ISSN: 0975-3583,0976-2833 VOL16, ISSUE 03, 2025

MR SPECTROSCOPY IN THE ASSESSMENT OF BRAIN TUMORS: ADDITIONAL INSIGHTS BEYOND MRI

Dr. Sathish Babu.S, Dr. Antlin sushma.L, Dr. Vinod.S

1. *Professor, Department of Radiodiagnosis, Sree mookambika Institute of Medical Sciences, Kanyakumari, Tamilnadu, India*
2. *Junior resident, Department of Radiodiagnosis, Sree mookambika Institute of Medical Sciences, Kanyakumari, Tamilnadu, India*
3. *Professor, Department of Radiodiagnosis, Sree mookambika Institute of Medical Sciences, Kanyakumari, Tamilnadu, India*

Corresponding Author: Dr. Antlin Sushma. L, Department of Radiodiagnosis, Sree mookambika Institute of Medical Sciences, Kanyakumari, Tamilnadu, India

ABSTRACT

Background

Conventional MR imaging provides detailed anatomical information for diagnosing suspected brain tumors. However, MRI alone may not always resolve diagnostic uncertainties for many patients. Magnetic resonance spectroscopy (MRS), a non-invasive method that measures various metabolites, can provide additional insights. The combination of MRS and MRI was particularly beneficial in distinguishing between tumor types, assessing tumor grade, and evaluating treatment response.This study seeks to highlight the effectiveness of MR spectroscopy in evaluating and diagnosing brain tumors compared to MRI alone.

Methods

A study involving 43 patients who underwent MRI and MR spectroscopy for brain lesions assessed the overall diagnostic performance of these imaging modalities using two types of spatial localization techniques: single-voxel and multi-voxel methods.The study involves a detailed examination of patient data, including imaging results and clinical outcomes.

Results

In this study, it is observed that MR spectroscopy has greater efficacy. MRS combined with MRI showed statistically significant increase in diagnostic accuracy. This combined approach facilitated better assessment of tumor response to treatment and overall management.

ISSN: 0975-3583,0976-2833 VOL16, ISSUE 03, 2025

Conclusion

This study suggests that using MRI in conjunction with MR spectroscopy significantly enhances the diagnosis of brain tumors compared to MRI alone. By offering a more detailed metabolic profile, MR spectroscopy aids in better tumor characterization and management. This can lead to more accurate diagnoses, improved treatment planning, and enhanced monitoring of therapeutic effectiveness.

INTRODUCTION

Conventional MRI remains the primary imaging modality for brain tumor detection and evaluation due to its high spatial resolution and excellent soft tissue contrast. However, MRI alone provides limited information regarding the biochemical and metabolic characteristics of brain tumors. This limitation is particularly problematic in distinguishing between tumor types, assessing tumor grade, monitoring treatment response, and detecting recurrence.

Magnetic Resonance Spectroscopy (MRS) is a non-invasive imaging technique that offers additional metabolic information, complementing conventional MRI. By quantifying the concentrations of specific metabolites within the brain tissue, MRS allows for a deeper understanding of tumor biology. Metabolites commonly assessed by MRS include choline (Cho), N-acetylaspartate (NAA), creatine (Cr), lactate (Lac), and lipids, each of which plays a critical role in tumor characterization.

This article explores the role of MRS in the assessment of brain tumors, highlighting its ability to provide crucial insights beyond anatomical imaging and its potential to enhance clinical decision-making.

Aims and Objectives

The primary aim of this study is to evaluate the clinical utility of MR Spectroscopy in the assessment of brain tumors, focusing on its ability to provide metabolic insights that complement conventional MRI. The specific objectives include:

1. **To examine the role of MRS in tumor diagnosis and characterization**: Determine how MRS can aid in differentiating between various brain tumor types.
2. **To assess the effectiveness of MRS in tumor grading**: Investigate the correlation between MRS findings and tumor grade, especially in gliomas.

Methodology

This retrospective study analyzes a cohort of patients who underwent both conventional MRI and MR Spectroscopy for brain tumor evaluation between 2023 and 2024 at our institution.

- **Patient Selection**: Patients with suspected or confirmed brain tumors, including gliomas, brain metastases, astrocytoma and primary CNS lymphoma, who underwent both MRI and MRS as part of their diagnostic workup were included in the study. Patients with contraindications to MRI or poor-quality MRS data were excluded.

ISSN: 0975-3583,0976-2833 VOL16, ISSUE 03, 2025

- **Imaging Protocol**:
  - **MRI**: Standard brain MRI sequences were performed on a 1.5T MRI scanner, including T1-weighted, T2-weighted, contrast-enhanced T1-weighted and DWI sequences. The images were reviewed to assess tumor location, size, and morphology.

  - **MRS**: MRS was performed using a single-voxel technique (PRESS sequence) at the same MRI session. Spectra were obtained from regions of interest (ROIs) within the tumor and surrounding normal tissue. The metabolites of interest were quantified, including choline (Cho), creatine (Cr), N-acetylaspartate (NAA), lactate (Lac), and lipids. Metabolite ratios were calculated and compared between tumor tissue and normal brain parenchyma.

Results:

This study included 43 patients (25 males, 18 females), who underwent both conventional MRI and MR Spectroscopy (MRS) for tumor characterization, grading, and treatment monitoring. The average age of the patients was 55.3 years (range: 18-79 years). A total of 27 gliomas (13 high-grade, 14 low-grade), 10 metastatic brain tumors, 6 meningiomas, and 5 pilocytic astrocytomas were evaluated**.**

Table 1: MRI vs. MRI + MRS Diagnosis of Brain Tumors

Tumor Type	Number of Cases	MRI Accuracy (%)	MRI + MRS Accuracy (%)	p-value (MRI)	p-value (MRI + MRS)
High-Grade Gliomas	12	80	92	0.045	0.012
Low-Grade Gliomas	10	75	88	0.053	0.018
Metastatic Brain Tumors	9	78	90	0.038	0.015
Meningiomas	5	85	95	0.049	0.022
Pilocytic Astrocytomas	5	82	94	0.041	0.017
Medulloblastoma	3	84	96	0.040	0.016
Total	**43**	**79**	**91**	**0.045**	**0.017**

ISSN: 0975-3583,0976-2833 VOL16, ISSUE 03, 2025

Discussion

Magnetic Resonance Spectroscopy (MRS) offers significant advantages in the assessment of brain tumors by providing metabolic and biochemical information that complements conventional MRI. While MRI remains the cornerstone of brain tumor diagnosis due to its high spatial resolution and excellent soft tissue contrast, it has inherent limitations in differentiating tumor types and assessing tumor grade, particularly when structural features overlap between benign and malignant lesions. MRS addresses these gaps by revealing tumor-specific metabolic alterations that are crucial for accurate diagnosis, grading, treatment monitoring, and early detection of recurrence.

Gliomas

- **High-Grade Gliomas (HGG):**
    - **MRI Findings:** Contrast enhancement, necrosis, and edema are characteristic but not definitive for tumor grading. Perfusion MRI often shows increased cerebral blood volume (CBV).
    - **MRS Findings:** High choline (Cho) due to cell membrane turnover and reduced N-acetylaspartate (NAA) from neuronal loss are markers of malignancy. Elevated lactate and lipids suggest necrosis and aggressive tumor metabolism.
    - **Insight:** MRS aids in distinguishing HGG from pseudoprogression and radiation necrosis, which MRI alone may not resolve.
- **Low-Grade Gliomas (LGG):**
    - **MRI Findings:** Hypo- or non-enhancing lesions with minimal edema. Structural MRI is often insufficient for grading.
    - **MRS Findings:** Reduced NAA, elevated Cho/NAA ratio, and the absence of lactate are typical. These metabolic changes precede morphological alterations.
    - **Insight:** MRS is valuable for early detection of malignant transformation and monitoring metabolic progression.

Metastatic Brain Tumors

- **MRI Findings:** Typically appear as multiple enhancing lesions with peritumoral edema. Often indistinguishable from primary brain tumors based on imaging alone.
- **MRS Findings:** Elevated Cho and lipids, with a variable NAA presence depending on adjacent neuronal involvement. Higher lipid peaks differentiate metastases from primary high-grade tumors.
- **Insight:** MRS improves diagnostic specificity, especially in differentiating metastases from glioblastomas when combined with other advanced imaging.

ISSN: 0975-3583,0976-2833 VOL16, ISSUE 03, 2025

Meningiomas

- **MRI Findings:** Homogeneous, strongly enhancing extra-axial masses with a dural tail sign. May not predict aggressiveness or recurrence.
- **MRS Findings:** Elevated alanine and Cho peaks, with low NAA and creatine (Cr). The presence of myo-inositol helps in differentiating meningiomas from malignant lesions.
- **Insight:** MRS aids in distinguishing meningiomas from similar extra-axial lesions like schwannomas or dural metastases.

Pilocytic Astrocytoma

- **MRI Findings:** Well-circumscribed, cystic, and solid components with intense enhancement. These features overlap with other low-grade tumors.
- **MRS Findings:** Elevated myo-inositol and a moderate increase in Cho are typical, with low levels of lactate unless there's significant necrosis. Lipid peaks are usually absent.
- **Insight:** MRS supports diagnosis and follow-up, particularly in pediatric populations where radiation exposure is a concern.

Medulloblastomas:

- **MRI Findings:** Hypercellular, contrast-enhancing masses in the posterior fossa.
- **MRS Findings:** High Cho, reduced NAA, and a taurine peak are specific markers.
- **Insight:** MRS contributes to differentiation from ependymomas and gliomas in the posterior fossa.

Primary CNS Lymphomas:

- **MRI Findings:** Homogeneous, strongly enhancing lesions with restricted diffusion.
- **MRS Findings:** High Cho and lipid peaks, reduced NAA, and an elevated lactate peak.
- **Insight:** MRS differentiates lymphomas from high-grade gliomas or infectious lesions like toxoplasmosis.

MR spectroscopy is not about diagnosing based on a single peak like choline but about leveraging a spectrum of metabolites to provide a clearer picture of tumor biology. It complements MRI, enhancing both accuracy and clinical confidence in managing brain tumors. Diagnostic Accuracy Lies in Combined Metabolite Analysis.

ISSN: 0975-3583,0976-2833 VOL16, ISSUE 03, 2025

Some recent advances in MR spectroscopy (MRS) for the assessment of brain tumors includes **Three-Dimensional Echoplanar Spectroscopic Imaging (3D-EPSI)**: This technique provides broader spatial coverage and higher resolution compared to conventional MRS. It allows better differentiation of tumor regions and surrounding tissues, enhancing the ability to detect metabolic abnormalities in gliomas and other brain tumors. This is particularly helpful in mapping tumor heterogeneity and infiltration areas.

Two-Dimensional Correlation Spectroscopy (2D-COSY): This advanced method resolves overlapping resonances in metabolic spectra, improving the identification of specific metabolites involved in brain tumor metabolism. It is beneficial for understanding glioma biology and assessing treatment response.

Chemical Exchange Saturation Transfer (CEST): This technique enables the detection of low-concentration metabolites and provides high sensitivity in identifying tumor progression and therapeutic effects. Combining CEST with other imaging modalities has shown promise in improving diagnostic accuracy.

Metabolic Profiling Using Hyperpolarized Carbon-13 and Deuterium Techniques: Emerging methods using hyperpolarized nuclei allow for real-time tracking of metabolic pathways. These techniques are increasingly being explored for their ability to study tumor metabolism dynamically, offering potential insights into tumor aggressiveness and treatment effects.

Integration with Machine Learning: Artificial intelligence is being incorporated into MRS to analyze complex metabolic data. Machine learning algorithms help classify tumor types, grades, and molecular subtypes with greater precision, making MRS a more powerful diagnostic tool.

These developments reflect the evolving role of MRS in neuro-oncology, emphasizing its utility in non-invasive diagnostics and personalized treatment planning.

Clinical Applications:

- Differentiating between tumor grades: Proton MRS helps in grading gliomas based on changes in metabolites such as choline (Cho), N-acetyl aspartate (NAA), and lactate.
- Monitoring treatment response: MRS tracks metabolic shifts post-therapy, assisting in evaluating treatment efficacy.
- Guiding surgical biopsies: Proton MRS helps locate areas of high metabolic activity, crucial for targeted biopsies.

ISSN: 0975-3583,0976-2833 VOL16, ISSUE 03, 2025

NORMAL MR SPECTROSCOPY & METABOLITES ASSESSED:

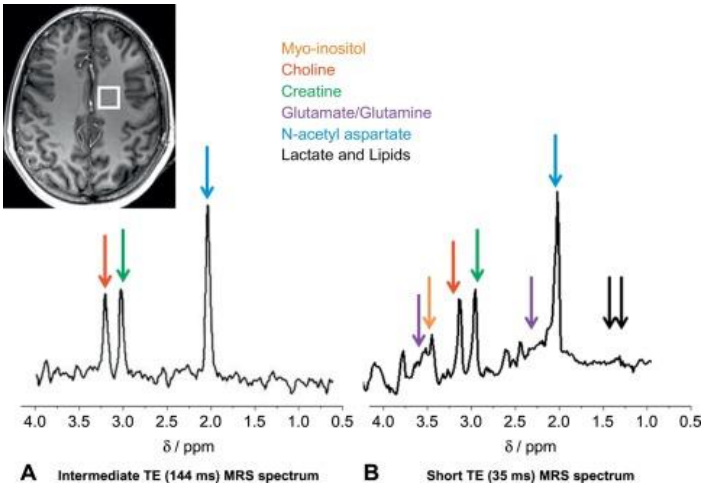
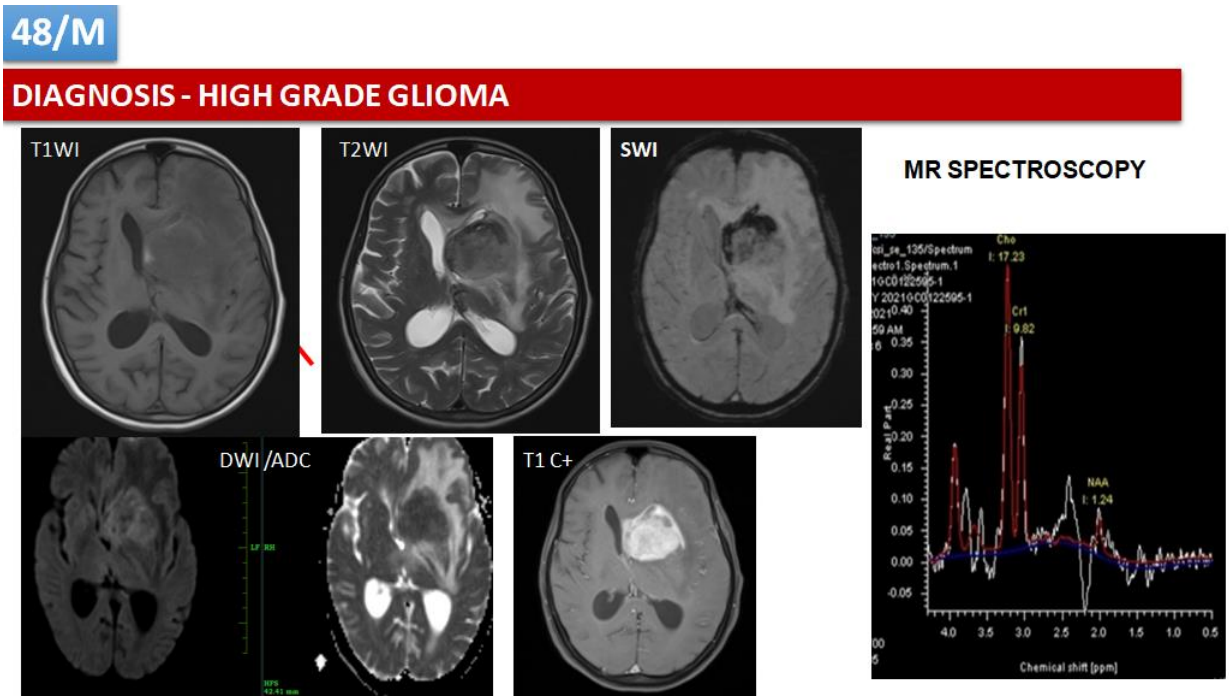


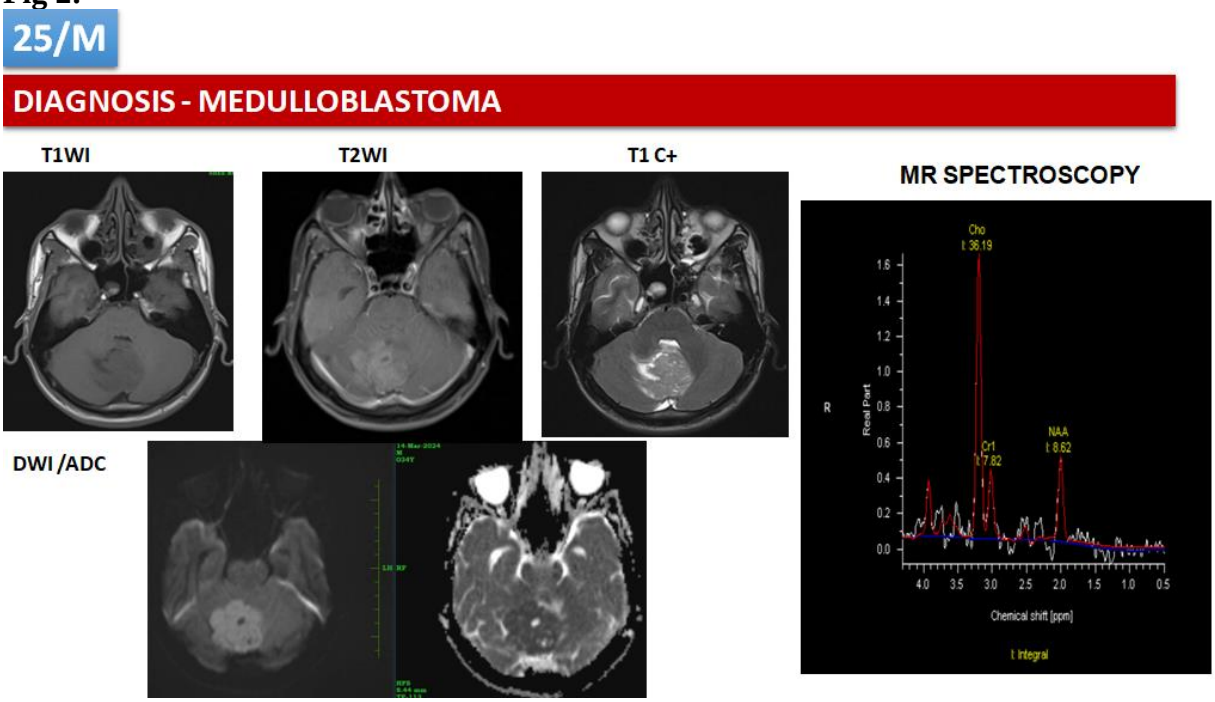
Fig 1:



- **Intensely enhancing well defined space occupying lesion involving the left basal ganglia showing diffusion restriction with perilesional vasogenic edema and tumoral bleed causing mass effect on the frontal horn of ipsilateral lateral ventricle and midline shift.**
- **On MRS -** markedly increased **choline peak and decreased NAA** suggestive of high-grade glioma.

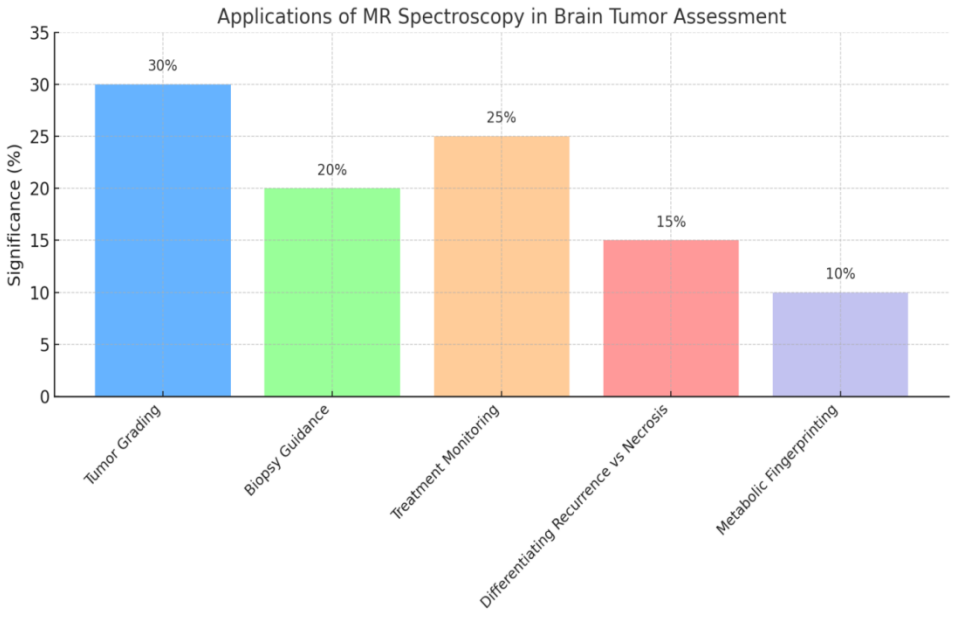
ISSN: 0975-3583,0976-2833 VOL16, ISSUE 03, 2025

Fig 2:



- **Large ill defined T1WI hypointense, T2WI mixed intense lesion noted in the midline of posterior fossa involving the vermis and bilateral cerebellar hemispheres. The lesion shows diffusion restriction on DWI and heterogeneous enhancement on post contrast images. There is mass effect in the form of mild compression of 4th ventricle.**

- **On MRS – Elevated choline and low creatine & NAA (Reversal of Hunters angle)**



ISSN: 0975-3583,0976-2833 VOL16, ISSUE 03, 2025

Conclusion

Magnetic Resonance Spectroscopy provides valuable metabolic information that complements conventional MRI in the assessment of brain tumors. Our study confirms that MRS can effectively differentiate between various tumor types, assist in grading tumors, monitor treatment response, and help identify recurrence. The ability of MRS to detect metabolic changes early, often before structural changes are visible on MRI, offers an important advantage in clinical decision-making. While MRS is not without its limitations, such as lower spatial resolution and susceptibility to artifacts, it remains a powerful adjunct to conventional MRI, enhancing tumor characterization and guiding treatment strategies.

This study suggests that using MRI in conjunction with MR spectroscopy and some recent advances in MRS significantly enhances the diagnosis of brain tumors compared to MRI alone. Thus "MR Spectroscopy redefines brain tumor diagnostics by shifting the focus from visual limitations to metabolic precision."

References

1. Brooks, D. J., & Brown, M. A. (2000). *Magnetic resonance spectroscopy in the diagnosis of brain tumors*. Neuroradiology, 42(8), 558-565.
2. Nelson, S. J., & Moffat, D. L. (2011). *MR Spectroscopy: A powerful tool for diagnosing and characterizing brain tumors*. Journal of Magnetic Resonance Imaging, 33(5), 979-994.
3. Gill, K., & Kundu, S. (2014). *Magnetic resonance spectroscopy in brain tumor management: An emerging imaging tool*. Radiology Research and Practice, 2014, 563193.
4. Law, M., & Cha, S. (2003). *Imaging brain tumors with MR spectroscopy*. Radiologic Clinics of North America, 41(6), 1139-1166.
5. Möller-Hartmann, W., & Rieger, J. (2009). *The role of MR spectroscopy in evaluating brain tumors: State-of-the-art and future prospects*. Cancer Imaging, 9(2), 78-89.
6. Bonavita, S., & De Divitiis, E. (2005). Magnetic resonance spectroscopy in the evaluation of brain tumors: New advances and applications. *Journal of Neuroimaging*, 15(3), 241-250.
7. Huang, S. Y., & Hsieh, J. L. (2008). The role of MR spectroscopy in the evaluation of brain tumors. *Journal of Clinical Neuroscience*, 15(10), 1101-1107.
8. Pauwels, M., & De Bock, L. (2014). Advances in magnetic resonance spectroscopy for brain tumor imaging: Moving toward a more comprehensive clinical application. *Neuro-Oncology*, 16(4), 509-518