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# ROLE OF MAGNETIC RESONANCE SPECTROSCOPY AND DIFFUSION WEIGHTED IMAGING IN CHARACTERIZATION OF BRAIN TUMORS AND ITS CLINICAL IMPLICATION – OUR EXPERIENCE

Radiodiagnosis

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## ABSTRACT

**Purpose:** To evaluate the imaging characteristics and differential diagnosis of Brain Tumours on multi-voxel proton Magnetic Resonance Spectroscopy (MRS) and Diffusion Weighted Imaging (DWI) with its clinical implications.

**Material/Methods:** The study comprised of 60 patients with a clinical diagnosis of brain tumour irrespective of age and sex. Detailed MR imaging, diffusion weighted imaging (DWI) and in vivo proton MR spectroscopy (H1- MRS) were performed using a 1.5 Tesla whole-body scanner (Siemens magnetom maestro class) available in the department using the MR and MRS pulse sequences and the standard head coil.

**Results:** In our study 20 cases of astrocytomas, 14 cases of meningiomas, 6 cases of vestibular schwannoma, 4 cases each of ependymoma and germinoma, 2 cases each of central neurocytoma, choroid plexus papilloma, craniopharyngioma, lymphoma, medulloblastoma, metastasis. On MRS, all gliomas showed increased choline with reduced N-acetylaspartate. All the cases of meningioma showed increase of choline peak with two cases (14%) showing lipid/lactate peaks. Alanine peak at 1.4-1.5 ppm was detected in 10/14 cases (71%). On MRS, metastases showed elevated choline peak with reduced NAA and creatine levels. Lipid and lactate peaks were also noted. On DWI two cases of astrocytoma (WHO Grade IV tumors) and medulloblastoma, 2 cases of germinoma and lymphoma showed restricted diffusion.

**Conclusion:** Magnetic Resonance Spectroscopy (MRS) and Diffusion weighted imaging (DWI) help in further characterization of the tumour as assessed by MR imaging and lead to more specificity in the final diagnosis of nature and differentiation of the type and grade of the tumour.

## KEYWORDS

Magnetic Resonance Spectroscopy, Diffusion Weighted Imaging, Brain Tumours.

## INTRODUCTION:

Brain tumors, though uncommon are not a rare entity in clinical practice and have been one of the major causes of cancer mortality. These tumors are quite diverse in neurosurgical and neuro-oncological practice ranging from benign to malignant tumour and affecting all age groups right from the very young to the very old. Brain tumors can produce symptoms and signs by local brain invasion, compression of adjacent structures, and increased intracranial pressure (ICP). The proper evaluation of the patient with a suspected brain tumour requires a detailed history, comprehensive neurologic examination, and appropriate diagnostic neuroimaging studies. However, there has been a steady increase in the incidence of primary brain tumors over the last decade or so primarily due to higher detection rates due to more widespread availability of diagnostic imaging.

The immediate goals of tumour imaging include (1) initial differential diagnosis, to aid in the distinction of newly diagnosed brain tumors from non-neoplastic conditions such as tumefactive demyelination and ischemia and to aid in the differentiation of glioma from extra-axial neoplasm and metastasis; (2) preoperative therapeutic planning, to provide an estimate of tumour grade and to guide biopsy, resection, and local ablative therapy; and (3) therapeutic follow-up, to monitor disease progression and therapeutic response, including the differentiation of recurrent tumour from delayed radiation necrosis.

Newer imaging techniques such as diffusion-weighted imaging (DWI) and fluid- attenuated inversion recovery imaging have been attempted for achieving this goals1-3. Diffusion-weighted imaging, which is considered the most sensitive technique for early detection of stroke, has been found to be useful in distinguishing brain abscesses from necrotic or cystic brain tumours1,4 and in evaluating epidermoid tumors and differentiation from arachnoid cysts5-7. Proton magnetic resonance spectroscopy has shown a high potential in the differentiation of neoplastic from non-neoplastic lesions8,9. Recently, the combined use of PMRS and DWI has been proved useful in discrimination of pyogenic brain abscesses from necrotic brain tumors and grading of some brain tumours10,11 but scanty data is available in the literature regarding the role of these two combined techniques in the diagnosis of brain tumors in all age groups.

Hence this study is planned to evaluate the combined use of PMRS and DWI in the diagnosis and differentiation of various brain tumors in all age groups.

## MATERIALS AND METHODS:

The study was carried out in the Department of Radiodiagnosis, Seth GS medical college & KEM Hospital, Mumbai, India.

A total number of sixty (60) patients with a clinical diagnosis of brain tumour were taken up for study, irrespective of age and sex. In all patients a detailed clinical history was taken with emphasis on duration of symptoms and specific complaints like headache, seizures, neurologic deficit and loss of consciousness. A detailed examination of CNS was carried out in all patients except the unconscious ones. Routine and other relevant laboratory investigations were done.

Any abnormal finding on the skiagram of the skull and chest radiograph, if available, was noted. The findings on the CT and/or MRI scan available with the patient were also documented.

Subsequently, all patients were subjected to a detailed MR examination. MR imaging, diffusion weighted imaging (DWI) and in vivo proton MR spectroscopy (H1- MRS) were performed using a 1.5 Tesla whole-body scanner (Siemens Sonata Maestro class Magnetom) available in the department using the commercially available MR and MRS pulse sequences and the standard head coil.

MRI: Multiplanar T1 and T2 weighted images were obtained using spin echo sequence.

**Parameters:**

T1 weighted imaging was performed at TR of 500 ms and TE of 14 ms.

T2 weighted imaging was performed at TR of 3500ms and TE of 26 ms.

Multivoxel proton spectroscopy was used to evaluate the lesions. The H-1 MR spectra were obtained with a point-resolved spectroscopy (PRESS) sequence and 33-mT gradients with an echo-time of 135 milliseconds and a repetition time of 1500 milliseconds and using the flip angle of 90 and band width of 1000H.

MR spectroscopy data were evaluated using the commercial program available at the Siemens Magnetom Symphony maestro class. Peak integral values were determined by a curve fitting algorithm at 3.0 ppm for creatine (Cr), 3.2 ppm for choline (Cho), and 2.0 ppm for N-acetylaspartate. In addition, all H-l spectra were inspected for resonances of lactate (p-methyl inverted doublet centered at 1.33 ppm), alanine (dephased doublet peak at 1.4 to1.5 ppm), lipid (in the range of 0.8-2.4 ppm), with/without additional resonances of taurine, myoinositol, succinate, acetate and glycine.

DWI: Echo planar imaging (EPI) was used to obtain diffusion weighted images at different b values and to construct ADC maps. Parameters are TR 3400ms and TE 122ms.Three diffusion weightings were obtained at b values of 0, 500 and 1000.

Final diagnosis was based on the histologic diagnosis. The spectral data were compared with the biopsy findings. In cases where histopathology was not possible the diagnosis was based on MR features, serological tests and response to specific treatment.

**RESULTS:**

Sixty patients were evaluated, whose age group ranged from <10 to < 60 years. The highest incidence of brain tumors was found in 41-50 years' age group accounting for 23.33% of cases and least incidence was seen in age group of 51-60 and >60 years each measuring 6.66%. In the study 42 males (70%) and 18 females (30%) were included. Astrocytoma was the most common tumor with 20 cases (33.3%) followed by meningioma 14 cases (23.33%), vestibular schwannoma 6 cases (10%), germinoma and ependymoma each 4 cases (6.67%). Least incidence of 3.33% were noted each for choroid plexus papilloma, medulloblastoma, craniopharyngioma, lymphoma, metastases and central neurocytoma. The most common tumor in males was astrocytoma accounting for 18 cases (43%) and in females 8 cases (45%) of meningioma.

**Table 1:MR Spectroscopy Findings in Various Tumors (n=60)**

| METABOLITE | | Glial Tumors | | | | Non-Glial Tumors | | | | | | Metastasis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Astrocytomas | Ependymoma | Choroid Plexus Papilloma | Central Neurocytoma | Meningiomas | Vestibular Schwannomas | Medulloblastoma | Craniopharyngioma | Germinoma | Lymphoma | |
| NAA | Decreased | 20 | 4 | 2 | 2 | 14 | 6 | 2 | 2 | 4 | 2 | 2 |
| | Normal/ Increased | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Creatine | Decreased | 16 | 0 | 0 | 2 | 12 | 4 | 0 | 0 | 2 | 2 | 2 |
| | Normal/ Increased | 4 | 4 | 2 | 0 | 2 | 2 | 2 | 2 | 2 | 0 | 0 |
| Choline | Increased | 20 | 4 | 2 | 2 | 14 | 6 | 2 | 2 | 4 | 2 | 2 |
| | Normal/ Decreased | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lipids | 10 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 2 | |
| Lactate | 12 | 4 | 0 | 0 | 4 | 2 | 0 | 0 | 2 | 2 | 2 | |
| Alanine | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Others | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | |

**Table 2: Diffusion Characteristics of the Lesions (n=60)**

| Diffusion | Glial Tumours | | | | Metastasis | | | | | | Non-Glial Tumours | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Astrocytomas | Ependymoma | Choroid Plexus Papilloma | Central Neurocytoma | Meningiomas | Vestibular Schwannomas | Medulloblastoma | Craniopharyngioma | Germinoma | Lymphoma | | |
| Equal/ Increasing Hyperintense Signal with Increasing b Values and Hypointense on ADC Maps | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 0 | 8 |
| Equal/ Increasing Hypointense/ Decreasin Hyperintense Signal with Increasing b Values, Hyperintense on ADC Maps | 16 | 4 | 0 | 2 | 2 | 2 | 0 | 4 | 0 | 0 | 2 | 32 |
| Equal/ Increasing Hypointense/ Decreasin Hyperintense Signal with Increasing b Values, Hypointense on ADC Maps | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Equal/ Increasing Hyperintense Signal with Increasing b Values, Hyperintense on ADC Maps | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| Varying/ Isointense Signal with Increasing b Values, Isointense on ADC Maps | 2 | 0 | 2 | 0 | 12 | 2 | 0 | 0 | 0 | 0 | 0 | 18 |
| TOTAL | 20 | 4 | 2 | 2 | 14 | 6 | 2 | 4 | 2 | 2 | 2 | 60 |

Tumour spectra is characterized by an elevated choline peak with reduced NAA and creatine peak thereby having reversal of Cho/Cr ratio and increased Cho/NAA ratio. DWI for different tumors is varying according to the character of the tumor.

In cases of astrocytic tumors, relative metabolite levels of choline as compared to normal brain show an increase from low grade tumor to high grade tumor. Similar is the pattern with Cho/Cr ratio. Lipid peaks are invariably seen in higher grades of tumor. In our study lipid was detected in anaplastic astrocytomas and Glioblastoma. However, Lactate may be present across entire spectrum of grades as seen in our study. No peaks of acetate, alanine, cytosolic amino acids, or succinate/pyruvate were detected, hence differentiating from abscesses. On DWI, gliomas have varying appearance (hyper-, iso-, or

hypointense). Occasionally, gliomas are hyperintense on DW images and show reduced ADC values (suggests reduced volume of extracellular space) or not reduced ADC values (suggests T2 shine-through effect). Tumor cellularity is probably a major determinant of ADC values of brain tumors. ADC values cannot be used in individual cases to differentiate glioma types reliably. In our study restricted diffusion was noted in two cases of Glioblastoma. All cases of ependymomas showed elevated choline and lactate peaks with reduced NAA level on MR spectroscopy. Lipid peak was also noted in two cases suggesting necrosis.MR Spectroscopy in both cases of Choroid plexus papilloma showed elevated choline peak with normal levels of creatine. Central neurocytoma (a neuronal or mixed neuronal-glial tumour) appears as an inhomogeneous solid cystic mass with MR spectroscopic findings of elevated choline with reduced NAA and creatine levels as seen in our cases. DWI did not show any diffusion restriction.

Meningiomas show elevated choline with quite a specific peak of alanine at 1.4-1.5 ppm (seen in 71% of our cases). No case showed diffusion restriction or increased NAA levels ruling out any atypical or malignant varieties. Schwannomas could be differentiated by lower Cho/Cr ratio and absence of alanine peak.

Medulloblastomas had the highest choline peak and on DWI showed restricted diffusion. Same diffusion pattern was also seen with presence of lipid and lactate peaks in two cases (50%) of germinoma. The two cases (100%) of lymphoma showed lipid and lactate peaks suggestive of necrotic degeneration. Diffusion weighted images showed restricted diffusion owing to high cellularity.

Both craniopharyngiomas in our case appeared as a solid cystic mass in sellar/parasellar region with intense enhancement of the solid part in the post-contrast images, MR Spectroscopy showed prominent choline peak with reduced NAA and creatine levels without any diffusion restriction on DWI.

All the cases of metastasis were characterized by elevated choline and reduced NAA with presence of lactate and lipid peaks (both at 0.9 and 1.3 ppm). The pattern is similar to high grade gliomas however differentiation could be made by elevated choline in peritumoral zone in high grade gliomas and not in metastasis. Moreover, higher values of ratio of the lipid at 1.3 ppm to lipid at 0.9 ppm points towards metastasis. On DWI signal suppression was noted with high signal on ADC maps due to the non-exudative character of the necrotic components.

## DISCUSSION:

The emergence of MRI has revolutionized the early and accurate diagnosis of Brain tumour. However, with conventional MR imaging, there remain areas with considerable overlap in imaging findings. Differentiation between various brain tumors is not always possible based on imaging morphology alone. Differentiation between these tumors is important in order to institute early and appropriate treatment.

Diffusion weighted imaging and MR spectroscopy are a step forward in this direction. In vivo MR spectroscopy allows the noninvasive evaluation of metabolic patterns in human brain tumors. In most cases, multivoxel spectroscopy was used in our study because the region of interest covered was large and hence lesion heterogeneity could be studied more accurately. However, where lesion was homogenous and well defined, single voxel spectroscopy was used. Hyperintensity on DWI and decreased signal on ADC map/reduced ADC value indicates the restricted diffusion of water across cell membranes.

In our study 60 patients (42 male, 18 female) with clinical or imaging diagnosis of brain tumour, were evaluated by MRI, Magnetic resonance spectroscopy (MRS) and Diffusion weighted imaging (DWI). The study group included 20 cases of astrocytomas, 14 cases of meningiomas, 6 cases of vestibular schwannoma, 4 cases each of ependymoma and germinoma, 2 cases each of central neurocytoma, choroid plexus papilloma, craniopharyngioma, lymphoma, medulloblastoma, metastasis.

An attempt was made to differentiate various brain tumors according to their MR imaging findings including Spectroscopy and Diffusion Weighted Imaging.

## TUMOURS:

### 1. GLIAL TUMOURS

Astrocytic Tumours

A total of 20 cases of astrocytic tumors were studied. It included six cases of glioblastoma multiforme (WHO Grade IV), 10 cases of anaplastic (WHO Grade III) and four cases of low grade (WHO grade II) astrocytoma. Most cases were seen in the second to fifth decade with two cases of anaplastic astrocytomas seen at 69 years of age. On T1WI, 16/20 (80%) cases were hypointense and 4/20 (20%) cases were isointense. On T2WI, 18/20 (90%) cases were hyperintense and 2 cases (10%) was heterogenous.

On MRS, all gliomas showed increased choline with reduced N-acetylaspartate. This corresponds to the findings in the study done by Kugel et al involving 36 patients of brain tumours12. Relative metabolite levels of choline as compared to normal brain tissue showed an increase from low grade astrocytoma to higher grades. This is similar to the findings obtained by Hartmann et al13. The choline/creatine ratio also showed increase from low grade, anaplastic to glioblastoma multiforme. Lactate peak was seen in four of the six cases (66.66%) of WHO Grade IV tumors, six cases (60%) of anaplastic and two cases (50%) of low grade astrocytoma. This finding correlates with the study conducted by Castillo M and Kwock L (1998) who stated that lactate may be present across the entire spectrum of grades of astrocytomas because lactate may arise not only from hypoxia developing within the tumor itself as a result of disruption of normal vascular networks but also from necrosis or cysts within the tumor14.

Lipid peak was seen in four of the six cases (66.66%) of WHO Grade IV tumors and six cases (60%) of anaplastic astrocytoma. This feature is in comparison with the study done by Negendank et al in 1996, who observed that although high levels of lipids may be specific for anaplastic astrocytoma or glioblastoma multiforme, their absence does not exclude the possibility of such high histologic grades15. Poptani et al (1995) observed that a large Cho resonance with decreased NAA, Cr and a lipid-lactate resonance is indicative of a malignant pathology16. No case showed peaks of succinate, alanine, acetate or cytosolic amino acids.

On DWI, out of the six WHO Grade IV tumors, two (33%) cases showed increasing hypointensity with increasing b values and hyperintensity on ADC maps, two (33%) cases showed increasing hypointensity with increasing b values and isointensity on ADC maps and two (33%) cases showed equal hyperintensity at all b values and hypointensity on ADC maps suggestive of diffusion restriction. All ten (100%) cases of grade III astrocytomas showed equal or increasing hypointensity at increasing b values and hyperintensity on ADC maps. All four cases of grade II astrocytomas, showed increasing hypointensity with b values and hyperintensity on ADC maps. Occasionally, gliomas are hyperintense on DW images and show reduced ADC values (suggests reduced volume of extracellular space) or not reduced ADC values (suggests T2 shine-through effect). Tumor cellularity is probably a major determinant of ADC values of brain tumors. ADC values cannot be used in individual cases to differentiate glioma types reliably17,18.

**Ependymomas**

Four cases were studied. On T1W images, two cases were hypointense while the other two were isointense. All cases were hyperintense on T2W images and showed heterogenous post-contrast enhancement. Two cases also showed rim enhancement with features of necrosis and hemorrhage. On MRS, there was increase of choline peak with reduction of NAA and creatine levels with presence of lactate peak in all cases. Lipid peak was also noted in two cases suggesting necrosis19-22. DWI showed isointense signal on b value of 1000 and slight hyperintense signals on b values of 0 and 500 and on ADC maps. Choroid Plexus Papilloma On T1WI, both tumors were located in the left lateral ventricle and were isointense. On T2WI, the tumors were slightly hyperintense with evidence of intense post-contrast enhancement. On MRS, there was increase of choline peak with reduction of NAA level and normal creatine peak. No documented spectral/diffusion pattern has been found after reviewing the literature. On DWI the tumors showed equal hyperintense signal only b value of zero and isointense signal on other b values and ADC maps.

### 2. MIXED NEURONAL-GLIAL TUMOURS

**Central Neurocytoma**

In both cases inhomogenous solid cystic mass was noted in Left lateral ventricle which was iso to hypointense on T1W images and hyperintense on T2W images with heterogenous post contrast enhancement. On MRS, choline peak was increased with reduced levels of NAA and creatine. No lipid, lactate or any other peak was noted. DWI showed isointense signals on b value of 1000 and hyperintense signals on other b values and ADC maps. This tumour has been classified by WHO under the category of Neuronal or Mixed Neuronal-Glial tumors.

### 3. NON-GLIAL TUMOURS

#### Meningiomas

Fourteen cases of meningioma were evaluated. On T1WI, 8/14 (57.14%) cases were iso to hypointense, 4/14 (28.5%) were isointense and 2 cases (14.28%) were hypointense. On T2WI, 6/14 (42.85%) cases were hyperintense, 4/14 (28.5%) cases were isointense and two cases (14.28%) each were heterogeneous and hypointense.

On MRS, all the 14 (100%) cases showed increase of choline peak with two cases (14.28%) showing lipid/lactate peaks. Alanine peak at 1.4-1.5 ppm was detected in 10/14 cases (71.42%). These findings correlate with the study by Hartmann et al 13 and Dorothee et al23 Creatine levels were reduced in 12/14 cases (85.7%), leading to marked increase of choline/creatine ratio. This finding matches with the study done by Castillo et al14 and Shimizu et al24. It is not uncommon to detect increased N-acetyl aspartate in these extra-axial tumors, particularly in atypical and malignant varieties14, 25, 26. However, in our study NAA levels were reduced in all 14 (100%) cases.

On DWI, no case showed restricted diffusion with variable diffusion patterns. The signal intensity of meningiomas on DW images is variable (hyper-, iso-, or hypointense) 17, 27. Most benign meningiomas are isointense on DW images and ADC maps 17, 27. High signal intensity on DW images and reduced ADC values suggest malignant meningioma 27.

#### Vestibular Schwannomas

Our study consisted of six cases of Schwannomas. On T1WI, two cases (33%) each showed the tumour to be isointense, hypointense and iso to hypointense. On T2WI, two cases (33.3%) each were hyperintense, isointense and heterogeneous. On MRS, choline was increased with reduction of NAA in all the six cases. Creatine was reduced in 4/6 cases (66.6%) and normal in two cases (33.3%). There was no evidence of alanine peak that differentiated it from the sphenoid wing meningioma. Two cases (33.3%) also showed lipid and lactate peaks. Hartmann et al 13 have suggested that the presence of lactate peak is due to cystic tumor degeneration in case of Schwannomas. On DWI, two cases (33.3%) were slightly hyperintense on zero b value and isointense on other b values and ADC maps. Two cases (33.3%) were isointense in b values of 0 and 500 and hyperintense in b value of 1000 and ADC maps. Two cases (33.3%) were increasingly hypointense with increasing b values and hyperintense on ADC maps.
Medulloblastoma On T1WI, both the lesions were hypointense and hyperintense on T2WI with intense post contrast enhancement. MRS revealed a large choline peak with reduced NAA levels hence leading to high choline/NAA ratio. Creatine level was normal hence causing lower choline/ creatine ratio in contrast to low grade gliomas. The findings correlate with the study by Wang Z et al 28. On DWI both the tumors showed restricted diffusion with hyperintense signal on all b values and hypointense signal on ADC maps. This might be because of the high cellularity of this tumour, as shown by Krabbe et al 7.

#### Germinoma

Our study evaluated four cases. On T1WI, all cases were isointense. On T2WI, two cases were isointense while others were heterogeneous. Post contrast, two cases showed intense enhancement while others were heterogeneous with a rim enhancing large cystic area. MRS showed increase in choline peak with reduced level of NAA. Lipid and lactate peaks were noted in two cases (50%) suggestive of necrosis. DWI showed decreasingly hyperintense or increasingly hypointense signals on increasing b values with hyperintense signal on ADC maps in two cases while in the other cases, the tumors showed restricted diffusion probably due to the same reason as in medulloblastoma (high cellularity).

#### Lymphoma

On T1WI and T2WI, both the tumors were heterogeneous with post-contrast intense heterogeneous enhancement. MRS showed marked increase in choline levels with reduced NAA and creatine levels. Lipid and lactate peaks were also observed suggestive of necrotic degeneration. On DWI, both the tumors showed restricted diffusion due to high cellularity 29-31.

#### Craniopharyngiomas

Two cases whose MR evaluation revealed solid-cystic mass in sellar/suprasellar region which were hypointense on T1W and hyperintense on T2W images. Post-contrast images showed intense enhancement in the solid part of the lesions. MRS showed increase in choline peak with reduced level of NAA and normal creatine peak. DWI showed decreasingly hyperintense signals on increasing b values with hyperintense signal on ADC maps.

### 4. METASTASIS

On T1WI, the lesions were hypointense and on T2WI, they were hyperintense associated with perilesional edema on FLAIR sequences. The lesions showed heterogeneous post contrast enhancement, few areas of rim and nodular enhancement. On MRS, the lesions showed elevated choline peak with reduced NAA and creatine levels. Lipid and lactate peaks were also noted. These findings correspond with the observations of Demaerel et al and Bendzus et al 32, 33. However, proton MR spectra of intracranial metastases are often nonspecific and indistinguishable from those of primary brain tumors. But the study by Fan G et al 34 showed that the choline peaks in the peritumoral zone/edema could differentiate between the high grade tumors and metastasis, wherein choline levels are raised in cases of high grade gliomas due to the infiltrative type of edema whereas in cases of metastasis peritumoral choline were normal due to the vasogenic type of edema. Another study by Opstad et al showed that the ratio of L1 (lipid at 1.3ppm) and L2 (lipid at 0.9ppm) i.e. L1/L2, if $3.8 \pm 1.4$ than it points toward metastasis, but if it is in the range of $2.6 \pm 0.6$ it indicates high grade glioma. In our case we could appreciate the low levels of choline in the peritumoral zone as stated by Fan G et al 34. On DWI, our cases showed increasing hypointensity with increasing b value and hyperintensity on ADC maps. The necrotic components of cerebral metastases show a marked signal suppression on DW images and increased ADC values [n = 7] in the report of Krabbe et al 7. This might be due to the nonexudative character of the necrotic components in case of metastasis.

**CONCLUSION:** Magnetic Resonance Spectroscopy (MRS) and Diffusion weighted imaging (DWI) help in further characterization of the tumour as assessed by MR imaging and lead to more specificity in the final diagnosis of nature and differentiation of the type and grade of the tumour. These should be included in the routine imaging workup of patients with clinically proven or suspected brain tumour, for their proper characterization.

### CONFLICT OF INTEREST

None of the authors declare any conflict of interest.

**FIGURE 1: Glioblastoma**

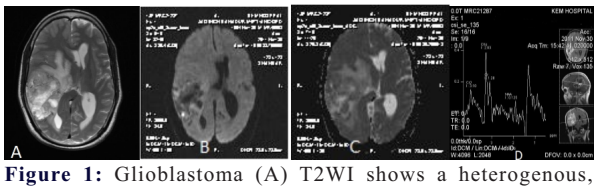
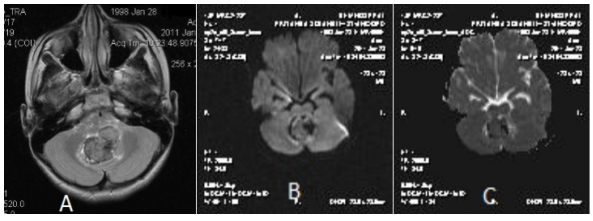



**Figure 1:** Glioblastoma (A) T2WI shows a heterogenous, predominantly T2 hyperintense mass lesion with necrotic areas in right parietal lobe. (B & C) DWI and ADC maps respectively show patchy areas of restricted diffusion in solid components of mass. (D) MRS shows elevated choline peak, reduced NAA & elevated lipid peak.

**FIGURE 2: Ependymoma**



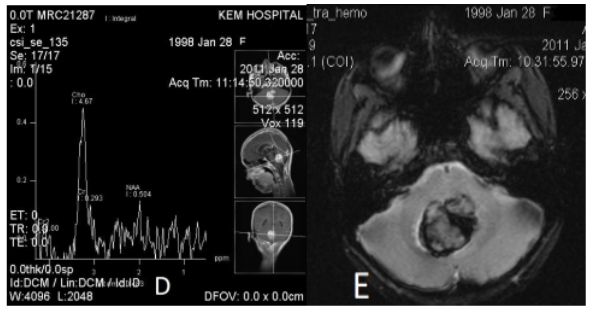



**Figure 2:** Ependymoma (A) T2WI shows a heterogenous mixed intensity mass in fourth ventricle. The mass shows T2 hypointense areas which correspond with hemorrhage on GRE (E). (B & C) DWI and ADC show no evidence of restricted diffusion. (D) MRS reveals elevated choline and reduced NAA levels.

**FIGURE 3: Lymphoma**

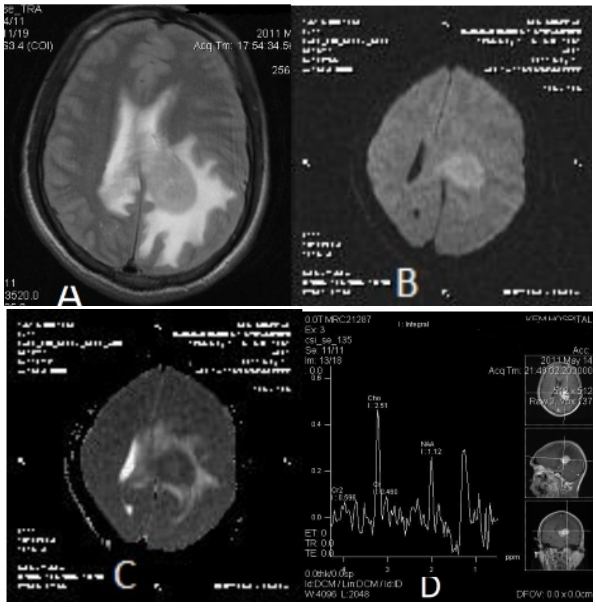



**Figure 3:** Lymphoma (A) T2WI shows T2 hyperintense solid mass in left parietal periventricular region with perifocal edema. (B & C) DWI and ADC maps show restricted diffusion in the mass. (D) MRS shows elevated choline, reduced NAA levels and lipid peak.

**FIGURE 4: Metastasis**

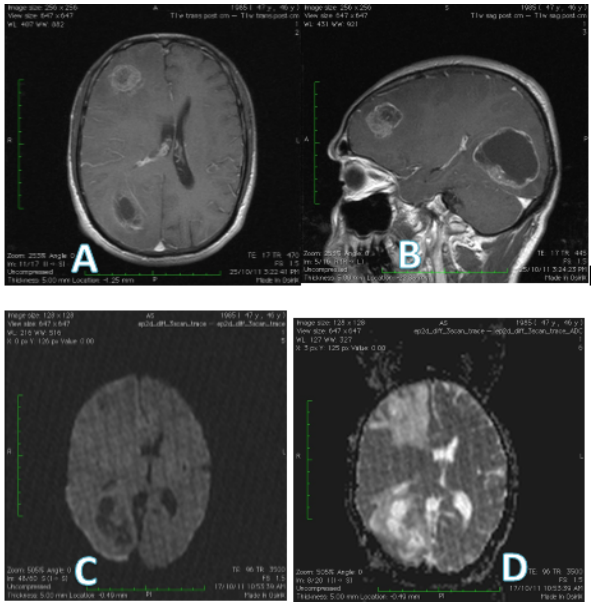



**Figure 4:** Metastases (A & B): Post-Contrast Axial(A) and Sagittal(B) images show heterogenous enhancement in a frontal lobe lesion and rim enhancement in an occipital lobe lesion. (C): DWI at b=1000 reveals hypointense signals. (D): ADC map reveals hyperintense signals

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