infiltrated or disrupted parenchymal architecture.

Furthermore, intravenous gadolinium-based contrast agents shorten T1 relaxation times and increase tissue contrast by accentuating areas where contrast agents have leaked out of the blood–brain barrier into the interstitial tissues, resulting in parenchymal enhancement.

Diffusion weighted imaging (DWI) although primarily used in the setting of suspected acute stroke also offers significant value in the evaluation of brain tumors along with conventional MRI.. Corresponding apparent diffusion coefficient (ADC) values, reflecting the magnitude of diffusivity, are derived for each voxel and displayed as a calculated ADC map. In the pretreatment evaluation of brain tumors, Low ADC values, representing decreased water diffusivity, can be used to suggest about high cellularity of tumors and increased grade of tumor [5] .

Proton magnetic resonance spectroscopy (H-MRS), a non-invasive technique, has been used to observe metabolite changes in different intracranial abnormalities such as tumors, stroke, tuberculomas, multiple sclerosis and metabolic-inherited brain disorders, epilepsy and traumatic injuries. Several types of non-neoplastic brain disorders (infectious demyelinating lesions, etc.) can be potentially misdiagnosed as brain tumors. H-MRS may improve the diagnosis of unknown brain lesions. Particularly H-MRS is added to the routine brain MRI in order to solve diagnostic problems such as differentiation of neoplastic and non-neoplastic lesions, low and high-grade tumors, ischemia from low-grade gliomas or discriminating the metastases from primary brain tumors and abscess[6] .

MATERIALS AND METHOD

The present study was conducted in the Department of Radiodiagnosis, SSIMS & RC, Davanagere, from July 2022 to December 2023. Institutional ethical clearance was obtained for the study by the Institutional Review Board.
Study design: Hospital based prospective clinical study.
Study place: Department of Radiodiagnosis, SSIMS& RC, Davanagere.
Study duration: July 2022 to December 2023.
Sample Size: 60
Equipment used –GE 1.5 T Signa at SSIMS and RC hospital, Davangere

SCANNING TECHNIQUE:

Position –Patient placed in supine head first position with shoulder & arm placed alongside parallel to body positioned in neutral position.
The tests were performed using following parameters.
Slice thickness –4 to 5mm
Matrix size – 512 x512
Sequences:
Conventional spin echo sequences, axial T1, T2 and FLAIR: Coronal T2 FLAIR, Sagittal T1 and axial SWAN.
Axial DWI done in b value 1000, and for some cases b value of 2000 was used.
Post contrast axial, coronal and sagittal.
Multivoxel spectroscopy was done at TR 144 and TR 35. The voxel was placed on the lesion so that it covers the maximum areaof the lesion in a single voxel. In addition CSI grid was placed above the voxel. We used T2 localiser and T1 post contrast sequence aslocalization sequence with 5 mm thickness. Spectroscopy was avoided in smalllesions close to the bone.
Timing: The overall duration of examination was from 40 to 50 minutes.

STATISTICAL ANALYSIS:

Statistical software SPSS version 22 (IBM SPSS Statistics, Somers NY, USA) was used to analyse the data. P-value of <0.05 was considered statistically significant.

RESULTS

Study group consists of 39 male and 21 female patients. In our study of 60 patients, majority of the participants i.e., about 40.0% belonged to the age group of 51-60 years. Nearly one third of them had even crossed 60 years. The next common age group was 41-50 years. Remaining cases were below 40 years.

In the study, diffusion weighted imaging was performed among the participants to diagnose the condition where the apparent diffusion coefficient values were utilized. Accordingly, the mean ADC value was 0.81 with a standard deviation of around ±0.216. However, the proportion of each diagnosis was found to be quite different from the actual diagnosis based on histopathological examination, thereby suggesting the possibility of false reports from the DWI procedure.

In the study, magnetic resonance spectroscopy was performed among the partcipants, which considered the ratios between choline and creatinine, N-acetyl aspartate and creatinine, and choline and N-acetyl aspartate, to diagnose the condition. Accordingly, the clinical condition was diagnosed. Although, the proportion of each diagnosis was found to be quite similar with the actual diagnosis based on histopathological examination, the study still needs to rule out the possibility of false reports from MR spectroscopy.

Table 1

Association between diagnosis and age of the study participants

Diagnosis	Mean age	Standard Deviation	Minimum age	Maximum age
Glioblastoma Multiforme	63.25	6.506	52	74
High Grade Glioma	48.45	7.188	35	59
Low Grade Glioma	49.80	8.786	40	60
Lymphoma	47.14	11.067	28	62
Meningioma	51.00	4.397	45	58
Metastasis	63.71	6.955	52	74
Total	**56.22**	**10.213**	**28**	**74**
p-value	**<0.001**			

Diagnosis of the study participants based on apparent diffusion coefficient values

Diagnosis	Frequency (%)	Mean ADC ± SD	Range
Glioblastoma Multiforme	17 (28.3%)	0.69 ± 0.075	0.6 - 0.8
High Grade Glioma	12 (20.0%)	0.65 ± 0.131	0.5 - 0.9
Low Grade Glioma	8 (13.3%)	1.02 ± 0.158	0.8 - 1.3
Lymphoma	5 (8.3%)	0.68 ± 0.837	0.6 - 0.8
Meningioma	7 (11.7%)	1.21 ± 0.107	1.1 - 1.4
Metastasis	11 (18.3%)	0.82 ± 0.087	0.7 - 0.9
Total	**60 (100.0%)**	**0.81 ± 0.216**	**0.5 - 1.4**

Diagnosis of the study participants based on magnetic resonance spectroscopy

Diagnosis	Frequency (%)	CHO/Cr (Mean ± SD)	NAA/Cr (Mean ± SD)	CHO/NAA (Mean ± SD)
Glioblastoma Multiforme	16 (26.7%)	2.99 ± 1.181	1.19 ± 0.442	2.93 ± 1.724
High Grade Glioma	11 (18.3%)	2.81 ± 1.013	1.12 ± 0.365	2.79 ± 1.618
Low Grade Glioma	5 (8.3%)	2.17 ± 0.674	1.29 ± 0.536	2.07 ± 1.212
Lymphoma	7 (11.7%)	2.87 ± 1.156	1.15 ± 0.402	2.86 ± 1.671
Meningioma	7 (11.7%)	2.25 ± 0.767	1.33 ± 0.587	2.11 ± 1.240
Metastasis	14 (23.3%)	2.45 ± 0.981	1.21 ± 0.488	2.51 ± 1.532

Sensitivity and specificity of diffusion weighted imaging and magnetic resonance spectroscopy in diagnosing glioblastoma multiforme

Reality		Glioblastoma Multiforme		Sensitivity	Specificity
		Positive	Negative		
Diffusion Weighted Imaging	**Positive**	11	6	**68.75**	**86.36**
	Negative	5	38		
MR Spectroscopy	**Positive**	12	4	**75.00**	**90.90**
	Negative	4	40		

DISCUSSION

The present hospital based prospective clinical study was conducted for a period of nearly 2 years on about 60 patients with history of headache and focal neurological deficits, who got referred to the department of RADIO-DIAGNOSIS at S.S. Institute of Medical Sciences & Research Centre, to study the role of DWI with ADC correlation in imaging of brain tumors and to understand the role of MR spectroscopy in imaging and grading of brain tumors. The study also tried to evaluate the role of DWI and MR spectroscopy in treatment of brain tumors where possible.

Various studies have been conducted all over the world in the recent years with the similar objectives. In Poland, Bobek-Billewicz B et al [7] conducted a retrospective analysis using perfusion, diffusion-weighted imaging and MR spectroscopy to differentiate brain tumor recurrence and radiation injury. Toussaint M et al [8] from France predicted tumor response to interstitial photodynamic therapy for glioblastoma using proton MR spectroscopy and Diffusion MR imaging. Another study in Italy by Zonari P et al[9] compared the value of DWI, PWI and MRS in evaluating the histologically proven high and low grade gliomas an around 105 patients.

In the study, histopathological examination was performed to obtain actual diagnosis of the participants. This is considered as gold standard for confirmation of diagnosis. Such that majority of them i.e., about 26.7% were diagnosed with glioblastoma multiforme. The next common condition was metastasis, followed by high grade glioma. This was quite different from the study by Bulakbasi N et al[10] in Turkey, the histological examination found that low grade glioma in larger proportions in comparison with high grade glioma, followed by metastasis.

Majority of the participants in the present study i.e., about 40.0% belonged to the age group of 51-60 years. Nearly one third of them had even crossed 60 years. The next common age group was 41-50 years. Remaining cases were below 40 years. This resembles the study by Naveen J et al [11] where the majority were in the range of 40-59 years. Such that the common age group with the occurrence of the brain tumours can be deduced. The mean age of the participants in the present study was estimated to be 56.22 years with a standard deviation of around ±10.213 years. This is similar to the findings from the study by Senft C et al[12] where the mean age was 55 years with a standard deviation of around ±13 years. However, in the study by Abul-Kasimet al[13], the participants were quite elderly with the mean age of 58 years and a standard deviation of around ±17 years. Further on comparing the mean age of the participants with respect to the diagnosis, the study found statistical significant association where the patients diagnosed with gliobalstoma multiforme and metastasis had crossed 60 years in majority cases, thereby suggesting that elderly age group are more prone with these clinical conditions.

In the study, majority of the participants i.e., nearly two third of them were males. Even with respect to each diagnosis, males were predominant except meningioma which had affected more females comparatively. This can be justified by the findings from various studies such as Caivano R et al[14], Fountas KN et al[15] and Murakami R et al[16], where the male predominance can be appreciated. However, on analysing further for existence of any association between gender of the participants and clinical condition, the present study did not find statistically significant relation.
Majority of the participants in the study i.e., about 58.3% were residing in urban areas. Even with respect to each diagnosis, urban people were predominant except lymphoma which was present more in rural people comparatively. On analysing for existence of any association between locality of the participants and clinical condition, the study did not show statistically significant relation. None of the previous studies have analysed the association between the locality and the types of brain tumours.

In the study, diffusion weighted imaging was performed among the participants to diagnose the condition where the apparent diffusion coefficient values were utilized.

Accordingly, the mean ADC value was 0.81 with a standard deviation of around ±0.216. In the studies such as Kang Y et al[17], Zonari P et al[9], Mulyadi R et al[13], and Bulakbasi N et al[10], ADC values had been used to differentiate low grade and high grade gliomas, where the mean ADC values were estimated to be closer to the value obtained in the present study. Also the studies such as Darwiesh AMN et al[18] and Naveen J et al[11] had graded the brain tumours keeping the ADC values as the diagnostic tool. In addition to these, the study by Bobek-Billewicz B et al [7] had shown that the recurrence of the brain tumour and radiation injury can be differentiated using ADC values. However, in the present study, the proportion of each diagnosis was found to be quite different from the actual diagnosis based on histopathological examination, thereby suggesting the possibility of false reports from the DWI procedure.

Magnetic resonance spectroscopy is another investigative tool performed among the participants in the present study, which considered the ratios between choline and creatinine, N-acetyl aspartate and creatinine, and choline and N-acetyl aspartate, to diagnose the condition. Accordingly, the clinical condition was diagnosed. This can be observed in multiple previous studies such as Darwiesh AMN et al [18], Abul-Kasim K et al[13], Caivano R et al[13] etc where the values of choline, creatinine, and N-acetyl aspartate were proven to be useful in gradin the tumours. Although, the proportion of each diagnosis was found to be quite similar with the actual diagnosis based on histopathological examination, the present study still needs to rule out the possibility of false reports from MR spectroscopy.

On comparing the actual diagnosis of the clinical condition based on histopathological examination, with the diagnosis made by the procedures such as diffusion weighted imaging and magnetic resonance spectroscopy, the study found few discrepancies. This helped in estimating the sensitivity of the procedures with respect to each condition. Accordingly, DWI achieved more than 75% sensitivity in diagnosing only low grade glioma. In all remaining cases, it was found to be less than 75% sensitive. Whereas MR spectroscopy proved to be quite superior comparatively as the sensitivity was estimated to be more than 75% in all cases except meningioma. These values are quite closer to the findings from previous studies such as Abul-Kasim K et al[13], and Zonari P et al[9] where all the MR spectroscopy was confirmed to be more sensitive than DWI.

Further, the study also estimated the specificity of the procedures with respect to each condition on comparing the actual diagnosis of the clinical condition based on histopathological examination, with the diagnosis made by the procedures such as diffusion weighted imaging and magnetic resonance spectroscopy. Accordingly, DWI and MR spectroscopy both achieved more than 85% specificity in grading the tumors. Such that DWI was more specific in diagnosing lymphoma and metastasis while MR spectroscopy proved to be quite superior comparatively as the specificity was estimated to be more in diagnosing remaining conditions. These values can be justified by the findings from previous studies such as Caivano R et al[13] and Wang W et al[19] where all both the procedures were proven to be highly specific in diagnosing the conditions.

CONCLUSION

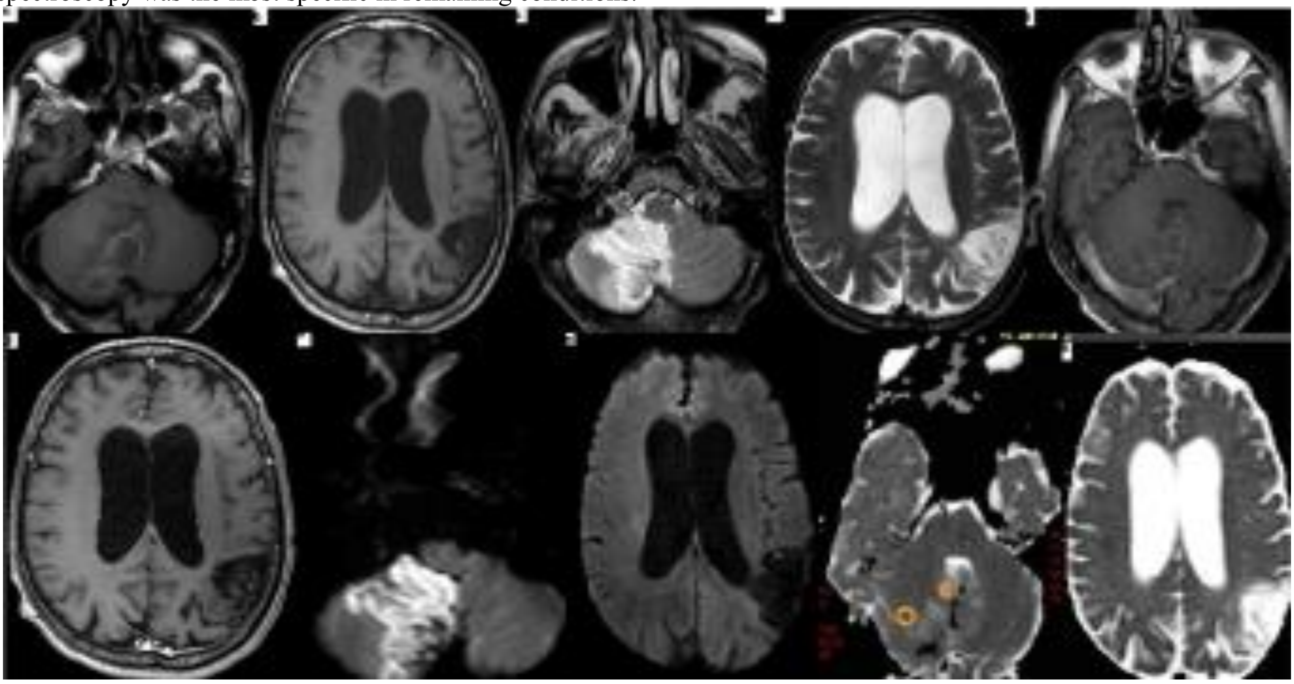
On performing both diffusion weighted imaging and magnetic resonance spectroscopy among the patients with history of headache and focal neurological deficits, the study observed the following;

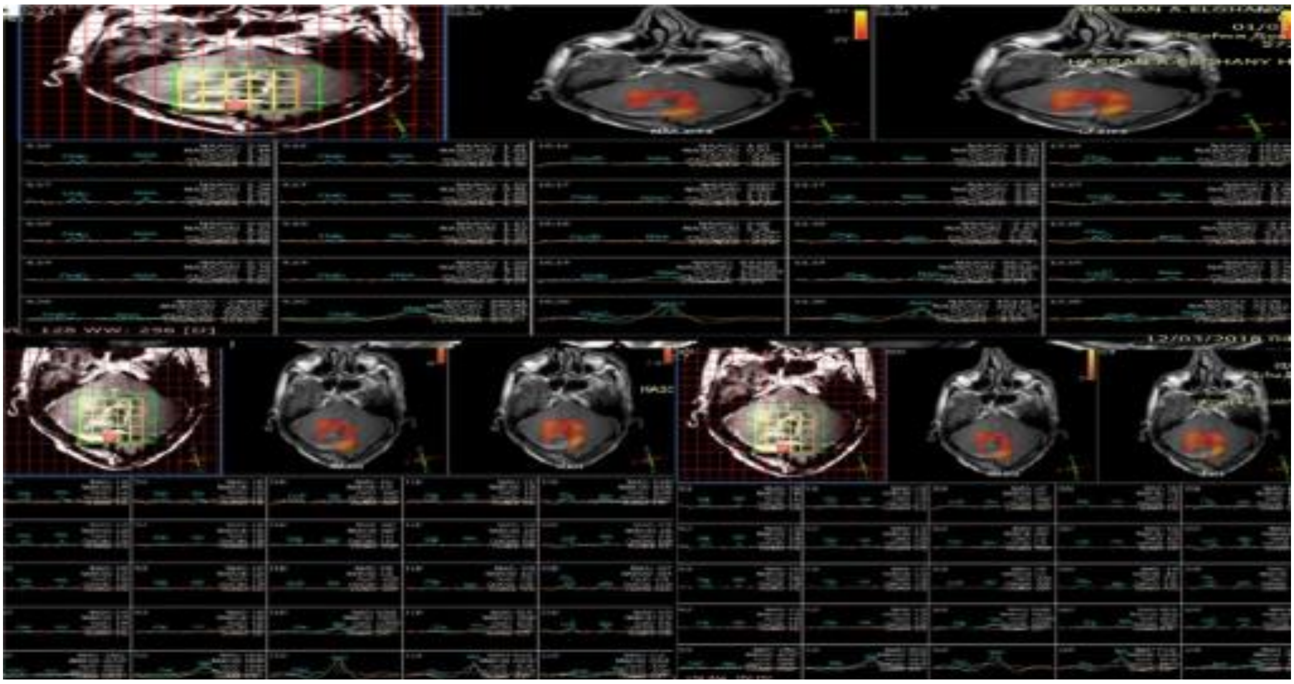
Diffusion weighted imaging was in correlation with the Apparent diffusion coefficient values which helped in diagnosing the condition appropriately in most of the cases.

MR spectroscopy was successful in imaging and grading the brain tumors using the ratios between choline and creatinine, N-acetyl aspartate and creatinine, and choline and N-acetyl aspartate.

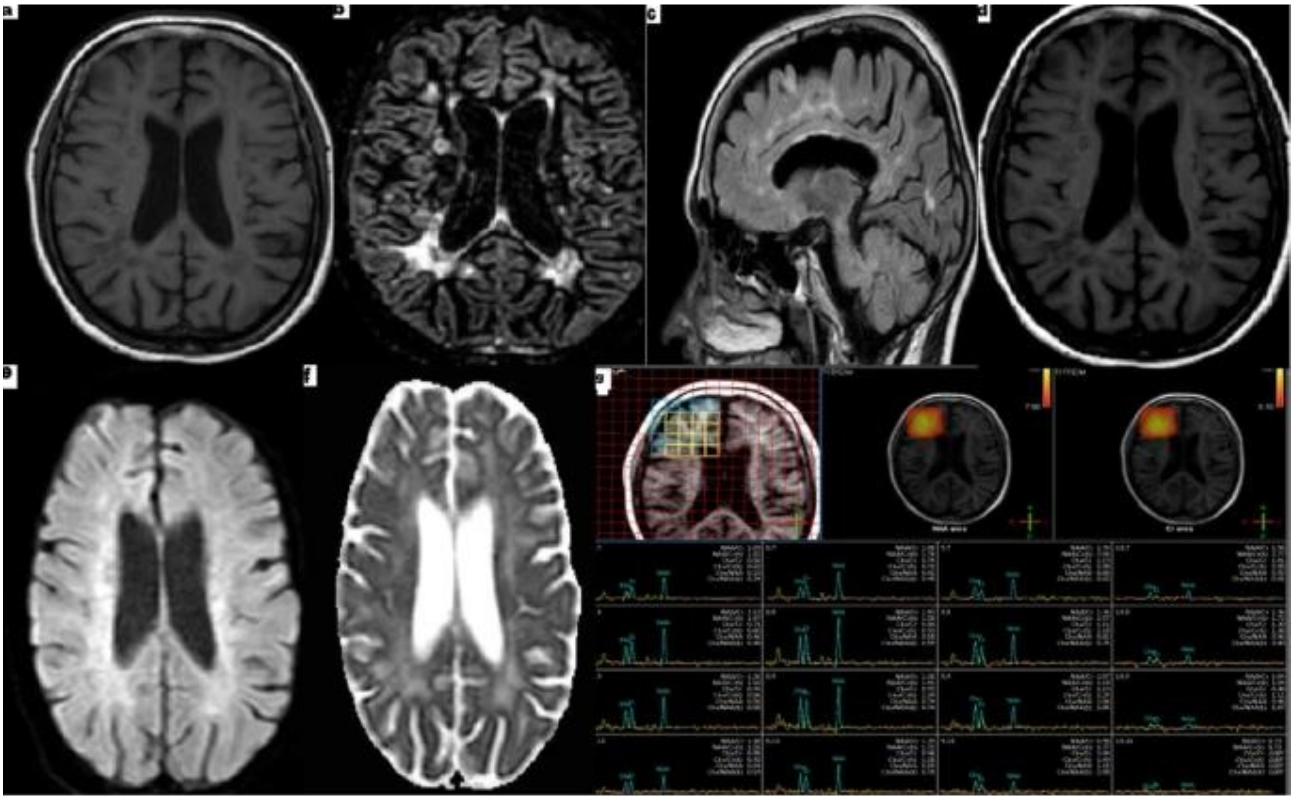
MR spectroscopy proven to be more sensitive than diffusion weighted imaging in all the cases.

Although, diffusion weighted imaging was capable of being more specific in diagnosing lymphoma and metastasis, MR spectroscopy was the most specific in remaining conditions.

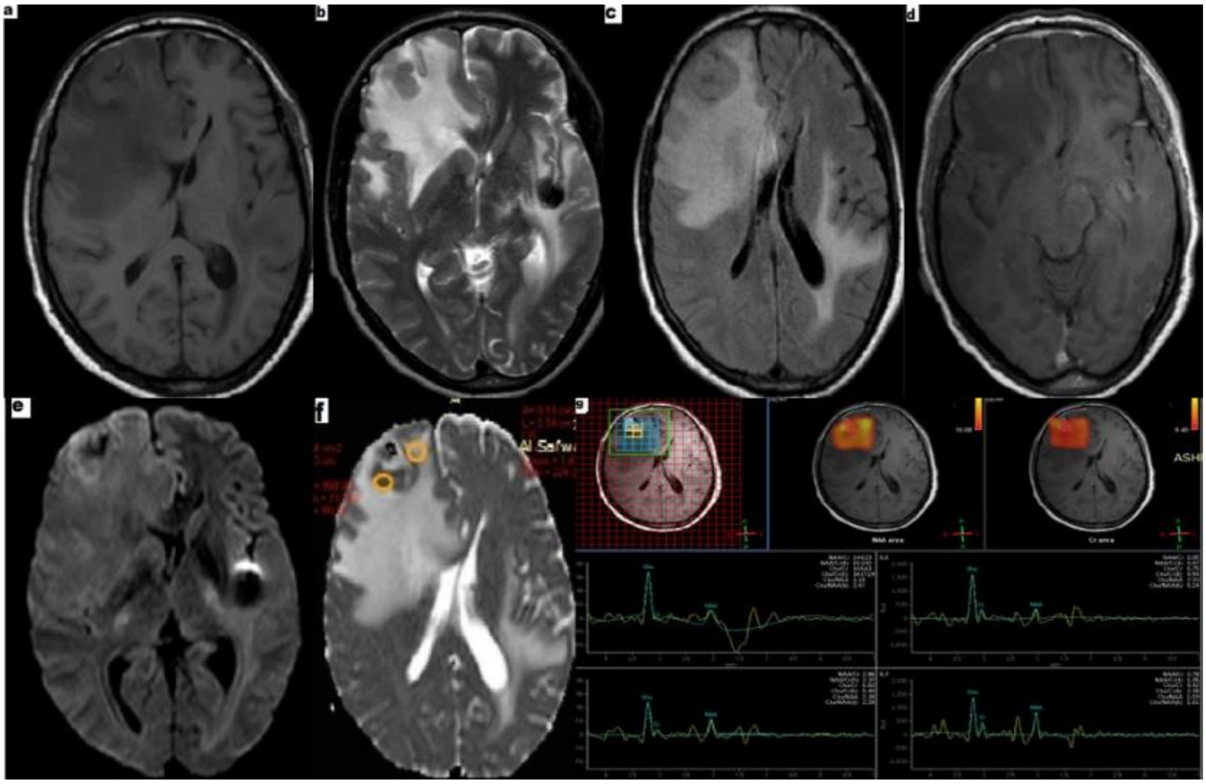




A 42-year-old female patient" MRI exam revealed multiple well-defined abnormal signal intensity lesions at the cerebellum and Lt. occipital regions that exhibit hypointense signal at T1 with hyperintense foci within cerebellum lesion (suggesting blood) (a, b) and hyperintense signals at T2 (c, d) with no associated edema. DWI and ADC map (e, f and g, h) showed mixed diffusion changes (restriction/T2 shin effect at cerebellum and facilitated diffusion of occipital lesion). Post Gad (i, j) showed no contrast appreciable enhancement. MRS (k) revealed no significant changes either of NAA, Cr, or Cho peaks with maintained ratios at the lesional and pre-lesional areas. MRI diagnosis: multiple infarcts of different chronologic ages that proved by clinical diagnosis and follow-up



A 33-year-old female patient" MRI exam revealed multiple well-defined abnormal signal intensity foci scattered at the white matter of both cerebral hemispheres and posterior fossa that exhibit iso-hypointense signal at T1 (a) and hyperintense at 3D Gr and FLAIR (b, c) with no associated edema. DWI and ADC map (d, e) showed mixed diffusion changes (restriction/T2 shin effect). Post Gad (f) showed no contrast enhancement. MRS (g) revealed no significant metabolic changes with maintained ratios at the lesional and pre-lesional areas. MRI diagnosis: multiple sclerosis. Clinical diagnosis and follow-up: MS



“A 54-year-old male patient” MRI exam revealed multiple poorly defined intra axial SOL shown in images at Rt. frontal and Lt. parietal regions, iso-hypointense at T1 (a) and hyperintense T2/FLAIR (b, c) that surrounded with moderate edema. DWI and ADC map (d, e) showed diffusion restriction with low ADC value. Post Gad (f) showed faint contrast enhancement. MRS (g) revealed marked reduction of NAA and Cr peaks with elevated Cho and reversed NAC/Cr and Chol/Cr ratios in lesional and pre-lesional areas. MRI diagnosis: multicentric primary high-grade glioma. Pathology: GBM

SUMMARY

In our study, MRI of 60 patients with ages ranging from 25 years to 75 years with history of headache, focal neurological deficits or known history of tumor was done with GE signa1.5 T MR Scanner, over a period of 2 years. Various parameters of the brain tumors were assessed.

Out of 60 patients, 39 were men (65%) and 21 (35%) women. The maximum number of patients were between 51 to 60 years (40%) of age.

Of all patients, the commonest observed pathology was glioblastoma multiforme 16 patients (27%) followed by metastasis 14 patients (24%).

The Apparent diffusion coefficient value in the diffusion weighted imaging suggested a trend of higher coefficient values for a tumor of lower grade and a lower coefficient value for a tumor of higher grade.

The presence of tumor on MR spectroscopy is detected by increase in choline and decrease in NAA levels in majority of cases. The ratios between choline and creatinine, N acetyl aspartate and creatinine, choline and N acetyl aspartate can be used to differentiate the grades of tumors.

The sensitivityand specificity of diffusion weighted imaging in diagnosing and grading of brain tumors was in the range of 68-80% and 86-100% respectively. Whereas the sensitivity and specificity of diffusion weighted imaging in diagnosing and grading of brain tumors was in the range of 75-85% and 90-96% respectively.

Hence, MR spectroscopy was more sensitive than diffusion weighted imaging in diagnosing, differentiation and grading of brain tumors. Whereas, both the techniques when used in correlation with the conventional MRI can significantly increase our ability to detect and correctly diagnose a brain tumor.

REFERENCES

1. Nair MK, Varghese C, Swaminathan R. Cancer: Current scenario, intervention strategies and projections for 2015. NCHM Background papers-Burden of Disease in India. 2005:219-5.
2. Jalali R, Datta D. Prospective analysis of incidence of central nervous tumors presenting in a tertiary cancer hospital from India. Journal of Neuro-oncology. 2008 Mar;87(1):111-4.
3. Jain A, Sharma MC, Suri V, Kale SS, Mahapatra AK, Tatke M, Chacko G, Pathak A, Santosh V, Nair P, Husain N. Spectrum of pediatric brain tumors in India: A multi-institutional study. Neurology India. 2011 Mar 1;59(2):208.
4. Villanueva-Meyer JE, Mabray MC, Cha S. Current clinical brain tumor imaging. Neurosurgery. 2017 Sep 1;81(3):397-415.
5. Aydın, Z. B., Aydın, H., Birgi, E., & Hekimoğlu, B. (2019). Diagnostic value of diffusion-weighted magnetic resonance (MR) imaging, MR perfusion, and MR spectroscopy in addition to conventional MR imaging in intracranial space-occupying lesions. Cureus.
6. Aydın, H., Lu, S. S., Oktay, N. A., Altın, E., Kızılgöz, V., & Hekimoglu, B. (2011). The value of proton mr-spectroscopy in the differentiation of brain tumours from non-neoplastic brain lesions. Journal of the Belgian Society of Radiology, 94(1), 1.
7. Bobek-Billewicz B, Stasik-Pres G, Majchrzak H, Zarudzki L. Differentiation between brain tumor recurrence and radiation injury using perfusion, diffusion-weighted imaging and MR spectroscopy. Folia Neuropathol. 2010 Jan 1;48(2):81-92.
8. Toussaint M, Pinel S, Auger F, Durieux N, Thomassin M, Thomas E, Moussaron A, Meng D, Plénat F, Amouroux M, Bastogne T. Proton MR spectroscopy and diffusion MR imaging monitoring to predict tumor response to interstitial photodynamic therapy for glioblastoma. Theranostics. 2017;7(2):436.
9. Zonari P, Baraldi P, Crisi G. Multimodal MRI in the characterization of glial neoplasms: the combined role of single-voxel MR spectroscopy, diffusion imaging and echo-planar perfusion imaging. Neuroradiology. 2007 Oct;49(10):795-803.
10. Bulakbasi N, Guvenc I, Onguru O, Erdogan E, Tayfun C, Ucoz T. The added value of the apparent diffusion coefficient calculation to magnetic resonance imaging in the differentiation and grading of malignant brain tumors. Journal of computer assisted tomography. 2004 Nov 1;28(6):735-46.
11. Naveen J, Mishra AM, Gupta RK, Jaggi RS. Role of diffusion-weighted imaging and in vivo proton magnetic resonance spectroscopy in the differential diagnosis of ring-enhancing intracranial cystic mass lesions. Journal of computer assisted tomography. 2004 Jul 1;28(4):540-7.
12. Senft, C, Bink, A, Franz, K, Vatter, H, Gasser, T and Seifert, V. Intraoperative MRI guidance and extent of resection in glioma surgery: a randomised, controlled trial. Lancet Oncol 12: 997-1003
13. Abul-Kasim K, Thurnher M, Puchner S, Sundgren P. Multimodal magnetic resonance imaging increases the overall diagnostic accuracy in brain tumours: Correlation with histopathology. SA Journal of Radiology. 2013 Mar 1;17(1):4-10.
14. Caivano R, Rabasco P, Lotumolo A, Cirillo P, D'Antuono F, Zandolino A, Villonio A, Macarini L, Salvatore M, Cammarota A. Comparison between Gleason score and apparent diffusion coefficient obtained from diffusion-weighted imaging of prostate cancer patients. Cancer investigation. 2013 Nov 1;31(9):625-9.
15. Fountas KN, Kapsalaki EZ, Gotsis SD, Kapsalakis JZ, Smisson III HF, Johnston KW, Robinson Jr JS, Papadakis N. In vivo proton magnetic resonance spectroscopy of brain tumors. Stereotactic and functional neurosurgery. 2000;74(2):83-94.
16. Murakami R, Sugahara T, Nakamura H, Hirai T, Kitajima M, Hayashida Y, Baba Y, Oya N, Kuratsu JI, Yamashita Y. Malignant supratentorial astrocytoma treated with postoperative radiation therapy: prognostic value of pretreatment quantitative diffusion-weighted MR imaging. Radiology. 2007 May;243(2):493-9.
17. Kang Y, Choi SH, Kim YJ, Kim KG, Sohn CH, Kim JH, Yun TJ, Chang KH. Gliomas: histogram analysis of apparent diffusion coefficient maps with standard-or high-b-value diffusion-weighted MR imaging—correlation with tumor grade. Radiology. 2011 Dec;261(3):882-90.
18. Darwiesh AM, Abd-El Maboud NM, Khalil AM, ElSharkawy AM. Role of magnetic resonance spectroscopy & diffusion weighted imaging in differentiation of supratentorial brain tumors. The Egyptian Journal of Radiology and Nuclear Medicine. 2016 Sep 1;47(3):1037-42.
19. Wang Q, Zhang H, Zhang J, Wu C, Zhu W, Li F, Chen X, Xu B. The diagnostic performance of magnetic resonance spectroscopy in differentiating high-from low-grade gliomas: a systematic review and meta-analysis. European radiology. 2016 Aug;26(8):2670-84.