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Role of Magnetic Resonance Spectroscopy in the Evaluation of Intracranial Brain Tumors on 3 Tesla MRI

Research Article

Malpani P[1], Pentyala S[2] and Manchikanti V[2]*

[1]*Niloufer Hospital for Women and Children, India*

[2]*Department of radiodiagnosis, Narayana medical college & hospital, India*

***Corresponding author:** Manchikanti V, Department of radiodiagnosis, Narayana medical college & hospital, Nellore-524 002, A.P, India

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Abstract

Background: The present study is aimed to assess the contribution of MR spectroscopy in correlation with other MRI sequences towards the evaluation of brain tumors and to diagnosing and grading the brain tumors with histopathological correlation.

Methodology: Analysis of spectra of 30 patients with brain tumors (27 intra axial and 3 extra axial) was done.

Results: 6 with GBM, 4 with anaplastic astrocytoma, 6 with diffuse infiltrative astrocytoma, 1 with oligodendroglioma, 1 with gliomatosis cerebri, 1 with ependymoma, 5 with metastasis, 1 with choroid plexus papilloma, 1 with medulloblastoma,1 with lymphoma, 2 with vestibular schwannomas and 1 with meningioma. Histopathology was not done in five cases. Five tumors didn't correlate histopathologically. MRS of tumors shows decreased NAA levels since neurons are superseded by the neoplasm cells. Furthermore, increase in choline levels are seen. Some tumors show Lac and Lip signals, which are markers of anaerobic metabolism and necrosis. High Lac-Lip concentration helps to distinguish high and low grade gliomas. Glioblastomas have a higher Lac-Lip concentration than anaplastic astrocytomas. Absence of the Lac-Lip signal does not exclude the diagnosis of high grade glioma. In our study peak Lac-Lip was present in all the cases of glioblastoma in the necrotic component of the tumor. Cho contents measured with the Cho/Cr ratio increase with the grade of astrocytoma. The decrease of Cho/Cr ratio in some glioblastoma is explained by the presence of necrosis in these tumours. No significant difference in NAA/Cr ratio was observed in different types of gliomas. Other intraaxial brain tumors namely Gliomatosis cerebri, medulloblastoma, ependymoma and choroid plexus papilloma showed elevated Cho/Cr and Cho/NAA ratios as well as decreased NAA/Cr ratios of varying degrees within the areas of hyperintensity on T2-weighted images and in enhancing part of the tumor. In lymphoma, similar findings are found except for increased lipid-lactate peak. Extra-axial tumors namely schwannoma and meningioma showed elevated Cho/Cr and Cho/NAA ratios as well as decreased NAA/Cr ratios of varying degrees and there was an alanine peak detected in meningioma.

Conclusion: the study conclude that in vivo MR spectroscopy can be used as a reliable method for distinguishing neoplastic from non-neoplastic lesions and also helpful in glioma grading. Some features of tumors on conventional MRI (e.g. contrast enhancement, surrounding edema, signal heterogeneity, necrosis, haemorrhage and midline crossing) suggest a high grade. Accurate grading of gliomas on the basis of MRS alone may be difficult. Combining MRS with conventional and other advanced MR imaging techniques, grading becomes more precise.

Keywords: Intraaxial brain tumors, MR spectroscopy, glioma grading, neoplastic lesions

Introduction

Intracranial tumors account for a significant proportion of morbidity in our country and present several imaging challenges. Primary brain cancers account for about 2% of all cancers. Apart from these, brain and meninges are common sites of secondary tumor implantation and their incidence increases with age.

The average Age Adjusted incidence Rates (AAR) for CNS cancers (per 1,00,000) as per three year NCRP report of population based cancer registries 2009-2011 are males: Delhi showed highest AAR (3.7) followed by Bangalore (3.4) and females: Sikkim state (3.6) followed by Bangalore (2.8) [1].

Therefore, intracranial tumors form an important indication for neuroimaging. Various modalities like plain radiograph, CT and MRI are available for investigation of intracranial tumors. Imaging plays an intrinsic role in intracranial tumor management. We are witnessing a shift in imaging from merely providing anatomical information towards providing information about tumor physiology [2].

Magnetic Resonance Imaging (MRI) has emerged as an important diagnostic modality most frequently used to evaluate intracranial tumors. Conventional MR imaging provides highly detailed anatomic information helping in accurate depiction, delineation, treatment planning and post treatment surveillance of intracerebral neoplasms. In addition to conventional MR imaging techniques, a variety of advanced techniques like MR spectroscopy, perfusion imaging, Diffusion weighted Imaging (including DTI), Blood Oxygen Level Dependent (BOLD) imaging and the emerging molecular imaging, have found their place in clinical practice or are the subject of intense research. These advanced techniques generate physiologic data and information on tissue biochemistry.

Magnetic Resonance Spectroscopy (MRS) is an appealing non-invasive adjunct to MR imaging [3]. It's a safe means of performing biochemical analyses *in vivo* [4]. MR spectroscopy provides additional information on the metabolic composition within an area of tissue. By comparing the relative concentration of metabolites such as choline, NAA, lactate etc., clinicians can judge factors like neuronal viability, neurotoxins and membrane turnover within the volume of interest and, thereby, the likely underlying pathology [3]. Widespread use of faster MRS applications with higher Signal to Noise Ratio (SNR) and spatial resolution allows us to detect functional metabolic changes, thereby providing more information to understand the accurate nature of the tumor and the morphological and physiological changes occurring in the adjacent brain parenchyma.

This study is selected to assess the important role of MR spectroscopy in the evaluation of brain tumors because when diagnostic dilemmas present themselves, MRS considered in perspective with MR imaging achieves a higher accuracy.

The multiplanar capability of MR imaging makes it the best technique for evaluation of brain tumors and the anatomical information from conventional MR sequences along with the biochemical information from MR spectroscopy will help in better assessment. This study was done in 30 patients on a 3T MR scanner.

Patients and Methods

Source of data: The main source of data for the study were patients attending the department of Radiodiagnosis, Narayana Medical College, Nellore.

Study design: Hospital based prospective study.

Sample size: The study is time bound study with sample size of 30 cases.

Method of collection of data

All patients with clinically suspected brain tumors in a period of 2 years from Oct 2013 to October 2015 were subjected for the study.

Nature of study

The study involved adult patients and children and no normal volunteers or pregnant women were included.

Inclusion criteria

- All patients with incidentally diagnosed brain tumors by CT.
- Follow up patients of brain tumors.
- Clinically suspected cases.
- Cases of all age groups irrespective of sex.

Exclusion criteria

- Patient having history of claustrophobia.
- Patient having history of metallic implants insertion, cardiac pacemakers and metallic foreign body in situ.
- Patient clinically unstable.
- Cases with benign lesions after histopathology confirmation.

Equipment: The conventional MRI and MRS scans were performed on a 3 TESLA whole body scanner (GE medical systems HDXT 750W) with a standard circularly polarised head coil during the same examination session without repositioning the patient.

Sequences: Conventional axial T1W, T2W, SWI, DWI; coronal FLAIR; Sagittal T1±post contrast T1 FSPGR axial, coronal and sagittal sequences were taken. 2D PRESS 144 multi voxel spectroscopy was performed at TE of 144ms and TR was at 1500 ms.

Cubic/nearly cubic MR spectroscopic voxels were centered over solid portions of the lesions to sample the most metabolically active tissue and to avoid necrotic debris with minimal contamination from the surrounding non-tumoral tissue. The voxel was extended to cover perilesional area in selective cases of high grade tumors.

The region of interest was defined by conventional T1 or T2W sequences and post contrast sequence whenever done. Volume of interest size ranged between 1.5x1.5x1.5 cm^3 (3.4 ml) and 2x2x2 cm^3 (8 ml). Spectroscopy was avoided in small lesions close to the bone and sinuses.

Gadopentetate Dimeglumine contrast was used with dosage being 0.1 mmol/kg bodyweight.

	TR	TE	No.of slices	Gap in mm	FOV(mm)
T1W	700	10	21	1.5	220
T2W	5500	114	21	1.5	220
FLAIR	12000	117	21	2.5	220
DWI	5400	96	21	1.5	240
FSPGR	9.0	3.6	Slice thickness=1.2 mm		240

Study Definition

The resonance assignments were as follows

Mobile lipids (Lip) at 0.9 - 1.4 ppm, Lactate doublet (Lac) at 1.15 - 1.50 ppm, Creatine (Cr) at 3.0 ppm, N-acetyl aspartate (NAA) at 2.02 ppm, Glutamate and glutamine (Glx) at 2.35 - 2.46 ppm, Choline (Cho) at 3.2ppm, Myoinositol (mI) at 3.54 - 3.63 ppm and alanine

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at 1.4 ppm. An increase in choline peak, myoinositol peak, lipid lactate peak and reduced NAA peak, creatinine peak was considered significant for diagnosing brain tumors. In combination with conventional MR sequences, we reported brain tumor as high grade if there was increase in Cho/Cr ratio of more than 2.0, choline/NAA ratio of more than 1.8, reduced NAA/Cr of less than 1.5. We reported brain tumors as low grade if Cho/Cr ratio was less than

2.0, this value was used as a threshold value in order to increase the specificity of detecting brain tumors.

Statistical analysis

Data was entered in Microsoft excel data sheet and analysis was done. Descriptive statistics, frequencies and proportions were calculated and tabulated. OPEN EPI software was used to calculate sensitivity, specificity, negative predictive value, positive predictive value and diagnostic accuracy to test the validity of MR Spectroscopy with respect to histopathological examination. Fisher exact test was the test of significance for categorical data. $p<0.05$ was considered as statistically significant (Table 1) (Figures 1 and 2).

In the study, majority of the patients i.e., 23% were between 31-40 years of age. The youngest patient was 2 year old with ependymoma and the oldest was 79 year old with glioblastoma. In the study, the majority i.e., 60% of the patients with intracranial brain tumors were males. In the study, the majority of the tumors i.e 90% was in intra-axial location. The majority of intra-axial tumors i.e 74% was in supratentorial location. It was observed that majority of the tumors i.e., 60% were well-defined and 40% were ill-defined with no definite tumor margins.

In the study, it was observed that majority of the tumors i.e., showed perilesional edema. It is evident that most of the brain tumors have perilesional edema.

In the study, it was observed that majority of the brain tumors i.e., 63% were solid. 37% of the brain tumors were solid with cystic / necrotic component within (Table 2).

From the above findings, it can be inferred that all brain tumors i.e 100% showed increased choline peak, Cho/Cr and Cho/NAA ratio and absent or reduced NAA peak and reduced NAA/Cr ratio. In 50% of cases, there was lipid lactate peak (Table 3 and 4).

There is significant association between MR spectroscopy findings and histopathological findings for Glioblastoma Multiforme ($p<0.05$).

There is significant association between MR spectroscopy findings and histopathological findings for Anaplastic astrocytoma ($p=0.03$).

There is significant association between MR spectroscopy findings and histopathological findings for Low grade astrocytoma ($p=0.0004$).

There is significant association between MR spectroscopy findings and histopathological findings for Ependymoma ($p=0.04$).

There is significant association between MR spectroscopy findings and histopathological findings for Gliomatosis cerebri ($p=0.04$).

There is significant association between MR spectroscopy findings and histopathological findings for Metastases ($p=0.004$).

There is no significant association between MR spectroscopy findings and histopathological findings for Choroid plexus carcinoma.

Table 1: Distribution of sample according to age.

Age (years)	No.of Cases	Percentage
0-10	2	6.7
11-20	1	3.3
21-30	4	13.3
31-40	7	23.3
41-50	4	13.3
51-60	4	13.3
61-70	5	16.7
71-80	3	10.0
Total	**30**	**100%**

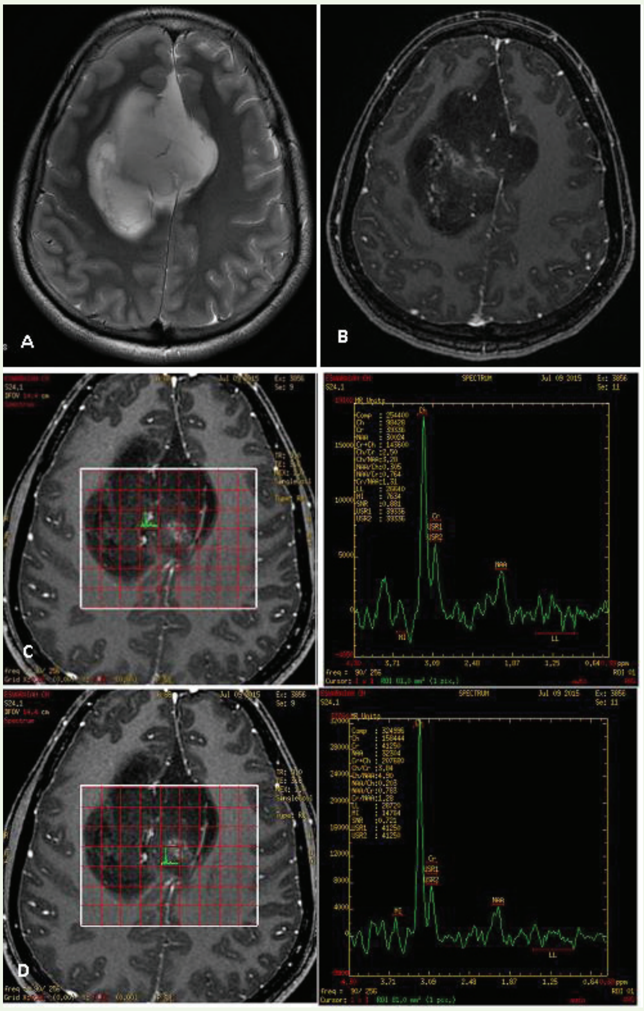

Figure 1: HIGH GRADE GLIOMA (ANAPLASTIC ASTROCYTOMA) (case no 1) A. Axial T2W MR image showing a well-defined solid heterointense lesion with mild perilesional edema predominantly in the right fronto-parietal lobe extending into the left frontal lobe infiltrating the body of corpus callosum. B. Axial post contrast gradient image showing mild heterogenous enhancement. C.D. Multivoxel MRS showing elevated choline levels in the lesion with increased Cho/Cr and Cho/NAA ratios. Lipidlactate peak was not seen in any of the voxels.

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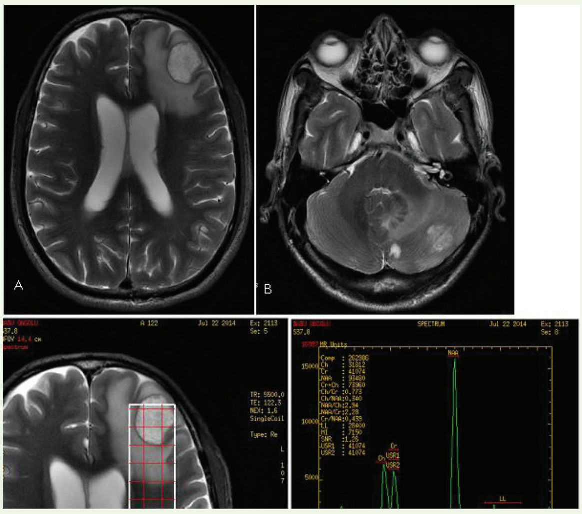

Figure 2: METASTASES (case no. 5). A,B. Axial T2W MR image showing a well-defined solid hyperintense lesion with peripheral rim of hypointensity and moderate perilesional edema in the left frontal lobe. Axial T2W MR image showing a similar intensity lesion in the left postero-superior cerebellar hemisphere. C. Multivoxel MR spectroscopy with voxel from the normal brain parenchyma showing normal brain metabolites with NAA forming the highest peak. MRS with the voxel from the lesion showing decreased NAA and elevated choline with Cho/NAA and Cho/Cr ratio being >2.0.

Table 2: Distribution of sample based on MR Spectroscopy findings.

Choline	No.of cases	Percentage
Increased	30	100
Reduced	-	-
TOTAL	**30**	**100%**
NAA	**No.of cases**	**Percentage**
Increased	-	-
Reduced / absent	30	100
TOTAL	**30**	**100%**
Lipid-Lactate	**No.of cases**	**Percentage**
Increased	15	50
Absent	15	50
TOTAL	**30**	**100%**
Cho/Cr	**No.of cases**	**Percentage**
Increased	30	100
Reduced	-	-
TOTAL	**30**	**100%**
Cho/NAA	**No.of cases**	**Percentage**
Increased	30	100
Reduced	-	-
TOTAL	**30**	**100%**
NAA/Cr	**No.of cases**	**Percentage**
Increased	-	-
Reduced	30	-
TOTAL	**30**	**100%**

There is significant association between MR spectroscopy findings and histopathological findings for Schwannoma (p=0.0033).

There is significant association between MR spectroscopy findings and histopathological findings for Meningioma (Table 5).

It can be inferred that for diagnosing intracranial brain tumors, MRI with MR spectroscopy has 100% diagnostic accuracy in diagnosing gliomatosis cerebri, ependymoma, meningioma and schwannoma. Whereas diagnostic accuracy of 96% was observed in low grade astrocytoma, GBM and choroid plexus carcinoma. A diagnostic accuracy of 92% was observed in metastases and 88% in anaplastic astrocytoma (Figures 3 and 4).

Discussion

Patients from all age groups were included in the study. Brain tumors were most commonly found in the 31-40 (n=7) years age group. The second most common age group was 61-70 (n=5) years age group.

Table 3: Distribution of cases according to histopathology 9.1: Intra-axial tumors

S.No	Intra-axial brain tumors	No.of cases	Percentage
1	High grade gliomas (grade 3 and 4)	9	40.90%
2	Metastases	5	22.72%
3	Low grade gliomas (grade 1 and 2)	4	18.18%
4	Oligodendroglioma	1	4.54%
5	Ependymoma	1	4.54%
6	Gliomatosis cerebri	1	4.54%
7	Choroid plexus carcinoma	1	4.54%
	Total	**22**	**100%**

Table 4: Distribution of cases based on MRI and MRS diagnosis in correlation with Histopathological Diagnosis.

S.no	Brain tumor	Histopathological diagnosis	MRI +MRS diagnosis
1	GBM (grade 4)	7	6
2	High grade (Grade 3) astrocytoma	2	5
3	Low grade (Grade 2) astrocytoma	4	5
4	Oligodendroglioma	1	-
5	Ependymoma	1	1
6	Gliomatosis cerebri	1	1
7	Metastases	5	3
8	Medulloblastoma	-	1
9	Choroid plexus carcinoma	1	-
10	Schwannoma	2	2
11	Meningioma	1	1
	Total	**25**	**25**

Table 5: Sensitivity, Specificity, PPV, NPV and diagnostic accuracy of brain tumors diagnosed on MRI in correlation with histopathological diagnosis.

S.No	Brain tumor	Sensitivity	Specificity	PPV	NPV	Diagnostic accuracy
1.	GBM	85%	100%	100%	95%	96%
2.	Anaplastic astrocytoma	100%	86.9%	40%	100%	88%
3.	Low grade astrocytoma	100%	95%	80%	100%	96%
4.	Ependymoma	100%	100%	100%	100%	100%
5.	Gliomatosis cerebri	100%	100%	100%	100%	100%
6.	Metastases	60%	100%	100%	90%	92%
7.	Choroid plexus carcinoma	0%	100%	-	96%	96%
8.	Schwannoma	100%	100%	100%	100%	100%
9.	Meningioma	100%	100%	100%	100%	100%

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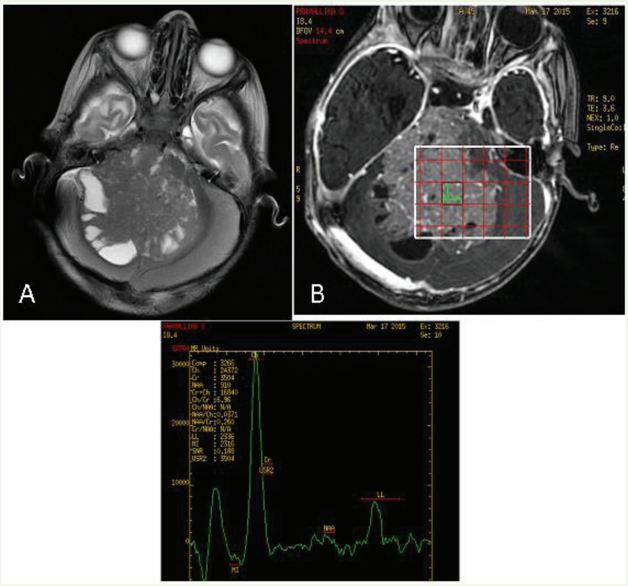

Figure 3: MEDULLOBLASTOMA (case no 10). A. Axial and Sag T2W MR images showing a well-defined lobulated heterointense mass in the midline in the fourth ventricle with multiple small cysts at the periphery. The lesion is compressing the midbrain and pons anteriorly and postero-inferiorly obliterating the cisterna magna. Infiltration of bilateral cerebellar hemispheres is seen laterally and obstructive hydrocephalus proximally. B. MRS showing significant elevation of the choline peak, decreased NAA and elevated lipidlactate peak. The Cho/Cr ratio is high at 6.9.

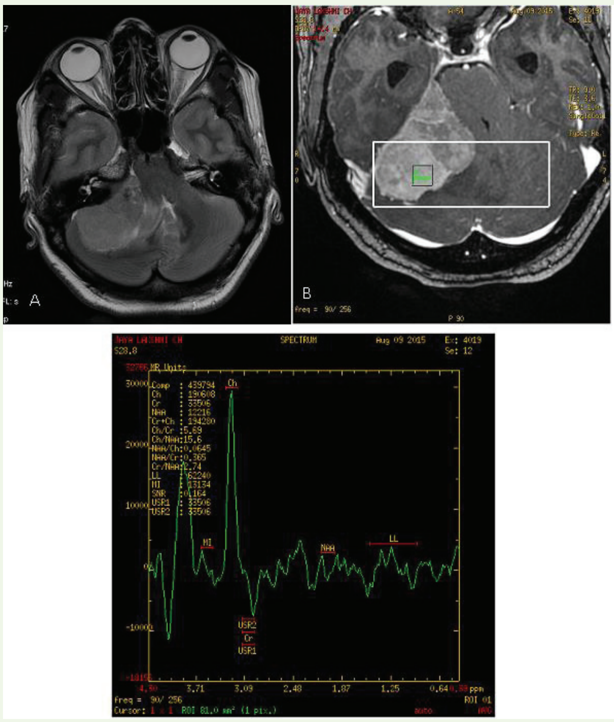

Figure 4: MENINGIOMA (case no 28). A. Axial T2W MR image showing a well-defined solid hyperintense extra-axial lesion in the right cerebello-pontine angle with broad base towards the dura. B. MRS showing elevated choline peak with an inverted alanine doublet at 1.5 ppm which is specific for meningioma.

PA McKinney studied the incidence of brain neoplasms in all age groups and found that primary brain neoplasms occur most commonly in 7th decade [5]. Out of the 30 patients present in the study, the incidence of intracranial brain neoplasms was more in males 60% (n=18) compared to females.

Krishnatreya et al. attempted to identify the epidemiology of primary malignant brain tumors in North-east India with data from a hospital cancer registry and their analysis showed a male-female ratio of 2.3:1 [6].

In the study of 30 cases, intra-axial tumors were more commonly present (n=27) and evaluated with MR spectroscopy than the extra-axial tumors (n=3). Out of the 27 intra-axial tumors, 74% (n=20) were supratentorial, 15% (n=4) were infratentorial and 11% (n=3) were combined supra and infratentorial. Intra-axial supratentorial tumors were more common in the study.

Out of the 30 cases present in the study, majority of the brain neoplasms were solid 63% (n=19) and the remaining were solid with cystic/necrotic component within 37% (n=11).

Gliomas were the most common brain neoplasm found in the study and constituted 63.33% (n=19) of the total 30 cases. Out of 19 cases of gliomas diagnosed on MRI, 6 were GBM, 4 were anaplastic astrocytoma, 6 were diffuse infiltrative astrocytoma, 1 case was of oligodendroglioma, 1 case of gliomatosis cerebri and 1 case of ependymoma.In the study, 17 out of 19 (95%) cases of glioma had perilesional edema. The cases which did not show perilesional edema were ependymoma (n=1) and a low grade glioma (n=1).

Dua RK et al. studied the expression of aquaporin-4 in 30 cases of brain tumors and concluded aquaporin-4 expression was increased in brain tumors compared to normal brain and that it could be playing a role in alteration of blood- brain barrier leading to contrast enhancement and perilesional edema [7].

In the study, most of the GBM and anaplastic astrocytoma cases were heterogenous lesions with both solid and necrotic components. 4 cases of diffuse infiltrative astrocytoma and 1 case of ependymoma were solid lesions showing no necrotic center.1 case of low grade glioma was a cystic lesion with solid mural nodule. The case of gliomatosis cerebri was solid.

In the study, all GBM showed moderate to intense heterogenous enhancement, anaplastic astrocytomas showed no obvious to mild enhancement, and diffuse infiltrative astrocytoma cases had minimal enhancement. Ependymoma showed homogenous intense enhancement and a case of gliomatosis cerebri showed no obvious enhancement.

The findings are in agreement with study conducted by R Felix, W Schörner et al. Histopathology was done in 18 out of 19 cases of gliomas [8]. MRI findings correlated with histopathology in 14 out of 18 cases. First case which did not correlate was of anaplastic astrocytoma which turned out to be anaplastic oligodendroglioma on histopathology. Second case was of a butterfly glioma given as anaplastic astrocytoma based on MRI and MRS findings but turned out to be grade 4 glioma on histopathology. Third case was of a low grade glioma, which turned out to be metastatic papillary

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adenocarcinoma deposit on histopathology. The fourth case was of a high grade glioma, which on histopathology turned out to be a follicular thyroid carcinoma deposit. Histopathology was not done in a case of hypothalamic glioma (n=1).

The cut-off value of Cho/Cr ratio>2.0 helped in accurate grading of the gliomas into high and low grades in 17 cases except for 1 case of high grade glioma which showed Cho/Cr<2.0 and 1 case of low grade with ratio>2.0.

Low Grade Astrocytoma (LGA) is less common than anaplastic astrocytoma and GBM, accounting for between 10-15% of astrocytomas in adults. Diffuse infiltrative astrocytoma are grade 2 astrocytomas.

There were 6 patients with diffuse astrocytoma in the study within the age group of 19 years to 53 years. Seizures was the most common presentation of the patients.

Most of the lesions were hypointense on T1W and hyperintense on T2W MR sequences. Lesions were solid to solid and cystic. Most of the lesions were well- defined. 5 lesions were supratentorial and one was infratentorial. On contrast study, the lesions showed minimal to mild enhancement. Post contrast study was not done in one of the patients. No blooming was observed on SWI sequence.

On MRS, the six tumors showed increased choline peak, reduced NAA and increased mI peak. There was increased Cho/Cr ratio in all the cases with ratio >2.0 in one of the cases and being <2.0 in five cases. The Cho/NAA ratio was increased in all the cases compared to the normal brain parenchyma being 2.2(±0.6) and there was decreased NAA/Cr ratio in all the cases. mI/Cr ratio was higher at 0.9(±0.3).

Histopathology didn't correlate in one of the case, it was biased towards low grade glioma based only on MRI findings of lack of perilesional edema and mild enhancement and MRS findings (elevated lipid lactate and raised Cho/Cr of 2.6) were ignored. But it turned out to be papillary adenocarcinoma metastatic deposit. Consideration of MRS findings might had helped in arriving to a more appropriate diagnosis. Histopathology was not done in one case.

However, the diagnostic accuracy was 96% and there was a significant association between MRS and histopathology findings with p=0.0004 (p<0.05 being significant). The sensitivity was 100% and specificity was 95%.

Meng Law et al. in their study on gliomas, gave the metabolite ratios range for low grade gliomas as Cho/Cr 0.85-4.0, Cho/NAA 0.6-6.8 and NAA/Cr 0.33-3.6 [9].

Mauricio Castilloa et al, in their study on mI levels in cerebral astrocytomas, showed a trend towards lower mI levels in the presence of anaplastic astrocytomas (mI/Cr 0.33±0.16) and GBMs (mI/Cr 0.15±0.12) compared with those of low-grade astrocytomas (mI/Cr 0.82±0.25) [10].

Anaplastic astrocytomas represent one-third of all astrocytomas, second in frequency only to GBM. Anaplastic astrocytomas are WHO grade III tumors, intermediate in malignancy between LGA (WHO grade II) and GBM (WHO grade IV). Five patients with anaplastic astrocytoma were evaluated in the study. Three were in 4^{th} decade and one each in the 3^{rd} and 6^{th} decades of life.

The lesions were all supratentorial and hypo to isointense on T1W and iso to heterointense on T2W conventional MR sequences. SWI blooming was seen in one of the lesions. The lesions showed no obvious to mild enhancement. Contrast study was not done in two of the patients.

There was a case of butterfly glioma, in the 3^{rd} decade, in which the lesion was seen crossing the midline via the corpus callosum anteriorly. Diffusion tensor imaging was done which showed the disruption of white matter tracts in the corpus callosum.

On MRS, the tumors showed significant increase in choline, correlating well with the high cell density in these tumors. The tumors also showed reduced NAA and reduced Cr peak. There was reduced mI peak in one and increased mI peak in the other three. There was increased Cho/Cr ratio of >2.0 in four of the cases and <2.0 in one of the cases. There was increased Cho/NAA and decreased NAA/Cr ratios in all the five cases. Two of the cases showed increased choline peak with raised Cho/Cr ratio in perilesional edema probably due to tumoral infiltration.

Histopathology findings correlated in two of the five cases and did not correlate in the other three. One turned out to be anaplastic oligodendroglioma. The butterfly glioma turned out to be grade 4 glioma which was diagnosed as anaplastic astrocytoma based on the MRS findings as there was no lipid lactate peak indicating necrosis in any of the tumor voxels placed in the enhancing or the non-enhancing part. The other case which turned out to be a follicular carcinoma thyroid metastatic deposit was diagnosed as high grade glioma based on MRI and MRS findings as the lesion was solitary with extensive perilesional edema and high Cho/Cr and Cho/NAA ratios with elevated lipidlactate peak.

The diagnostic accuracy turned out to be 88% with sensitivity of 100% and specificity of 87% but a low positive predictive value of 40%. There was significant association between MR spectroscopy findings and histopathological findings, with p=0.03.

Glioblastoma multiforme is the most common primary brain tumor and the most malignant of the astrocytomas. GBM are WHO grade IV neoplasms.

6 patients with GBM were evaluated in the study. All the cases were adults with most being in the 6^{th} to 8^{th} decades. Seizures and focal neurological deficits were the most common presenting symptoms.

All the cases were supra-tentorial and appeared hypo to hetero-intense on T1W and hetero-intense on T2W conventional MR sequences. Most of the cases were combined solid and cystic. They were predominantly ill-defined with moderate to extensive vasogenic edema. Blooming was a prominent feature observed in 5 of the 6 cases. All the cases showed enhancement on post contrast gradient sequence but the enhancement was irregular and heterogenous.

There were one case of butterfly glioma in 8^{th} decade, in which the lesion was seen crossing the midline *via* the corpus callosum posteriorly.

Gliomatosis cerebri is a distinct entity of glial tumors characterized by diffuse infiltration of the glial cell neoplasm throughout the brain. The WHO classification denotes grades II, III and IV gliomatosis cerebri [11].

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The study includes one patient with gliomatosis cerebri, in the 4th decade, who presented after experiencing the first instance of a generalised seizure. On conventional MR sequences, the lesion was diffusely infiltrating subtle T1 hypointense and T2 hyperintense in both frontal and parietal lobes. The lesion was ill-defined and showed no enhancement on post contrast gradient echo T1 sequence. No blooming was seen on SWI sequence.

On MRS, the tumor showed increased choline peak, reduced NAA, increased mI peak and mildly elevated Cr peak. There was increased Cho/Cr ratio of 2.0, increased Cho/NAA ratio of 2.4 and reduced NAA/Cr ratio of 0.9. mI/Cr ratio was higher at 0.80.

Martin Bendszus et al. evaluated 8 patients with gliomatosis cerebri and found elevated Cho/Cr and Cho/NAA as well as varying degrees of decreased NAA/Cr ratios [12], which were most pronounced in the anaplastic lesions.

Damien Galanaud et al. studied 9 patients affected with gliomatosis cerebri and confirmed markedly elevated levels of Cr and mI [13], reduced levels of NAA and a moderately elevated level of Cho. And also studies done by Mohana-Borges et al. and Peretti-Viton P et al. [14,15].

In our study, intermediate TE was used, so mI level was not appreciately accurately as it is a short TE metabolite.

Brain metastases are not only a leading cause of cancer mortality but as a group have become the most common CNS neoplasm in adults. The brain parenchyma is the most common site (80%), followed by the skull and dura (15%). Although they usually do not pose much of a diagnostic challenge when they are multiple, based on conventional MRI, metastases can be problematic when they are solitary because it may be difficult to distinguish them from primary brain neoplasms [16].

5 cases of metastases were evaluated in the study. They were in 5th, 6th and 7th decades. Headache, seizures and focal neurological deficits were the most common presenting symptoms. Histopathology was not done in two cases.

On MRS, strong Cho peak was seen without elevation in surrounding peritumoral edema. The lesions showed reduced NAA and Cr. Increased lipid/lac peak in two of the tumors. There was increased Cho/Cr ratio of >2.0 in 4 cases and <2.0 in 1 case with the mean Cho/Cr ratio being 2.0(±0.55), increased Cho/NAA ratio in all cases with ratio being 2.1(±0.3) and reduced NAA/Cr ratio at 0.9(±0.4).

Cho/Cr ratio was not elevated in peritumoral edema.

Meningioma is the most common intracranial extra-axial tumour in adults, but is the second most frequent lesion in the Cerebello-Pontine (CP) angle after vestibular schwannoma, representing 10%-15% of all tumours in this location [17].

Proton MR Spectroscopy, at intermediate TE=144 ms, showed a marked reduction in NAA and Cr, elevated choline peak with the characteristic presence of a negative doublet of alanine observed at 1.5 ppm. There was elevated Cho/Cr, Cho/NAA and reduced NAA/Cr ratio.

There was a diagnostic accuracy of 100% and significant association between MR Spectroscopy findings and histopathological findings for meningioma with p=0.04 (p<0.05 being significant).

Medulloblastoma (MB), a highly malignant neoplasm, is the most common posterior fossa neoplasm in children, representing 15% to 20% of all pediatric brain tumors and 30% to 40% of posterior fossa neoplasms [18,19].

Based on MRI and MRS findings, a diagnosis of medulloblastoma was made. But the histopathological and immunohistochemical findings diagnosed it as choroid plexus carcinoma.

The specificity was 100% but the sensitivity was 0% and there was no significant association between MRI and histopathological findings (p=1.000).

Lymphoma of the CNS consists of 2 major subtypes: secondary CNS involvement by systemic lymphoma (the most common) and primary CNS lymphoma, in which the lymphoma is restricted to the brain, leptomeninges, spinal cord, or eyes, without evidence of it outside the CNS at primary diagnosis [20].

The study included an 8th decade female presenting with altered mental status and neuropsychiatric disturbances.

On MRS, increase in choline, reduction in NAA and creatine was seen. There was also increased Cho/Cr ratio of 1.6, increased Cho/NAA ratio of 1.8 and decreased NAA/Cr ratio of 0.8. Lipid lactate peak was not elevated.

However, based on conventional MRI findings, a diagnosis of lymphoma was made. The study done is partly in agreement with previous study done by:

MRS in a case series by Asem Mansour et al. on 21 patients with lymphoma, consistently showed increased choline and decreased NAA along with the presence of lipid peak [21].

Conclusion

The study conclude that *in vivo* MR spectroscopy can be used as a reliable method for distinguishing neoplastic from non-neoplastic lesions and also helpful in glioma grading. Some features of tumors on conventional MRI (e.g. contrast enhancement, surrounding edema, signal heterogeneity, necrosis, haemorrhage and midline crossing) suggest a high grade. Accurate grading of gliomas on the basis of MRS alone may be difficult. Combining MRS with conventional and other advanced MR imaging techniques, grading becomes more precise. The study also demonstrates that spectroscopic MR measurements in the peritumoral region can be used to demonstrate peritumoral infiltrative nature of certain intraaxial brain tumors.

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