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Original Research Article

DIAGNOSTIC ACCURACY OF MAGNETIC RESONANCE SPECTROSCOPY IN DETECTING FOCAL BRAIN LESION KEEPING HISTOPATHOLOGY AS GOLD STANDARD

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ABSTRACT

Background: *Magnetic resonance spectroscopy (MRS) is a valuable non-invasive imaging modality that provides metabolic information useful in differentiating neoplastic from non-neoplastic focal brain lesions. Accurate preoperative characterization of these lesions is essential for clinical management and treatment planning.* ***Objective:*** *To determine the diagnostic accuracy of magnetic resonance spectroscopy (MRS) in distinguishing neoplastic from non-neoplastic focal brain lesions, using histopathology as the gold standard.* ***Study Design:*** *Cross-sectional validation study.* ***Setting:*** *The Department of Neurosurgery at Ayub Teaching Hospital, Abbottabad, Pakistan.* ***Duration of Study:*** *From 08-01-2025 to 08-05-2025.* ***Methods:*** *A total of 63 patients aged 5–70 years with radiologically suspected focal brain lesions were included. All participants underwent MRS using a single-voxel technique to measure key metabolites—choline (Cho), N-acetylaspartate (NAA), and creatine (Cr). The Cho/NAA and Cho/Cr ratios were evaluated for lesion characterization. Histopathological findings from biopsy specimens served as the reference standard. Diagnostic accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated using a 2×2 contingency table. Data were analyzed using SPSS version 25.* ***Results:*** *The mean age of patients was 39.10 ± 20.60 years, with 32 (50.8%) males and 31 (49.2%) females. MRS demonstrated a sensitivity of 89.19%, specificity of 92.31%, PPV of 94.29%, NPV of 85.71%, and an overall diagnostic accuracy of 90.48% in differentiating neoplastic from non-neoplastic lesions.* ***Conclusion:*** *Magnetic resonance spectroscopy is a highly sensitive and specific non-invasive diagnostic tool for differentiating neoplastic from non-neoplastic focal brain lesions. Its integration with conventional MRI enhances diagnostic confidence and assists in appropriate therapeutic decision-making.*

Keywords: Magnetic Resonance Spectroscopy, Focal Brain Lesions, Neoplastic, Non-Neoplastic, Diagnostic Accuracy, Histopathology

INTRODUCTION

For those suffering from intracerebral tumors, optimal treatment care requires an in-depth evaluation. When possible, the vast majority of tumors are surgically excised; nevertheless, there is an equilibrium between removing as much tumor tissue as feasible while retaining essential brain functions (1, 2). Any remnant neoplastic tissue follows treatment with radiation-based therapies. A large number of brain lesions, i.e, 62% have been determined to be cancerous, whereas 38% are benign. From a radiologic standpoint, an array of noncancerous lesions could look like focal lesions in the brain. Magnetic resonance spectroscopy (MRS) is one of the most widely used methods for diffusion-weighted imaging as well as lesion definition for various neurological diseases (3-5).

Noninvasive in vivo metabolites evaluation is made possible by MRS, a rapidly expanding field of neuroimaging. The resonance range of different chemical compounds within tissues can be identified by MRS, which provides structural data regarding chemical components as well as data about the metabolic activity of tissues (4, 5). A non-invasive testing technique called MRS analyzes the chemical makeup of human tissues. In the 1980s, MRS was applied in medical settings. Every molecule in the body has a purpose in MRS. When these substances come into contact with a strong magnetic field, they generate radio-frequency waves. Through analysis of molecules present in a specific area of aberrant tissue, MRS may provide vital information that can help detect abnormal situations (6-10). In a study, 60 cases were diagnosed as neoplastic on histopathology, while the sensitivity and specificity of MRI and MRS in differentiating neoplastic from non-neoplastic brain lesions were 92.68% and 94.74% respectively (11). Discriminating between neoplastic and non-neoplastic brain lesions is extremely necessary since a misdiagnosis can lead to severe consequences in Neurosurgery. Unnecessary brain biopsies may be performed on patients with benign lesions and exposure to toxic chemotherapy and radiotherapy, which may cause damage to brain tissue. There are very few studies available on this topic in our local population. This study aims to describe the diagnostic value of MRS in discrimination between neoplastic and non-neoplastic lesions in comparison to histopathological analysis.

METHODOLOGY

The study employed a cross-sectional validation design conducted in the Department of Neurosurgery at Ayub Teaching Hospital, Abbottabad, over the time span from 08-01-2025 to 08-05-2025. We received an ethical certificate for the study from the hospital.

Participants were selected using a non-probability consecutive sampling technique with a cohort of 63 patients. This estimation was derived using the WHO calculator for diagnostic accuracy based on sensitivity 92.68% and specificity 94.74% as reported in a prior study[11] with an assumed prevalence of 68% and an absolute precision of 10%. The inclusion criteria encompassed patients aged 5 to 70 years presenting with focal brain lesions as defined by clinical symptoms such as headache, vomiting, visual disturbances, or altered consciousness, corroborated by signal abnormalities on CT or MRI but confirmed histopathologically. Patients with multiple brain tumors or a history of prior brain tumor surgery were excluded to minimize confounding variables. Data collection commenced after taking consent from all participants. Demographic details, including age, gender, profession, education level, socioeconomic status, and residence, were recorded for each participant. Magnetic Resonance Spectroscopy (MRS) is a non-invasive diagnostic imaging technique that measures the biochemical composition of brain tissue by

detecting and quantifying specific metabolites in parts per million. MRS analyzes metabolic changes by measuring the concentration of molecules such as choline (Cho), N-acetylaspartate (NAA), creatine (Cr), lactate, and lipids in parts per million (ppm). In brain lesions, neoplastic tissues typically exhibit elevated choline (indicating increased cell membrane turnover) and reduced NAA (reflecting neuronal loss). Magnetic resonance spectroscopy was performed using a single-voxel technique. Initial post-contrast conventional MRI localized the lesion, after which a voxel was positioned over the volume of interest to measure metabolic profiles. Subsequently, intracranial biopsies were performed in the neurosurgery department, and the excised specimens were sent for histopathological analysis. The histopathology reports served as the definitive diagnostic reference. The MRS findings were compared against these reports.

Statistical analysis was conducted with SPSS 23. Age was calculated using mean ± standard deviation. Gender and lesion classification on MRS and histopathology were presented as frequencies and percentages. A 2×2 contingency table was constructed to compute sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy. Stratification by age and gender was performed employing the chi-square test at a 5% significance level.

RESULTS

Our study had 63 participants with a mean age of 39.10 ± 20.60 years. The cohort comprised 32 (50.8%) males and 31 (49.2%) females. Magnetic resonance spectroscopy (MRS) identified neoplastic lesions in 35 (55.6%) cases, while histopathology, serving as the Gold standard, confirmed neoplastic lesions in 37 (58.7%) participants (Table 1). Cross-tabulation revealed that MRS correctly detected 33 of the 37 histopathology-positive cases, yielding a sensitivity of 89.19%. Additionally, MRS accurately ruled out neoplasms in 24 of the 26 histopathology-negative cases, reflecting a specificity of 92.31%. The positive predictive value of MRS was 94.29% while the negative predictive value stood at 85.71%. The overall diagnostic accuracy of MRS was 90.48% underscoring its strong agreement with histopathological findings. Notably, MRS produced false-negative results in 4 (10.8%) cases and false-positive results in 2 (7.7%) cases, further highlighting its robust performance in differentiating neoplastic from non-neoplastic brain lesions (Table 2). Stratifications can be viewed in Tables 3 and 4.

Table 1: MR spectroscopy and histopathology findings

MR spectroscopy and histopathology findings		n	%
Neoplastic lesion on MR spectroscopy	Positive	35	55.6%
	Negative	28	44.4%
Neoplastic lesion on histopathology	Positive	37	58.7%
	Negative	26	41.3%

Table 2: Diagnostic accuracy of MRS with age

		Neoplastic lesion on histopathology		Total
		Positive	Negative	
Neoplastic lesion on MR spectroscopy	Positive	33	2	35
		89.2%	7.7%	55.6%
	Negative	4	24	28
		10.8%	92.3%	44.4%
Total		37	26	63
		100.0%	100.0%	100.0%

Sensitivity 89.19%, Specificity 92.31%, Positive predictive value 94.29%, Negative predictive value 85.71%, Diagnostic accuracy 90.48%

Table 3: Stratification of diagnostic accuracy of MRS with age

Age (Years)	Sensitivity	Specificity	PPV	NPV	Diagnostic accuracy	P value
5 to 20	81.82%	80.00%	90.00%	66.67%	81.25%	0.01
21 to 40	88.89%	100.00%	100.00%	88.89%	94.12%	0.0001
> 40	94.12%	92.31%	94.12%	92.31%	93.33%	0.0001

Table 4: Stratification of diagnostic accuracy of MRS with gender

Gender	Sensitivity	Specificity	PPV	NPV	Diagnostic accuracy	P value
Male	89.47%	92.31%	94.44%	85.71%	90.62%	0.0001
Female	88.89%	92.31%	94.12%	85.71%	90.32%	0.0001

DISCUSSION

The cohort comprised 63 participants with a mean age of 39.10 ± 20.60 years, including 32 (50.8%) males and 31 (49.2%) females, reflecting a balanced gender distribution. MRS identified neoplastic lesions in 35 (55.6%) cases, while histopathology confirmed neoplasms in 37 (58.7%) patients. The sensitivity of MRS was 89.19%, specificity 92.31%, positive predictive value (PPV) 94.29%, negative predictive value (NPV) 85.71% and diagnostic accuracy 90.48%.

Reddy et al. combined MRS with MRI, achieving a sensitivity of 92.68% and a specificity of 94.74% underscoring the complementary role of MRS in improving diagnostic confidence over MRI alone. This aligns with the current study's emphasis on MRS as a valuable adjunct to conventional imaging (11).

A study by Butzen et al. explored the efficacy of MRS using a logistic regression model, reporting a sensitivity of 85% and a specificity of 87% for distinguishing neoplasms from non-neoplastic lesions. Their findings were comparable to unblinded readers who had access to clinical and imaging data, suggesting MRS can achieve high diagnostic performance when combined with advanced statistical models (12).

Similarly, Alam et al. reported a sensitivity of 93.02% and a specificity of 70% highlighting MRS as a sensitive but less specific tool. The lower specificity in their study was attributed to challenges in differentiating inflammatory or infectious lesions from neoplasms, particularly when lipid/lactate peaks were present in both. In contrast,

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the current research demonstrated higher specificity (92.31%), possibly due to a more homogeneous sample (13).

The study by Musawar et al. involved 127 patients and documented a sensitivity of 97% and a specificity of 94.10% with a PPV of 78.60% and an NPV 88%. Their higher sensitivity may reflect advancements in MRS technology or differences in participant selection, such as excluding ambiguous cases (14).

False-positive and false-negative results were noted in the current study, with two false positives (7.7%) and four false negatives (10.8%). These discrepancies may arise from technical limitations such as voxel placement near bony structures or necrotic tissue, which can distort spectral readings (15). For instance, radiation necrosis or inflammatory lesions with high cellular turnover can mimic neoplastic spectra as observed in Alam et al's study (13). Conversely, low-grade gliomas or necrotic tumors with suppressed Cho peaks may be misclassified as non-neoplastic, contributing to false negatives.

The current study's diagnostic accuracy of 90.48% surpasses that of a study such as Alam et al. (88.67%) but aligns closely with Reddy et al. (93.33%) (13, 11). This variability may reflect differences in sample size, lesion heterogeneity, or methodological rigor.

In light of these findings, MRS emerges as a robust non-invasive tool for preoperative assessment of brain lesions. However, its limitations, such as susceptibility to artifacts, dependency on voxel placement, and overlap in metabolite profiles, necessitate cautious interpretation. Future studies should explore hybrid techniques to enhance specificity.

CONCLUSION

In conclusion, MRS exhibited high diagnostic accuracy; it is an efficient and effective modality in detecting neoplastic from non-neoplastic focal brain lesions, keeping histopathology as the Gold standard.

DECLARATIONS

Data Availability Statement

All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department Concerned. (IRB)

Consent for publication

Approved

Funding

Not applicable

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

GULLALY (Postgraduate Resident)

Collection of Data, Literature search, Manuscript drafting and Manuscript revisions.

BAYNAZIR KHAN (Assistant Professor)

Supervision, Study Design, Critical Input, Conception of Study, Final approval of manuscript.

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