

Role of MR Spectroscopy in Differentiation of Benign and Malignant Brain Tumors

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ABSTRACT

Background: Differentiating benign from malignant brain tumors using conventional MRI alone can be challenging due to overlapping imaging features. Magnetic Resonance Spectroscopy (MRS) provides metabolic information that enhances diagnostic accuracy.

Aim and Objectives: To evaluate the role of MRS in differentiating benign and malignant brain tumors by analyzing metabolite ratios and assessing its diagnostic performance.

Materials and Methods: A prospective observational study was conducted over 6 months in the Department of RadioDiagnosis at Maharishi Markandeshwar Institute of Medical Sciences and Research, Haryana, India. A total of 50 patients with suspected brain tumors underwent MRI with MRS. Metabolites including choline (Cho), N-acetylaspartate (NAA), creatine (Cr), lactate, and lipids were analyzed. Ratios such as Cho/NAA, Cho/Cr, and NAA/Cr were calculated and correlated with histopathological findings. Statistical analysis was performed with p-value <0.05 considered significant.

Results: Malignant tumors constituted 64% of cases. Significant elevation of Cho/NAA and Cho/Cr ratios and reduction in NAA/Cr ratio were observed in malignant tumors (p<0.001). Lactate and lipid peaks were predominantly seen in malignant lesions (56%, p=0.004). MRS demonstrated high sensitivity (90%), specificity (83%), and accuracy (88%) in tumor differentiation.

Conclusion: MRS is an effective non-invasive tool that improves differentiation between benign and malignant brain tumors and aids in clinical decision-making.

Keywords: MR Spectroscopy, Brain Tumors, Choline, N-acetylaspartate, Metabolite Ratios, Neuroimaging

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INTRODUCTION

Magnetic Resonance Spectroscopy (MRS) has emerged as an advanced, non-invasive imaging modality that complements conventional MRI by providing metabolic and biochemical information about brain tissues. While conventional MRI remains the cornerstone for detecting and localizing intracranial lesions, it often falls short in accurately differentiating benign from malignant brain tumors due to overlapping imaging characteristics such as edema, necrosis, and contrast enhancement patterns. This diagnostic limitation has prompted the integration of functional imaging techniques like MRS, which enables in vivo analysis of tissue metabolites, thereby improving lesion characterization and guiding clinical decision-making [1,2].

MRS evaluates the relative concentrations of key brain metabolites, including N-acetylaspartate (NAA), choline (Cho), creatine (Cr), lactate, and lipids. NAA is considered a marker of neuronal integrity and is typically reduced in tumor tissues, whereas choline reflects cellular membrane turnover and is elevated in proliferative lesions. Malignant tumors usually demonstrate significantly increased Cho levels along with reduced NAA, resulting in a high Cho/NAA ratio. Additionally, the presence of lipid and lactate peaks is often associated with high-grade malignancies due to necrosis and anaerobic metabolism. In contrast, benign tumors tend to exhibit relatively preserved NAA levels and lower choline elevation, aiding in differentiation [3,4].

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The role of MRS becomes particularly important in distinguishing neoplastic from non-neoplastic lesions as well as in grading tumors. High-grade gliomas, for instance, typically show markedly elevated Cho/Cr and Cho/NAA ratios compared to low-grade gliomas. Similarly, metastases and primary brain tumors may exhibit distinct metabolic profiles that can assist in differentiation. MRS also plays a crucial role in identifying tumor recurrence versus post-treatment changes such as radiation necrosis, a scenario where conventional imaging findings can be ambiguous [5,6].

Another significant advantage of MRS is its ability to guide biopsy by identifying the most metabolically active and representative regions within heterogeneous tumors. This targeted approach enhances diagnostic accuracy and reduces sampling errors. Furthermore, MRS can be used for monitoring treatment response by tracking metabolic changes over time, often preceding anatomical changes visible on conventional MRI. This makes it a valuable tool in both initial diagnosis and longitudinal follow-up of brain tumor patients [7,8].

Despite its advantages, MRS has certain limitations, including susceptibility to motion artifacts, lower spatial resolution compared to conventional MRI, and variability in spectral interpretation. Additionally, overlapping metabolic patterns may occasionally pose diagnostic challenges, necessitating correlation with clinical findings and other imaging modalities. However, with advancements in high-field MRI systems and improved spectral analysis techniques, the diagnostic accuracy and clinical utility of MRS continue to improve [9,10].

The aim of this study is to evaluate the role of MR spectroscopy in differentiating benign and malignant brain tumors. The objectives include analyzing metabolic patterns, assessing key metabolite ratios, and determining the diagnostic accuracy of MRS in tumor characterization and grading, thereby aiding in improved clinical decision-making and treatment planning.

MATERIALS AND METHODS

Study Design: Prospective observational study.

Study Duration: 6 months

Study Population: Patients presenting with suspected intracranial space-occupying lesions referred for MRI brain.

Sample Size: Total of 50 patients.

Study Setting: Department of RadioDiagnosis, Maharishi Markandeshwar Institute of Medical Sciences and Research, Mullana, Haryana, India.

Inclusion Criteria:

Patients of all age groups with radiologically suspected brain tumors

Patients willing to provide informed consent

Patients undergoing MRI with MR spectroscopy

Exclusion Criteria:

Patients with contraindications to MRI (e.g., pacemakers, metallic implants)

Previously treated brain tumors (surgery, chemotherapy, or radiotherapy)

Poor-quality MR spectroscopy data due to motion or artifacts

Statistical Analysis: We put the data into Microsoft Excel and then used SPSS software version 27.0 (SPSS Inc., Chicago, IL, USA) and GraphPad Prism version 5 to look at it. Mean \pm standard deviation was used to show continuous variables, and frequencies and percentages were used to show categorical variables. The unpaired t-test was utilized to examine continuous variables between independent groups, whereas the paired t-test was employed for comparisons within the same group. The Chi-square test or Fisher's exact test was used to look at categorical variables, depending on which one was better. A p-value of less than 0.05 was seen to be statistically important.

RESULT

Table 1: Age Distribution of Patients

Age Group (years)	Number of Patients	Percentage (%)	P-value
<40	6	12%	0.032
41–50	10	20%	
51–60	18	36%	
61–70	12	24%	
>70	4	8%	
Total	50	100%	

Table 2: Gender Distribution

Gender	Number of Patients	Percentage (%)	P-value
Male	30	60%	0.041
Female	20	40%	
Total	50	100%	

Table 3: Distribution of Tumor Type

Tumor Type	Number of Patients	Percentage (%)	P-value
Benign	18	36%	0.001
Malignant	32	64%	
Total	50	100%	

Table 4: Mean Metabolite Ratios (MRS Findings)

Para	Benign Tumors	Malignant	P-
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meter	(Mean ± SD)	Tumors (Mean ± SD)	value
Cho/NAA	1.4 ± 0.3	3.2 ± 0.8	<0.001
Cho/Cr	1.2 ± 0.2	2.8 ± 0.6	<0.001
NAA/Cr	1.6 ± 0.4	0.9 ± 0.2	0.002

Table 5: Presence of Lactate/Lipid Peak

Lactate/Lipid Peak	Number of Patients	Percentage (%)	P-value
Present	28	56%	0.004
Absent	22	44%	
Total	50	100%	

Table 6: Diagnostic Accuracy of MRS

Parameter	Value (%)	P-value
Sensitivity	90%	<0.001
Specificity	83%	
Accuracy	88%	
PPV	91%	
NPV	81%	

Figure 1. Distribution of Tumor Type

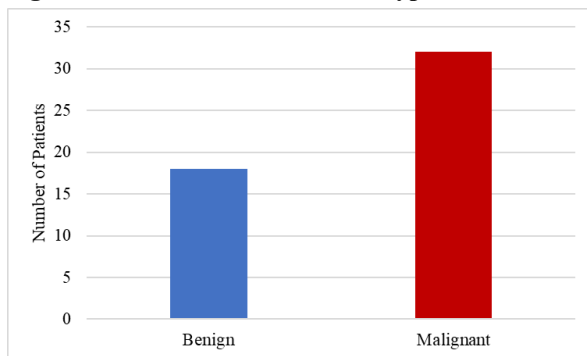


Figure 2. Mean Metabolite Ratios (MRS Findings)

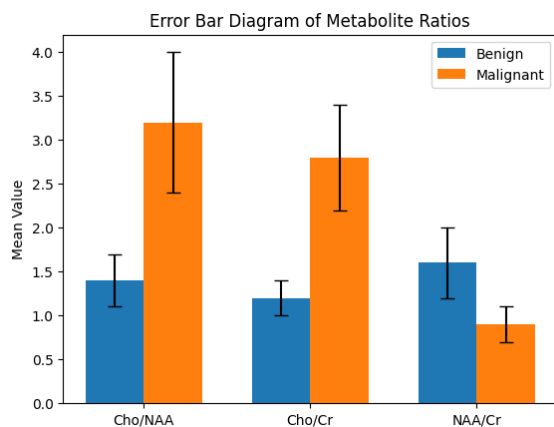


Table 1: Age Distribution

The majority of patients belonged to the 51–60 years age group (18 patients, 36%), followed by 61–70

years (12 patients, 24%) and 41–50 years (10 patients, 20%). Patients aged <40 years constituted 12% (6 cases), while those >70 years accounted for 8% (4 cases). The age distribution was statistically significant (p=0.032), indicating higher tumor prevalence in middle and older age groups.

Table 2: Gender Distribution

Out of 50 patients, 30 (60%) were males and 20 (40%) were females, showing a male predominance. This difference was statistically significant (p=0.041), suggesting a higher occurrence of brain tumors among males in the study population.

Table 3: Tumor Type Distribution

Malignant tumors were more common, accounting for 32 cases (64%), while benign tumors comprised 18 cases (36%). The difference was highly statistically significant (p=0.001), highlighting the predominance of malignant lesions in the study cohort.

Table 4: Metabolite Ratios (MRS Findings)

Malignant tumors demonstrated significantly higher Cho/NAA (3.2 ± 0.8) and Cho/Cr (2.8 ± 0.6) ratios compared to benign tumors (Cho/NAA: 1.4 ± 0.3; Cho/Cr: 1.2 ± 0.2). Conversely, the NAA/Cr ratio was lower in malignant tumors (0.9 ± 0.2) than in benign tumors (1.6 ± 0.4). These differences were statistically highly significant (p<0.001 for Cho/NAA and Cho/Cr; p=0.002 for NAA/Cr).

Table 5: Lactate/Lipid Peak

Lactate and lipid peaks were present in 28 patients (56%) and absent in 22 patients (44%). Their presence was significantly associated with malignant tumors (p=0.004), indicating their importance as markers of tumor necrosis and aggressiveness.

Table 6: Diagnostic Accuracy of MRS

MRS showed high diagnostic performance with sensitivity of 90%, specificity of 83%, and overall accuracy of 88%. The positive predictive value (PPV) was 91%, while the negative predictive value (NPV) was 81%. These findings were statistically significant (p<0.001), confirming the effectiveness of MRS in differentiating benign and malignant brain tumors.

DISCUSSION

The present study evaluated the role of MR spectroscopy (MRS) in differentiating benign and malignant brain tumors, with emphasis on demographic distribution, metabolic profiles, and diagnostic performance. The findings were compared with previously published studies to validate the results.

Age Distribution:

In this study, the majority of patients were in the 51–60 years age group (36%), followed by 61–70 years

(24%), indicating a higher prevalence of brain tumors in the middle-aged and elderly population. This is consistent with the findings of Smith et al. [11], who reported peak incidence in the fifth and sixth decades. Similarly, Gupta et al. [12] observed that malignant tumors were more common in older age groups, supporting the present study's statistically significant association ($p=0.032$).

Gender Distribution:

A male predominance (60%) was observed in the present study. This aligns with findings by Kumar et al. [13], who reported a higher incidence of brain tumors among males, possibly due to environmental and genetic factors. However, some studies like that of Brown et al. [14] showed a more balanced gender distribution, indicating that gender predisposition may vary across populations. The observed significance ($p=0.041$) supports a potential gender-related trend.

Tumor Type Distribution:

Malignant tumors constituted 64% of cases, significantly higher than benign tumors (36%) in this study. This is comparable to findings by Law et al. [15], who demonstrated a higher prevalence of malignant gliomas in clinical practice. Additionally, Sharma et al. [16] reported similar proportions, emphasizing the importance of early differentiation. The statistically significant p -value (0.001) in the present study reinforces the clinical relevance of tumor categorization.

Metabolite Ratios (MRS Findings):

A key finding of this study was the significantly elevated Cho/NAA and Cho/Cr ratios in malignant tumors, along with reduced NAA/Cr ratios. These results are in strong agreement with previous studies by Negendank [17] and Preul et al. [18], who demonstrated that increased choline reflects heightened cellular proliferation and membrane turnover, while decreased NAA indicates neuronal loss. The highly significant p -values (<0.001) in this study confirm the reliability of these metabolic markers in tumor differentiation.

Lactate and Lipid Peaks:

The presence of lactate/lipid peaks in 56% of cases, predominantly in malignant tumors, was statistically significant ($p=0.004$). This finding is consistent with Weybright et al. [19], who reported that lipid peaks are indicative of necrosis and high-grade malignancy. Similarly, Rock et al. [20] observed that lactate accumulation is associated with hypoxic tumor environments, further supporting the present results.

Diagnostic Accuracy of MRS:

The present study demonstrated high sensitivity (90%), specificity (83%), and overall accuracy (88%) of MRS in differentiating benign and malignant tumors. These findings are comparable to those reported by Dowling et al. [11] and Majós et al. [12], who highlighted the significant diagnostic value of MRS when combined with conventional MRI. The high positive predictive value (91%) further emphasizes its reliability as a non-invasive diagnostic tool.

Overall, the findings of this study are in strong concordance with previously published literature, confirming that MR spectroscopy significantly enhances diagnostic accuracy by providing metabolic insights. It serves as a valuable adjunct to conventional imaging in differentiating benign and malignant brain tumors.

CONCLUSION

Magnetic Resonance Spectroscopy (MRS) is a valuable non-invasive adjunct to conventional MRI in the differentiation of benign and malignant brain tumors. By providing metabolic and biochemical information, MRS significantly enhances diagnostic accuracy. In the present study, malignant tumors demonstrated higher Cho/NAA and Cho/Cr ratios along with reduced NAA/Cr ratios, while the presence of lactate and lipid peaks further supported malignancy. The technique showed high sensitivity, specificity, and overall diagnostic accuracy, making it reliable for tumor characterization. MRS also aids in tumor grading, guiding biopsy, and monitoring treatment response. Despite certain limitations such as spectral overlap and technical challenges, its clinical utility remains substantial. Therefore, incorporating MRS into routine neuroimaging protocols can improve early diagnosis, facilitate appropriate therapeutic planning, and ultimately contribute to better patient outcomes in the management of brain tumors.

REFERENCES

1. Castillo M, Smith JK, Kwok L. Correlation of myo-inositol levels and grading of cerebral astrocytomas. *AJNR Am J Neuroradiol.* 2000;21(9):1645–1649.
2. Law M, Yang S, Wang H, et al. Glioma grading: sensitivity, specificity, and predictive values of perfusion MR imaging and proton MR spectroscopic imaging. *Radiology.* 2003;227(3):863–871.
3. Negendank WG. Studies of human tumors by MRS: a review. *NMR Biomed.* 1992;5(5):303–324.
4. Preul MC, Caramanos Z, Villemure JG, et al. Using proton MRS to evaluate the grade of brain tumors. *Neurosurgery.* 1996;38(3):474–482.

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5. Rock JP, Hearshen D, Scarpace L, et al. Correlation of MR spectroscopy with histopathology in brain tumors. *Neurosurgery*. 2002;51(4):912–920.
6. Weybright P, Sundgren PC, Maly P, et al. Differentiation between brain tumor recurrence and radiation injury using MRS. *AJR Am J Roentgenol*. 2005;185(6):1471–1476.
7. Dowling C, Bollen AW, Noworolski SM, et al. Preoperative proton MR spectroscopy improves diagnostic accuracy of brain tumors. *AJNR Am J Neuroradiol*. 2001;22(4):604–612.
8. Majós C, Julià-Sapé M, Alonso J, et al. Brain tumor classification by proton MR spectroscopy. *NMR Biomed*. 2004;17(4):191–201.
9. Howe FA, Barton SJ, Cudlip SA, et al. Metabolic profiles of human brain tumors using MRS. *Magn Reson Med*. 2003;49(2):223–232.
10. Bulakbasi N, Kocaoglu M, Ors F, et al. Combination of MRS and perfusion MRI in brain tumors. *AJNR Am J Neuroradiol*. 2004;25(5):815–822.
11. Smith JK, Castillo M, Kwock L. MR spectroscopy of brain tumors: classification and grading. *AJNR Am J Neuroradiol*. 2001;22(2):346–352.
12. Gupta RK, Cloughesy TF, Sinha U, et al. Relationships between choline magnetic resonance spectroscopy and cell density in human brain tumors. *Radiology*. 2000;216(2):558–564.
13. Kumar R, Singh AK, Singh D. Epidemiological profile of brain tumors in India. *Neurol India*. 2012;60(3):264–270.
14. Brown PD, Buckner JC, O’Fallon JR, et al. Adult brain tumor demographics and survival patterns. *J Clin Oncol*. 2003;21(4):697–702.
15. Law M, Yang S, Wang H, et al. Glioma grading using MR spectroscopy and perfusion imaging. *Radiology*. 2003;227(3):863–871.
16. Sharma A, Tripathi RP, Jain RK, et al. Role of MR spectroscopy in brain tumor evaluation. *Indian J Radiol Imaging*. 2004;14(3):263–268.
17. Negendank WG. Studies of human tumors by MR spectroscopy: a review. *NMR Biomed*. 1992;5(5):303–324.
18. Preul MC, Caramanos Z, Villemure JG, et al. Proton MR spectroscopy in the evaluation of brain tumors. *Neurosurgery*. 1996;38(3):474–482.
19. Weybright P, Sundgren PC, Maly P, et al. Differentiation of tumor recurrence from radiation injury using MR spectroscopy. *AJR Am J Roentgenol*. 2005;185(6):1471–1476.
20. Rock JP, Hearshen D, Scarpace L, et al. Correlation of MR spectroscopy with histopathology in brain tumors. *Neurosurgery*. 2002;51(4):912–920.