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Original Article

Radiology Section

# Magnetic Resonance Spectroscopy in Diagnosing Brain Tumours? Is it Worth Doing

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## ABSTRACT

**Introduction:** Magnetic Resonance Spectroscopy (MRS) is a non-invasive diagnostic method useful in providing information about specific metabolites in brain tissue that can indicate the presence of tumour, necrotic tissue and other pathologic entities.

**Aim:** To evaluate the diagnostic performance of MRS in detecting, differentiating and grading brain tumours and to determine the diagnostic value of MRS.

**Materials and Methods:** Prospective study was performed on 31 patients falling in the sampling frame. Patients were subjected to conventional MRI followed by MR Spectroscopy using 1.5 Tesla machine. Findings of conventional MRI brain and MRS were compared and correlated with the histopathological data in every case. Statistical analysis was done using SPSS version 21. The data represented as number, percentage and mean±SD. Independent sample t-test was used to analyse the data. A p-value less than 0.05 was considered significant.

**Results:** The study demonstrated correlation agreement of 83.87% (in diagnosing brain tumours) between conventional MRI and histopathological diagnosis while correlation agreement of 90.3% between MRI combined with MRS diagnosis and histopathological diagnosis. Mean Cho/Crand Cho/NAA levels showed a significant association with histopathological diagnosis with p-value <0.001 for Cho/Cr Ratio and p-value=0.002.

**Conclusion:** MRS is a useful aid to routine MRI in characterization of brain tumours and helps to differentiate among different histopathological diagnoses. Mean Cho/Cr and Cho/NAA levels showed significant association with histopathological diagnosis. Mean Cho/Cr and Cho/NAA levels were minimum in low grade tumours and maximum in meningioma/ metastasis cases.


**Keywords:** Choline, Creatine, Cho/Cr (Choline/Creatine) Ratio, Cho/NAA (Choline/N-acetyl aspartate) ratio

## INTRODUCTION

The term brain tumour refers to diverse groups of cancers arising from different cells of brain parenchyma (primary tumours) or from systemic tumours that have metastasized to the brain. The incidence of primary brain tumour is 8/100000. They are the most common solid tumour in children and the eighth most common cancer in people of working age [1]. These include a number of histologic types with assorted gross and molecular characteristics and are classified based on the World Health Organization (WHO) classification of tumours of the CNS [2].

Brain tumours can present with physical or behavioural symptoms [1]. Most common symptoms of brain tumours are headaches, fatigue, sleep disturbance, drowsiness, motor difficulties, communication difficulties, dry mouth and depression. These can have significant impact on quality of life of the patients [3-6].

A comprehensive medical history, neurologic examination and diagnostic neuroimaging are useful to evaluate a patient with suspected brain tumour. Specific tests, such as formal visual field examination and hearing tests are at times useful depending on the area of the brain involved and relevant signs and symptoms [7].

Imaging tools such as Computerized Tomography (CT), Positron Emission Tomography (PET) may be used for brain imaging but Magnetic Resonance Imaging (MRI) is commonly used to help diagnose brain tumours. Functional MRI, perfusion MRI and Magnetic Resonance Spectroscopy (MRS) are more helpful in evaluation of tumour and plan of treatment. Although conventional MRI provides images with excellent structural detail, it cannot always be used alone to accurately identify specific tumour type or grade [8-12], confidently differentiate neoplastic from non-neoplastic lesions [11,13,14] or determine the optimal site for biopsy in heterogeneous tumours [15]. MRS is useful in providing information about specific metabolites in brain tissue that can indicate the presence of tumour, necrotic tissue and other pathologic entities [16].

Biopsy is the gold standard to determine cancer type and degree of malignancy [17]. MRI can diagnose intracranial mass lesion with a success rate of 30-90% depending on tumour type [18,19]. MRS is useful in improving the demarcation of cancerous brain tissue for radiotherapy planning [20], aid in tumour localization for stereotactic biopsy [21] and for surgical resection [22]. Perfusion Weighted MRI (PWI) and MRS as advanced MRI techniques are successfully used to differentiate brain tumours. PWI provide sensitivity and specificity of 70%-100% and 95%-100% respectively [23]. MRS reached sensitivity and specificity of 100% [24] in diagnosing brain tumours.

The present study was planned to evaluate the diagnostic performance of MRS in detecting, differentiating and grading brain tumours and to determine the diagnostic value of MRS.

## MATERIALS AND METHODS

The present study was a prospective study which was performed on 31 patients for period extending from Jun 2017 to Jun 2018 at Department of Radiodiagnosis, Command Hospital (Central Command), Lucknow, Uttar Pradesh, India. Hospital ethical committee clearance for conduction of this study was taken. Informed written consent from all the patients participating in study was taken.

### Inclusion Criteria

- Patients with all age group and suspected /known brain tumours.
- Patients with positive/indeterminate MR findings.
- Follow-up cases of brain tumours.

### Exclusion criteria

- Patients with cardiac pacemakers and metallic implants.
- Motion disorder and claustrophobia.
- Patients with brain tumours which were not operated were excluded from the study.

All the patients falling in the sampling frame were invited to participate in the study. On enrolment, age and gender of patients was noted. Location of lesion was identified. Subsequently, they were subjected to imaging assessment:

### MRI Protocol

Patients were subjected to conventional MRI and MRS, as per following protocol:

Equipment: Siemens Magneto Avanto 1.5 Tesla.

Protocol: Brain MRI performed with

- Conventional MRI
- MRS

Conventional MRI was performed with following basic sequences.

- Axial Fluid Attenuated Inversion Recovery (FLAIR) sequences
- Axial and coronal T2- weighted TSE sequences
- Axial and sagittal T1 weighted TSE sequence
- Post-Gadolinium T1 weighted TSE in all three planes. (Prior to contrast study patients were injected 0.1 mmol/kg of Gadobenate Dimeglumine).

Conventional MRI parameters on a 1.5T MRI unit used in the study is shown in [Table/Fig-1].

| Technique | Flair (axial) | T2WI (axial) | T1WI (axial) | Post Gd T1WI (axial) |
|---|---|---|---|---|
| TR (ms) | 8690 | 4400 | 610 | 610 |
| TE (ms) | 84 | 89 | 8.4 | 8.4 |
| TI (ms) | 2462 | - | - | - |
| FOV (mm) | 230 | 230 | 230 | 230 |
| Slice thickness (mm) | 4 | 4 | 4 | 4 |
| Distance factor | 40% | 40% | 40% | 40% |

**[Table/Fig-1]:** Conventional MRI parameters on a 1.5T MR imaging unit.

The intracranial lesions were diagnosed based on their imaging characteristics in above described sequences. Low grade gliomas usually do not reveal areas of haemorrhage/necrosis with no or minimal perifocaloedema/enhancement. High grade gliomas reveal areas of haemorrhage/necrosis with significant perifocaloedema and heterogeneous enhancement.

### MRS

All the cases were evaluated by multivoxel spectroscopic technique. Multivoxel 2D CSI with VOI positioning on three reference images was performed using the following parameters: SE sequence with automatic dynamic high-order shimming and Gaussian water suppression, TR 1500 ms, TE 135 and 270 ms, FOV 160 mm, slice thickness 15 mm and 4 acquisition averages. A VOI of 30×30 mm was placed inside a FOV of 160×160 mm on a 15 mm transverse section in most examinations.

The spectra were automatically analysed for the relative signal intensities (areas under the fitted peaks in the time domain) of the following metabolites: Cho, Cr and NAA. Cho/Cr and Cho/NAA ratio were calculated at TE 135 ms. Post processing steps were performed first automatically and then manually if necessary using the software package provided by the manufacturer. Spectral analysis was performed in a window from 0.50 to 4.30 ppm. The maximum values of Cho/Cr and Cho/NAA ratios were considered from these spectral maps.

Spectrum of N-acetyl aspartate (NAA), Cho (Choline), and Creatine (Cr), lipid or lactate peaks was interpreted. Ratios for Cho/Cr and Cho/NAA were calculated. NAA is the indicator of neuronal integrity with its highest point at 2.02 ppm. Cho, on the other hand, indicates cell turnover with its highest point at 3.22 ppm. Cr takes part in cellular metabolism with its peak occurring at 3 ppm. Alanine, Lactate and Lipid peaks were identified at 1.48, 1.33 and 0.9-1.3 ppm [12].

The lesions can be differentiated on the basis of various ratios and peaks of these brain metabolites. A raised Cho, decreased NAA with associated raised Cho/Cr and Cho/NAA ratios indicates malignancy. High-grade neoplasms and infections show lipid and lactate peaks. The Cho/Cr and Cho/NAA ratios remain unchanged in benign lesions. Findings of MRS were compared and correlated with the histopathological data in every case.

## STATISTICAL ANALYSIS

Statistical analysis was done using Statistical Package for Social Sciences version 21. The data has been represented as number, percentage and mean±SD. Independent sample t-test was used to analyse the data. A p-value less than 0.05 was considered significant.

## RESULTS

Age of patients ranged from 4 to 72 years. Majority of cases were above 50 years of age (n=18; 58.1%). There was only one case aged <20 years and only two cases above 70 years of age. Mean age of patients was 50.61±15.44 years. The gender ratio (M:F) was 0.94 [Table/Fig-2].

| SN | Variable | No. of cases | Percentage |
|---|---|---|---|
| 1. | **Age group** | | |
| | ≤10 years | 1 | 3.2 |
| | 11-20 years | 0 | 0 |
| | 21-30 years | 2 | 6.5 |
| | 31-40 years | 4 | 12.9 |
| | 41-50 years | 6 | 19.4 |
| | 51-60 years | 9 | 29.0 |
| | 61-70 years | 7 | 22.6 |
| | 71-80 years | 2 | 6.5 |
| | Mean Age±SD (Range) yrs | 50.61±15.44 (4-72) | |
| 2. | **Gender** | | |
| | Male | 15 | 48.4 |
| | Female | 16 | 51.6 |

**[Table/Fig-2]:** Age and gender profile of cases enrolled in the study.

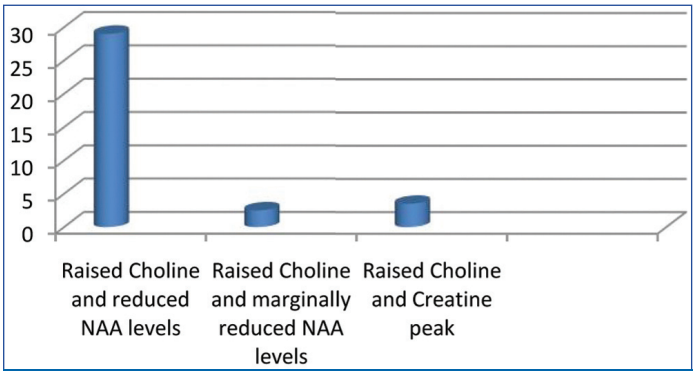
Restricted diffusion was seen in 17 (54.8%) cases while 22 (70.96%) cases showed magnetic susceptibility. Perifocaloedema Grade I, II and III was seen in 14 (45.2%), 8 (25.8%) and 9 (29.0%) cases respectively [Table/Fig-3].

| SN | Pattern | No. of cases | Percentage |
|---|---|---|---|
| 1. | Restriction of Diffusion | 17 | 54.8 |
| 2. | Magnetic susceptibility on SWI | 22 | 70.96 |
| 3. | **Perifocal oedema** | | |
| | Grade I | 14 | 45.2 |
| | Grade II | 8 | 25.8 |
| | Grade III | 9 | 29.0 |

**[Table/Fig-3]:** Distribution of cases according to imaging characteristics (n=31).

Post contrast enhancement was seen in all except one case (96.8%). Cho/Cr values showed a range starting from 1.25 to 4.70. Mean value was 2.87±0.98 while median was 2.80. Cho/NAA values ranged from 0.59 to 4.30 with a mean of 2.69±0.91 and a median of 2.90.

A total of 29 (93.5%) cases had raised choline and reduced NAA levels, 1 (3.2%) had raised choline and marginally reduced NAA and 1 (3.2%) had raised choline with creatine peak [Table/Fig-4].




**[Table/Fig-4]:** Distribution of cases according to Choline, NAA and Cr levels (Qualitative) (n=31).

No other metabolite peak was seen in 8 (25.8%) cases. Lipid and lactate peak was observed in 14 (45.2%) cases. One case (3.2%) had myoinositol peak, 5 (16.1%) had Alanine peak and 3 (9.7%) had lipid peak [Table/Fig-5].

| SN | Finding | No. of cases | Percentage |
|---|---|---|---|
| 1. | None | 8 | 25.8 |
| 2. | Lipid and lactate peak | 14 | 45.2 |
| 3. | Lipid peak | 3 | 9.7 |
| 4. | Alanine peak | 5 | 16.1 |
| 5. | Myoinositol peak | 1 | 3.2 |

**[Table/Fig-5]:** Distribution of other metabolite peaks on MRS (n=31).

On MRI, maximum (n=12; 38.7%) cases were diagnosed as high grade glioma. There were 6 (19.4%) cases diagnosed as low grade glioma and 5 (16.1%) as meningioma. A total of 4 (12.9%) cases were diagnosed as metastasis. Two (6.5%) cases were diagnosed as Lymphoma and 1 (3.2%) case each was diagnosed as central neurocytoma (low grade) and craniopharyngioma (low grade) respectively [Table/Fig-6].

| SN | Diagnosis | No. of cases | Percentage |
|---|---|---|---|
| 1. | High Grade Glioma | 12 | 38.7 |
| 2. | Low Grade Glioma | 6 | 19.4 |
| 3. | Meningioma | 5 | 16.1 |
| 4. | Metastasis | 4 | 12.9 |
| 5. | Lymphoma | 2 | 6.4 |
| 6. | Central Neurocytoma | 1 | 3.2 |
| 7. | Craniopharyngioma | 1 | 3.2 |

**[Table/Fig-6]:** Distribution of cases according to MRI diagnosis.

On combined MRI+MRS evaluation, maximum (n=11; 35.5%) were diagnosed as high grade glioma followed by low grade glioma (n=7; 22.6%), metastasis and meningioma (n=5; 16.1% each). There was 1 (3.2%) case each diagnosed as Central Neurocytoma (low grade), Lymphoma and craniopharyngioma (low grade) respectively [Table/Fig-7].

| SN | Diagnosis | No. of cases | Percentage |
|---|---|---|---|
| 1. | High Grade Glioma | 11 | 35.5 |
| 2. | Low Grade Glioma | 7 | 22.6 |
| 3. | Meningioma | 5 | 16.1 |
| 4. | Metastasis | 5 | 16.1 |
| 5. | Central Neurocytoma | 1 | 3.2 |
| 6. | Lymphoma | 1 | 3.2 |
| 7. | Craniopharyngioma | 1 | 3.2 |

**[Table/Fig-7]:** Distribution of cases according to MRI+MRS diagnosis.

Histopathologically, maximum number of cases were high grade tumours (n=14; 45.2%) (5 anaplastic astrocytoma, 5 glioblastoma multiforme, 1 anaplastic oligodendrogliomas, 1 thalamic high grade glioma, 1 PNET, 1 infiltrative astrocytoma) followed by low grade tumours (n=6; 19.4%) (3 diffuse astrocytoma, 1 astrocytoma, 1 oligodendrogliomas and 1 craniopharyngioma), metastasis (n=5; 16.2%), meningioma (n=5; 16.2%) and lymphoma (n=1; 3.2%) [Table/Fig-8].

| SN | Diagnosis | No. of cases | Percentage |
|---|---|---|---|
| 1. | High Grade Tumour | 14 | 45.2 |
| 2. | Low Grade Tumour | 6 | 19.4 |
| 3. | Metastasis | 5 | 16.2 |
| 4. | Meningioma | 5 | 16.2 |
| 5. | Lymphoma | 1 | 3.2 |

**[Table/Fig-8]:** Distribution of cases according to histopathological diagnosis.

Out of 14 high grade tumours by HPE, 11 were diagnosed correctly by MRI, two were diagnosed as low grade tumour (central neurocytoma and low grade glioma each) and 1 as lymphoma.

All the six low grade tumours by HPE were diagnosed correctly by MRI. All the five cases of meningioma by HPE were diagnosed correctly by MRI. Out of five cases of metastasis by HPE, four were diagnosed correctly by MRI, while one was diagnosed as high grade glioma. One case diagnosed as lymphoma by MRI was proven as lymphoma by HPE. Overall, MRI showed agreement on 26/31 (83.87%) case [Table/Fig-9].

| MRI Diagnosis | HPE Diagnosis | | | | |
|---|---|---|---|---|---|
| | High Grade Tumour (n=14) | Low Grade Tumour (n=6) | Meningioma (n=5) | Metastasis (n=5) | Lymphoma (n=1) |
| High Grade | 11 | 0 | 0 | 1 | - |
| Low Grade | 2 | 6 | - | - | - |
| Meningioma | - | - | 5 | - | - |
| Metastasis | - | - | - | 4 | - |
| Lymphoma | 1 | - | - | - | 1 |

**[Table/Fig-9]:** Agreement between HPE diagnosis and MRI diagnosis.

Out of 14 cases diagnosed as high grade tumours by HPE, 11 were diagnosed correctly by MRI+MRS, while three were diagnosed as low grade by MRI+MRS (one central astrocytoma, and two low grade glioma).

All the 6 cases of low grade tumours, 5 cases of meningioma, 5 cases of metastasis and one case of lymphoma was diagnosed correctly by combined use of MRI with MRS. Overall MRI+MRS showed agreement with HPE on 28 out of 31 (90.3%) cases [Table/Fig-10].

| MRI+MRS Diagnosis | HPE Diagnosis | | | | |
|---|---|---|---|---|---|
| | High Grade Tumour (n=14) | Low Grade Tumour (n=6) | Meningioma (n=5) | Metastasis (n=5) | Lymphoma (n=1) |
| High Grade | 11 | - | - | - | - |
| Low Grade | 3 | 6 | - | - | - |
| Meningioma | - | - | 5 | - | - |
| Metastasis | - | - | - | 5 | - |
| Lymphoma | | - | - | - | 1 |

**[Table/Fig-10]:** Agreement between HPE diagnosis and MRI+MRS diagnosis.

Mean Cho/Cr levels were recorded as 1.61±0.31, 2.94±0.75, 3.38±0.72 and 3.92±0.63 for low grade tumours, high grade tumours, meningioma and metastasis respectively. Statistically, there was a significant difference among different HPE diagnoses for

Cho/Cr levels (p<0.001). On comparing between group differences, maximum difference was observed between low grade and metastasis and minimum difference was observed between high grade and meningioma. It was observed that low grade tumours had significantly lower mean value as compared to all the three other diagnoses, while high grade tumours had lower mean value as compared to metastasis. Statistically, there was no significant difference between high grade and meningioma and meningioma and metastasis. The order of Cho/Cr values in different diagnoses was as follows: Metastasis ≃ Meningioma > High Grade > Low grade [Table/Fig-11,12].

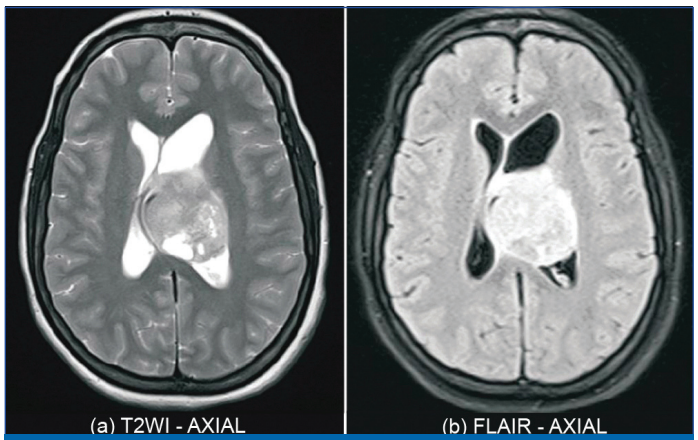
| SN | Diagnosis | N | Cho/Cr | | Cho/NAA | |
|---|---|---|---|---|---|---|
| | | | Mean | SD | Mean | SD |
| 1. | Low Grade (Grade I/II) | 6 | 1.61 | 0.31 | 1.99 | 0.55 |
| 2. | High Grade (Grade III/IV) | 14 | 2.94 | 0.75 | 2.60 | 0.75 |
| 3. | Meningioma | 5 | 3.38 | 0.72 | 3.56 | 0.66 |
| 4. | Metastasis | 5 | 3.92 | 0.63 | 3.34 | 0.39 |
| Statistical Significance (ANOVA) | | | F=12.557; p<0.001 | | F=6.773; p=0.002 | |

**[Table/Fig-11]:** Comparison of metabolite ratios among different HPE diagnoses.

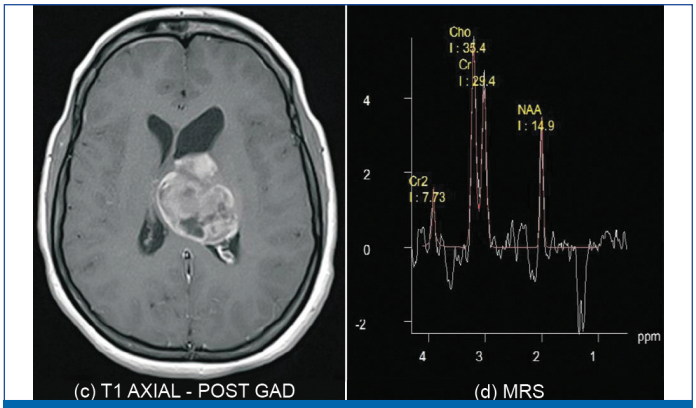
| Comparison | Cho/Cr | | | Cho/NAA | | |
|---|---|---|---|---|---|---|
| | Mean Diff. | SE | 'p' | Mean Diff. | SE | 'p' |
| Low vs High Grade | -1.33 | 0.32 | 0.002 | -0.60 | 0.32 | 0.260 |
| Low Grade vs Meningioma | -1.78 | 0.40 | 0.001 | -1.57 | 0.40 | 0.003 |
| Low Grade vs Metastasis | -2.32 | 0.40 | <0.001 | -1.35 | 0.40 | 0.011 |
| High Grade vs Meningioma | -0.44 | 0.34 | 0.579 | -0.96 | 0.34 | 0.043 |
| High Grade vs Metastasis | -0.98 | 0.34 | 0.039 | -0.74 | 0.34 | 0.159 |
| Meningioma vs Metastasis | -0.54 | 0.42 | 0.576 | 0.22 | 0.42 | 0.951 |

**[Table/Fig-12]:** Between HPE diagnosis comparison of metabolite ratios (Tukey HSD test).

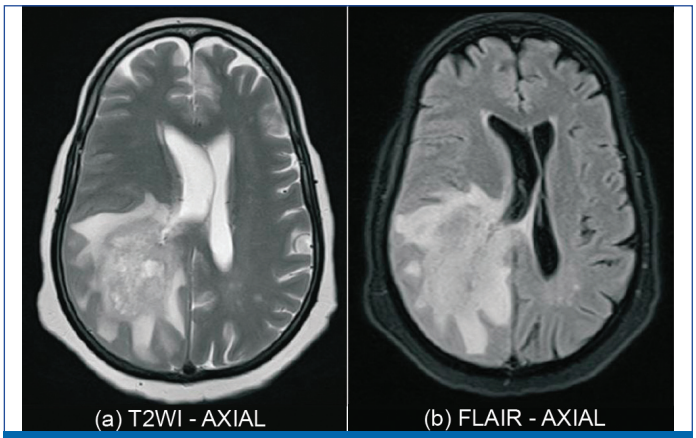
Mean Cho/NAA levels were recorded as 1.99±0.55, 2.60±0.75, 3.56±0.66 and 3.34±0.39 for low grade tumours, high grade tumours, meningioma and metastasis respectively. Statistically, there was a significant difference among different HPE diagnoses for Cho/NAA levels (p<0.001). On between diagnosis comparisons, low grade tumours were found to have significantly lower mean value as compared to meningioma and metastasis while high grade tumours were found to have a significantly lower mean value as compared to meningioma. Statistically, there was no significant difference between low grade and high grade, high grade and metastasis and meningioma and metastasis. The order of Cho/NAA values for different diagnoses was as follows: Low grade <High grade < Meningioma ~ Metastasis [Table/Fig-11,12]. The present study shows the MRI and MRS findings of few cases in [Table/Fig-13-18].



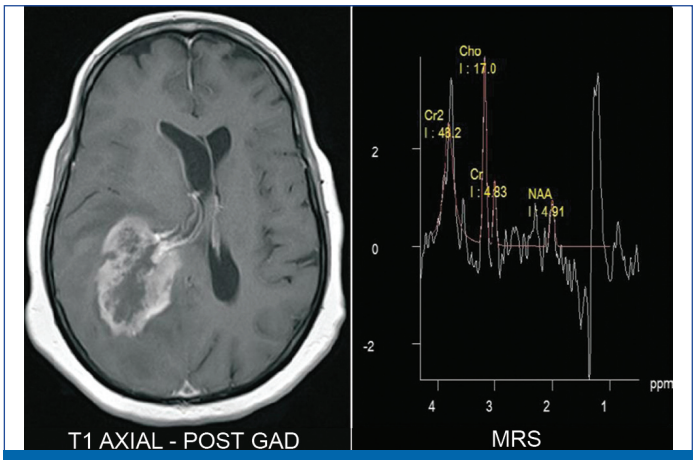

**[Table/Fig-13a,b]:** Mass lesion arising from left thalamus with intraventricular extension. It appears heterogeneously hyperintense with small cystic areas within on T2WI and FLAIR sequences.



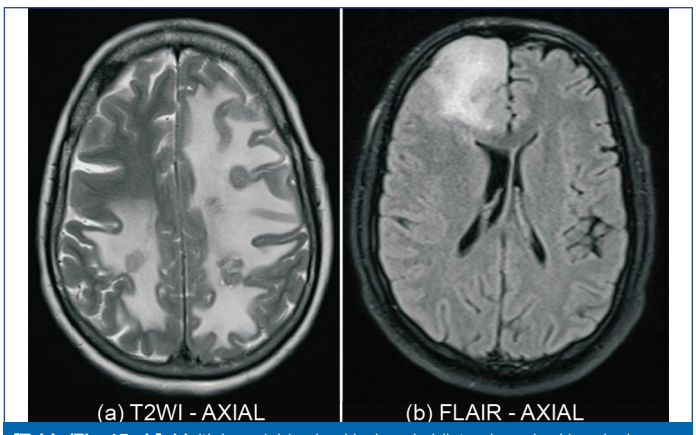

**[Table/Fig-13c,d]:** Heterogeneous enhancement on post GAD sequences. MRS revealed raised choline and reduced NAA levels Diagnosis: High grade thalamic glioma.



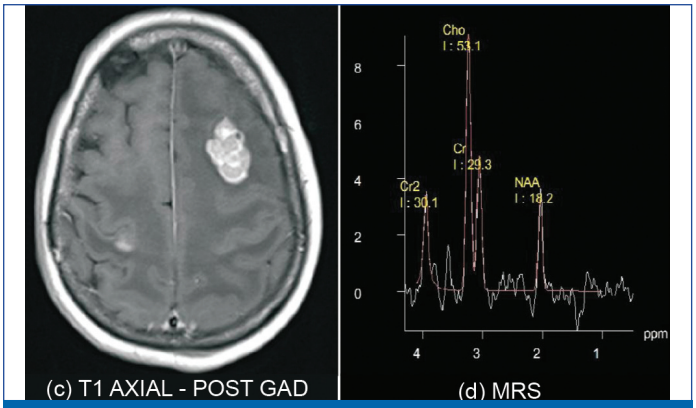

**[Table/Fig-14a,b]:** Mass lesion in right temporo-parietal region involving right ventricle. It appears heterogeneously hyperintense with cystic area within on T2WI and FLAIR sequences.



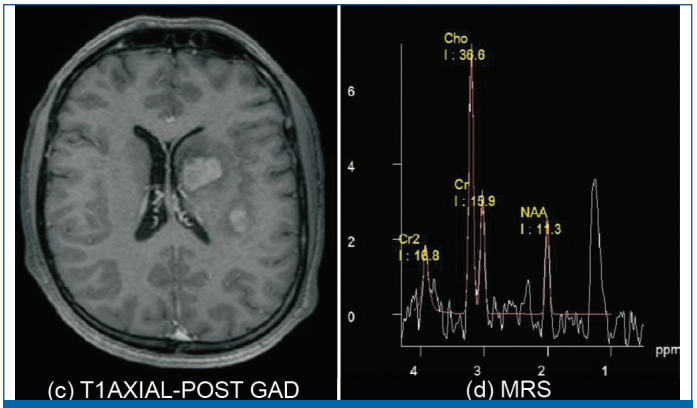

**[Table/Fig-14c,d]:** Heterogeneous peripheral enhancement with large central non-enhancing area onpost GAD sequences. MRS revealed raised choline and reduced NAA levels with prominentlactate peak. Diagnosis: Glioblastoma Multiforme



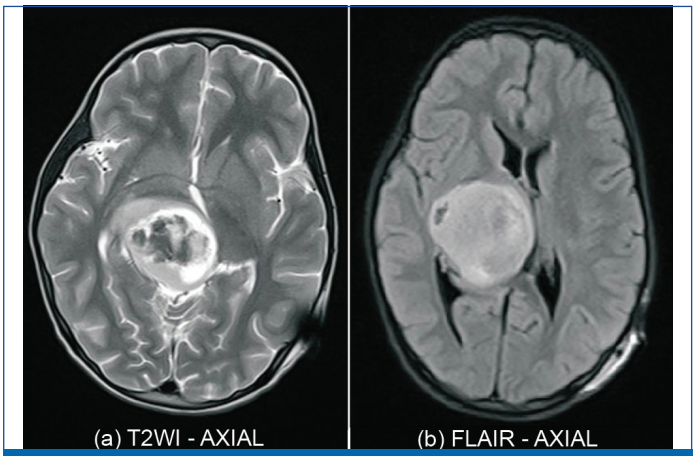

**[Table/Fig-15a,b]:** Multiple variable sized lesions in bilateral cerebral hemispheres. It appears heterogeneously hyperintense on T2WI and FLAIR sequences.



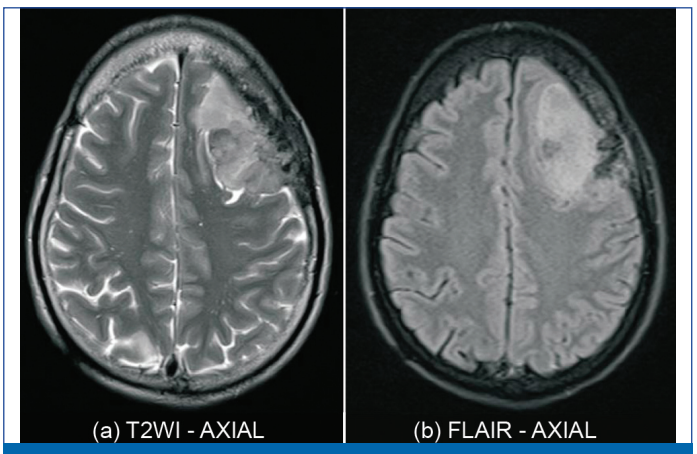

**[Table/Fig-15c,d]:** Heterogeneous enhancement on post GAD sequences. MRS revealed raised choline and reduced NAA levels with absent choline peak in peritumoural region. Diagnosis: Metastases



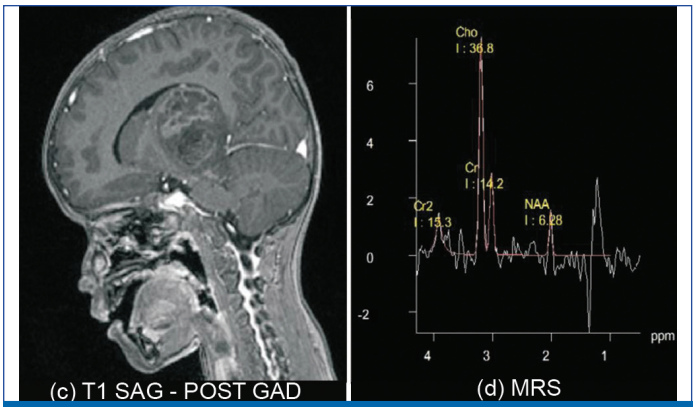

**[Table/Fig-17c,d]:** Homogenous enhancement on post GAD sequences. MRS revealed raisedcholine and reduced NAA levels with prominent lactate peak. Diagnosis: Primary CNS Lymphoma



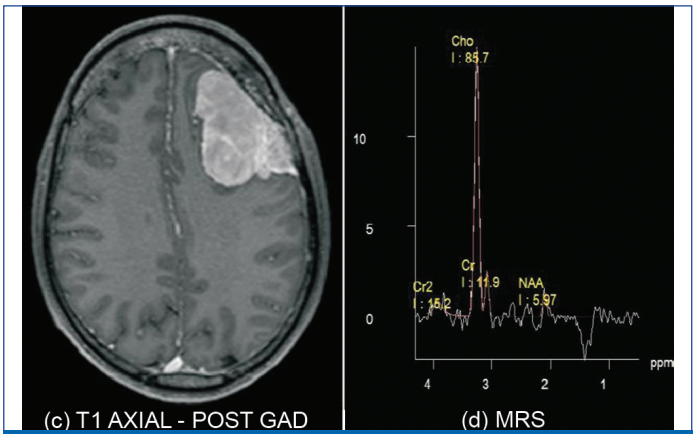

**[Table/Fig-16a,b]:** Mass lesion arising from right thalamus involving right ventricle. It appears heterogeneously hyperintense with irregular hypointense areas within on T2WI and FLAIR sequences.



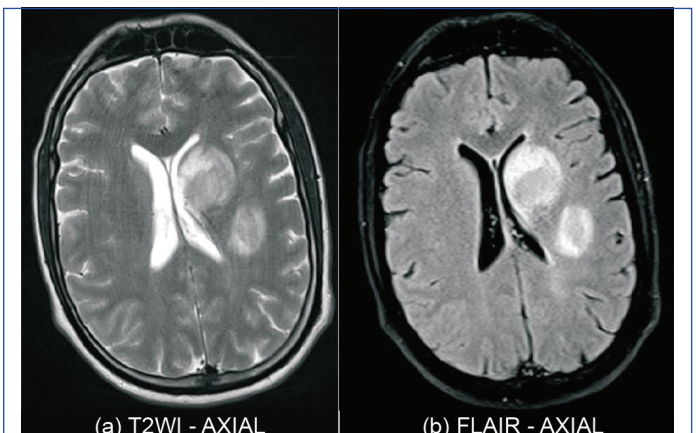

**[Table/Fig-18a,b]:** Dural based mass lesion in left frontal region. It appears heterogeneously hyperintense on T2WI and FLAIR sequences.




**[Table/Fig-16c,d]:** Heterogeneous enhancement with non-enhancing areas within on post GADsequences. MRS revealed raised choline and reduced NAA levels with lactate peak. Diagnosis: Primitive Neuroectodermal Tumour.




**[Table/Fig-18c,d]:** Heterogeneous enhancement on post GAD sequences. MRS revealed raised choline and reduced NAA levels with reversed Alanine peak Diagnosis: Left Frontal Meningioma




**[Table/Fig-17a,b]:** Multiple variable sized lesions in left basal ganglia and internal capsule. It appears heterogeneously hyperintense on T2WI and FLAIR sequences.

## DISCUSSION

With this background, the present study was planned with a primary aim to study the diagnostic performance of MRS for detecting, differentiating and grading brain tumours and to determine the diagnostic value of MRS. MRS is non-invasive method for characterizing chemical metabolites of the brain. Thus, it is used to measure the chemical composition of tissues and characterization of certain tissue metabolic processes. The concentrations of various MRS-visible brain metabolites are observed as spectral peaks which can be used to detect abnormalities in brain regions that appear normal in MRI.

In present study, a total of 31 patients aged between 4 and 72 years were enrolled. Mean age of patients was 50.61±15.44 years. Majority were aged >50 years (n=18; 58.1%). The gender ratio of the study was 0.94. Brain tumours affect almost all age groups. However, in different studies age profile of patients varies owing to

difference in nature of facility or the inclusion criteria used by the authors. In a recent study, Solanki RN et al., enrolled patients from 0 to 90 years of age; but found majority of patients in 31 to 50 years of age [25]. Subsequently, they reported the gender ratio to be 2. Yamasaki F et al., on the other hand reported the age range of patients (1-85 years) to be as diversified as in present study and also reported the mean age of patients as 46.5 years which is close to that observed in present study [26]. They also reported a male dominance (58.2%). The findings in general suggest that brain tumours can occur at any age and in either gender, the present study also supports this view point.

In present study, on MRI, restriction of diffusion was seen in 17 (54.8%) cases. Restricted diffusion is generally attributable to highly cellular tumours (primitive neuroectodermal tumour, Glioblastoma multiforme (GBM), meningioma, lymphoma, metastases) that increase cellularity [2-5] and affects the perifocal areas too as observed in present study. Thus majority of cases in present study indicated a high cellular activity. Magnetic susceptibility on SWI was observed in 81% cases. SWI was better than the conventional contrast-enhanced T1-weighted imaging in visualizing small tumour vessels. A high-grade astrocytoma revealed increased tumour vascularity and large areas of micro-haemorrhage. On the contrary, low-grade tumours have sparse vascularity and small areas of micro-haemorrhages [27]. Thus, diffusion weighted and susceptibility weighted imaging helped to enhance the characteristics of tumours quite vividly and helping in their understanding. MRI revealed Grade I, II and III perifocal oedema in 45.2%, 25.8% and 29% cases. In present study, we performed grading of the perifocal oedema and reported Grade III oedema in 29% of cases.

The present study found post contrast enhancement in 30/31 (96.8%) of cases, thus reflecting nonspecific breakdown of the blood–brain barrier. Within diffuse gliomas, contrast enhancement is positively correlated with tumour grade. Although, few high-grade gliomas may show no or minimal enhancement and certain WHO grade I gliomas such as pilocytic astrocytoma or ganglioglioma can enhance avidly [28]. Thus, MR images obtained in present study were suggestive of a high dominance of high grade gliomas which was finally confirmed histopathologically too.

In present study, on MRS, mean Cho/Cr and Cho/NAA ratios were 2.87±0.98 and 2.69±0.91 respectively. Raised choline and reduced NAA levels were observed in 29 (93.5%) cases, 1 (3.2%) case had raised choline and marginally reduced NAA levels while remaining 1 (3.2%) case had raised choline and creatine peak. Among other metabolites, Lipid and lactate peak was observed in 14 (45.2%) cases. One case (3.2%) had myoinositol peak, 5 (16.1%) had Alanine peak and 3 (9.7%) had lipid peak.

Cho resonance is most prominent in regions with high neoplastic cellular density and is progressively lower in moderate and low-grade tumours [29,30]. Similarly, decrease in NAA was reflective of impairment of normal functioning of neurons and axons with neoplastic tissue. Presence of creatine peaks has been taken as indication of low grade tumours as below normal creatine levels have been considered to be the features of high grade gliomas, metastasis and meningiomas [31,32]. Similarly, observation of lipid and lactate peaks in a sizeable proportion of cases also indicated dominance of high-grade tumours and metastasis [33]. Thus, in general, the MR spectroscopic profile of cases was reflective of dominance of high grade and metastatic tumours. Similarly, Alanine peaks have been reported to be quite consistent with diagnosis of meningioma [34] while Myo-inositol peak is consistent with the possibility of Schwannoma [34].

In present study, on histopathology, maximum number of cases (n=14; 45.2%) were diagnosed as high grade tumours followed by low grade tumours (n=6; 19.4%), meningioma (n=5; 16.1%), metastasis (n=5; 16.1%) and lymphoma (n=1; 3.2%) respectively.

Brain tumours often have diversified pathologies. Shokry A in a series of 42 patients had 15 patients with brain glioma (10 high grade, 5 low grade), 10 patients with meningioma, 10 patients with brain metastasis and 7 cases of treated glioma with post radiation necrosis [35]. Alam MS et al., in their series of 53 cases divided histopathological diagnosis into neoplastic and non-neoplastic types and found dominance of neoplastic cases (n=43; 81%) over non-neoplastic (n=10; 19%) cases [12]. In present study, we did not find any negative cases on histopathology. In fact, the benefit of using MRI, MRS and other highly sensitive and specific diagnostic modalities is to rule out undesired intervention and to rule out negative findings during the imaging itself. Nevertheless, the histopathological profile of brain tumours cannot be restricted to a particular stereotype and varies from study to study.

In present study, MRI diagnosed high grade tumours in 12 (38.7%), low grade tumours in 6 (19.4%), meningioma in 5 (16.1%), metastasis in 4 (12.9%) and lymphoma in 2 (6.4%) case. On correlation with histopathology, the agreement was observed on 26/31 (83.87%) cases. However, MRS in combination with MRI diagnosed high grade tumours in 11 (35.5%), low grade tumours in 7 (22.6%), meningioma in 5 (16.1%), metastasis in 5 (16.1%) and Lymphoma in 1 (3.2%) case. On correlation with histopathology, the agreement was observed on 28/31 (90.3%) cases. Thus, MRS in combination with MRI helped to attain precise diagnosis in 2 (6.5%) additional cases. It has already been stated above that metabolite levels helps in differentiating high grade/metastatic tumours from low grade/non-neoplastic conditions successfully. Kumar A et al., too in their study made similar observation that MR spectroscopy helps to arrive at a more definitive diagnosis in doubtful brain tumours with similar morphological imaging patterns [36]. In present study, we did not detect the diagnostic accuracy of two techniques for each independent diagnosis yet found that enhancement of accuracy for overall assessment (83.87% to 90.3%). Here the point is not in getting only a marginal increase in accuracy; however, the point is to have an accurate diagnosis in patients supposed to go for brain surgery. In present study, the diagnostic accuracy of MRS was observed to be 90.3%. Majós C et al., reported its accuracy in 90-94% range using two different protocols [37]. Alam MS et al., similar to our study found it to be 88.67% accurate [12]. Solanki RN et al., too showed that addition of MRS to MRI enhances the sensitivity and specificity for tumour differentiation in a dramatic manner [25]. In their study they found it to increase to reach 100% for detection of toxoplasmosis. Although in present study, no such infectious lesions were taken in to account, however, a high accuracy of MRS combined with MRI endorses the viewpoint expressed by previous workers.

In present study, we evaluated the role of metabolite ratios viz., Cho/Cr mean Cho/Cr and Cho/NAA levels and found a significant association with histopathological diagnosis. Mean Cho/Cr and Cho/NAA levels were minimum in low grade tumours and maximum in meningioma/ metastasis cases. It was seen that these ratios had potential for differential diagnosis of different types of brain tumours. Despite small sample size, it was observed that Cho/Cr had ability to differentiate between low grade and high grade, low grade and meningioma and high grade and metastasis cases. For Cho/NAA levels too, low grade and high grade tumours could be differentiated from meningioma and low grade tumours from metastasis. However; the limitation of the study was small sample size and despite this limitation these trends indicate of the differentiating potential of these metabolites. Solanki RN et al., too in their study highlighted the role of Cho/Cr and Cho/NAA ratios as successful differentiating markers between low and high grade gliomas [25]. However, in their study they did not evaluate its usefulness beyond differentiation of low and high grade gliomas. In present study we went a step further and found its possible usefulness. Tong T et al., too found them useful for differentiation between high and low grade brain tumours [38]. Similar observations were also made by other workers too [17,35,39].

The findings in the study thus suggest that MRS in combination with MRI is a useful modality in the evaluation of brain tumours. Interestingly, while MRI provides useful information regarding the morphological changes, MRS provides clues to the underlying pathophysiological changes thus helping in understanding the problem from a holistic perspective.

## LIMITATION

One of the limitations of the present study was small sample size, owing to which adequate representation of all types of brain tumours could not be done. Further studies on a larger sample size with longer duration are recommended in order to get more robust results.

## CONCLUSION

The present study was planned to assess the diagnostic performance of MRS for detecting, differentiating and grading brain tumours. The study highlighted the usefulness of Cho/Cr and Cho/NAA in histopathological differentiation. Mean Cho/Cr and Cho/NAA levels showed signifiacnt association with histopathological diagnosis. Mean Cho/Cr and Cho/NAA levels were minimum in low grade tumours and maximum in meningioma/metastases cases. Alanine peak was consistent with diagnosis of meningioma.

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