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ORIGINAL RESEARCH

Clinico-radiologic profile of intracranial space occupying lesion imaged with MRI and spectroscopy in a tertiary care centre

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ABSTRACT

Background: Intracranial space-occupying lesions (ICSOL) encompass a variety of pathologies, ranging from primary brain neoplasms and metastatic tumors to infections. Although Magnetic Resonance Imaging (MRI) is fundamental for initial localization and characterization, certain lesions display overlapping morphologic features. In these scenarios, Magnetic Resonance Spectroscopy (MRS) provides additional metabolic information, aiding in the distinction between benign and malignant processes. **Methods:** This prospective investigation took place at a tertiary care center in India. Thirty-nine individuals with ICSOL on conventional MRI were considered, and among them, 30 underwent MRS using a 3T MRI system equipped with spectroscopic functionality. Single-voxel or multi-voxel techniques were employed to determine metabolite ratios—such as Cho/Cr, NAA/Cr, and Cho/NAA—and to detect minor metabolites including lactate, lipids, alanine, and amino acids. Standard thresholds were used to characterize lesions. Final diagnoses were confirmed by histopathology or microbiological analysis. **Results:** Of 39 patients, 30 produced analyzable spectroscopic data. Headaches (71%) and seizures (46%) were the most common symptoms. Gliomas constituted the largest subset (56%), followed by metastatic lesions (10%); 23% were infection-related. High-grade gliomas demonstrated markedly elevated Cho/Cr ratios as well as lactate–lipid peaks. Meningiomas were associated with alanine peaks, while abscesses often showed amino-acid resonances. The combined accuracy of MRI+MRS (83.3%) surpassed that of MRI alone (71%). **Conclusion:** MRS provides valuable biochemical insights that complement standard MRI for diagnosing ICSOL. Characteristic spectral patterns, particularly changes in choline and N-acetyl aspartate along with specific minor metabolites, facilitate differentiation of high-grade and low-grade tumors and help distinguish infections from necrotic tumors. This integrated approach is beneficial for guiding focused biopsies, optimizing treatment decisions, and assessing post-therapy alterations.

Keywords: Intracranial space-occupying lesion, Magnetic Resonance Imaging, Magnetic Resonance Spectroscopy, Glioma, Meningioma, Brain abscess

INTRODUCTION

Intracranial space-occupying lesions (ICSOL) comprise a broad range of conditions, including primary tumors (gliomas, meningiomas) as well as metastatic lesions and infections [1]. Early, accurate differentiation between benign and malignant etiologies is essential since treatment strategies vary significantly based on underlying pathology. In clinical practice, Magnetic Resonance Imaging (MRI) is the key tool for initial assessment of ICSOL because it delivers excellent soft-tissue contrast and detailed anatomical information [2]. Nevertheless, conventional MRI occasionally produces indeterminate results, particularly in distinguishing abscesses from necrotic neoplasms or differentiating tumor grades [3].

Magnetic Resonance Spectroscopy (MRS) has emerged as a useful adjunct to MRI, as it measures the relative concentrations of metabolites like choline (Cho), creatine (Cr), and N-acetyl aspartate (NAA) within lesions. A heightened Cho/Cr ratio signals increased membrane turnover, typical of malignancies, whereas a reduction in NAA/Cr suggests neuronal loss or dysfunction [4]. Further, the presence of lactate or lipid peaks often signifies necrotic or anaerobic processes, commonly found in high-grade gliomas or certain infections [5]. Abscesses may exhibit amino-acid peaks, while

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meningiomas often reveal an alanine resonance that is not usually seen in other intracranial tumor types [6].

Previous investigations have highlighted that MRS provides metabolic signatures that improve diagnostic confidence beyond the morphological details offered by conventional imaging [7]. By delineating these metabolic alterations, clinicians can more accurately select targets for biopsy, identifying zones of highest cellular activity within heterogeneous tumors. MRS is also beneficial in monitoring post-therapy changes, helping distinguish between recurrent malignancy and treatment-induced necrosis [8].

Although histopathology remains the benchmark for definitive diagnosis, a noninvasive metabolic perspective can be particularly valuable when surgical intervention is high-risk or contraindicated [9]. Combining MRS with standard MRI sequences (e.g., T1, T2, FLAIR, and contrast-enhanced scans), and possibly with advanced functional sequences, enlarges the diagnostic repertoire and refines decision-making [10].

This study evaluates the clinico-radiologic and spectroscopic profiles of ICSOL at a tertiary healthcare facility. Our focus includes how metabolite ratios and unique resonance peaks distinguish between neoplastic and non-neoplastic processes, delineate tumor grade, and guide appropriate therapeutic strategies. By comparing MRI alone to MRI combined with MRS, we aim to demonstrate the incremental benefit MRS adds and underscore its role in enhancing patient outcomes in situations where conventional MRI is ambiguous.

MATERIALS AND METHODS

Study Design and Ethical Approval

This prospective study received approval from the Institutional Ethics Committee of a tertiary referral hospital. All patients provided written informed consent to participate.

Patient Selection

Over a predefined duration, 39 patients with suspected intracranial lesions on conventional MRI sequences (T1, T2, FLAIR) were recruited.

Inclusion criteria

1. Individuals of any age, sex, or profession.
2. Positive MRI findings indicating a space-occupying brain lesion.

Exclusion criteria

- Contraindications to MRI (e.g., certain pacemakers or metallic implants).
- Significantly impaired renal function that precluded gadolinium administration.

Imaging Protocol

All participants underwent baseline MRI on a 3T MAGNETOM SKYRA scanner (Siemens Healthineers). The routine imaging panel included T1-weighted, T2-weighted, FLAIR, diffusion-weighted imaging (DWI), and post-gadolinium T1-weighted sequences.

Subsequently, MRS was performed on 30 out of 39 patients. Individuals with hemorrhagic transformations or lesions situated near bone/air interfaces (affecting spectral quality) were not suitable for MRS. Single-voxel or multi-voxel techniques were employed depending on lesion size and location, using standard echo times (30–144 ms) to identify peaks for Cho, Cr, NAA, lactate, lipids, alanine, and amino acids.

Data Analysis

Spectral data were processed to calculate key metabolite ratios:

- **Cho/Cr > 1.5** was deemed abnormal.
- **NAA/Cr < 1.6** indicated compromised neuronal integrity.
- **Cho/NAA > 0.8** signified a probable neoplastic process.

Elevated lactate/lipid peaks typically suggested high-grade malignancy or abscess, whereas alanine was specific to many meningiomas. Amino-acid peaks were strongly indicative of pyogenic abscess.

Confirmatory Diagnosis

Biopsy and surgical intervention, when clinically necessary, provided histopathological confirmation. Infectious etiologies were further validated through microbiological methods (e.g., cultures, gene expert) or a significant response to antimicrobial therapy.

Statistical Analysis

The diagnostic accuracies of standalone MRI and combined MRI+MRS were compared using the definitive diagnosis (histopathology/microbiology) as the reference. Chi-square tests and standard metrics (sensitivity, specificity, accuracy) were employed, with a p-value below 0.05 considered significant.

RESULTS

Thirty-nine patients with ICSOL based on conventional MRI were included. Of these, 30 produced interpretable spectroscopic data. In the remaining nine, hemorrhage or adjacency to bone structures compromised data quality.

Clinical Profile and Demographics

- **Age Range**: 4–75 years, mean of 40.12 years
- **Frequent Age Group**: 30–45 years (28.3%)
- **Sex Ratio**: 58.3% male vs. 41.7% female

Headache (71%) and seizures (46%) emerged as prominent symptoms, accompanied by signs of raised intracranial pressure (30%) and focal neurological deficits (18%).

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Table 1. Age Distribution (n=39)

Age Group (yrs)	Number of Patients	Percentage (%)
0–14	4	10.3
15–29	7	17.9
30–45	11	28.3
46–60	9	23.1
61–75	8	20.5
Total	**39**	**100**

AGE DISTRIBUTION OF PATIENTS

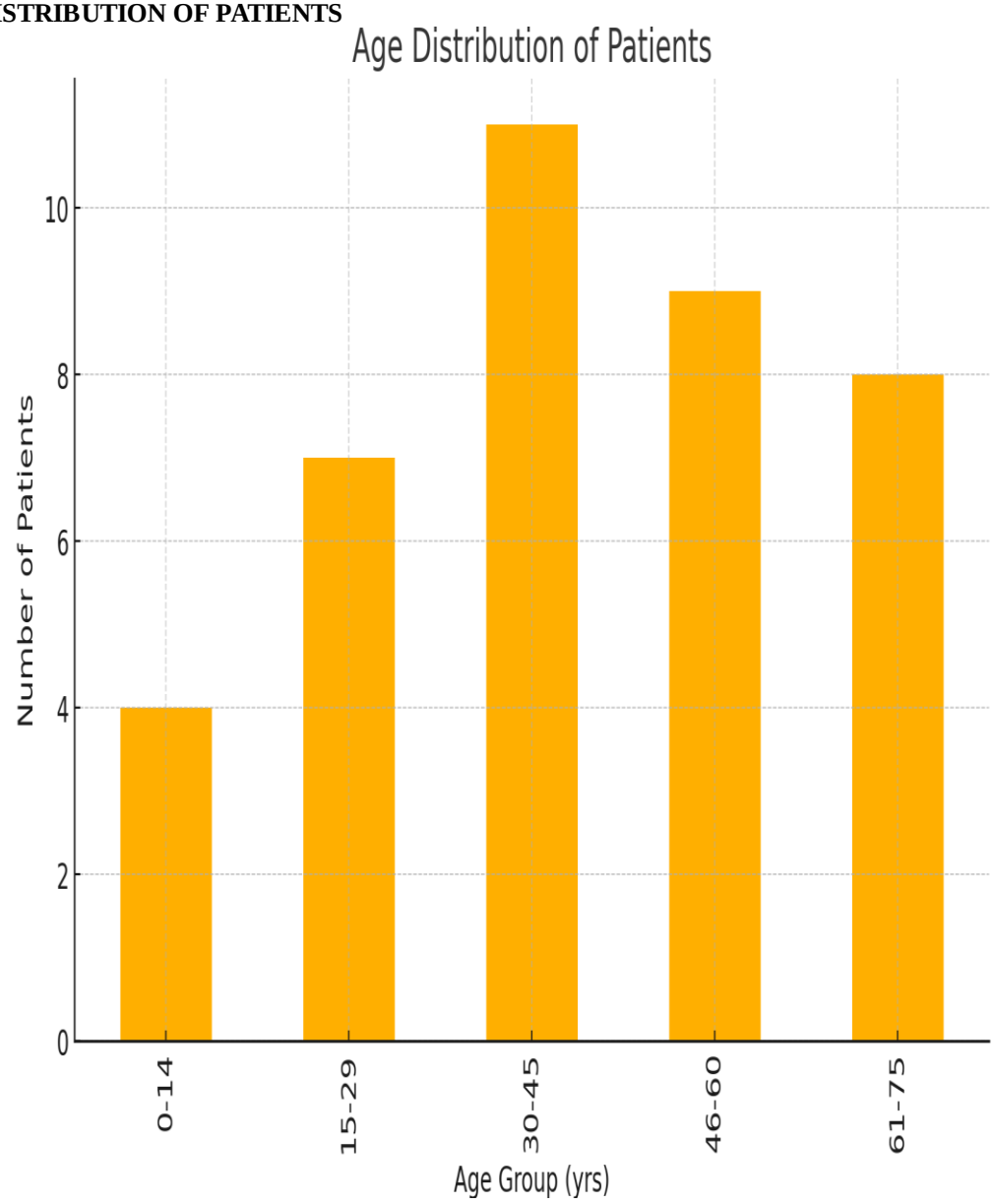

Table 2. Main Clinical Presentations (n=39)

Symptom/Sign	No. of Patients	Percentage (%)
Headache	28	71
Seizures	18	46
Raised Intracranial Pressure/Vomiting	12	30
Weakness/Hemiparesis	7	18
Fever	3	8
Gait Disturbances	2	5
Personality Changes	1	2
Dementia	2	5

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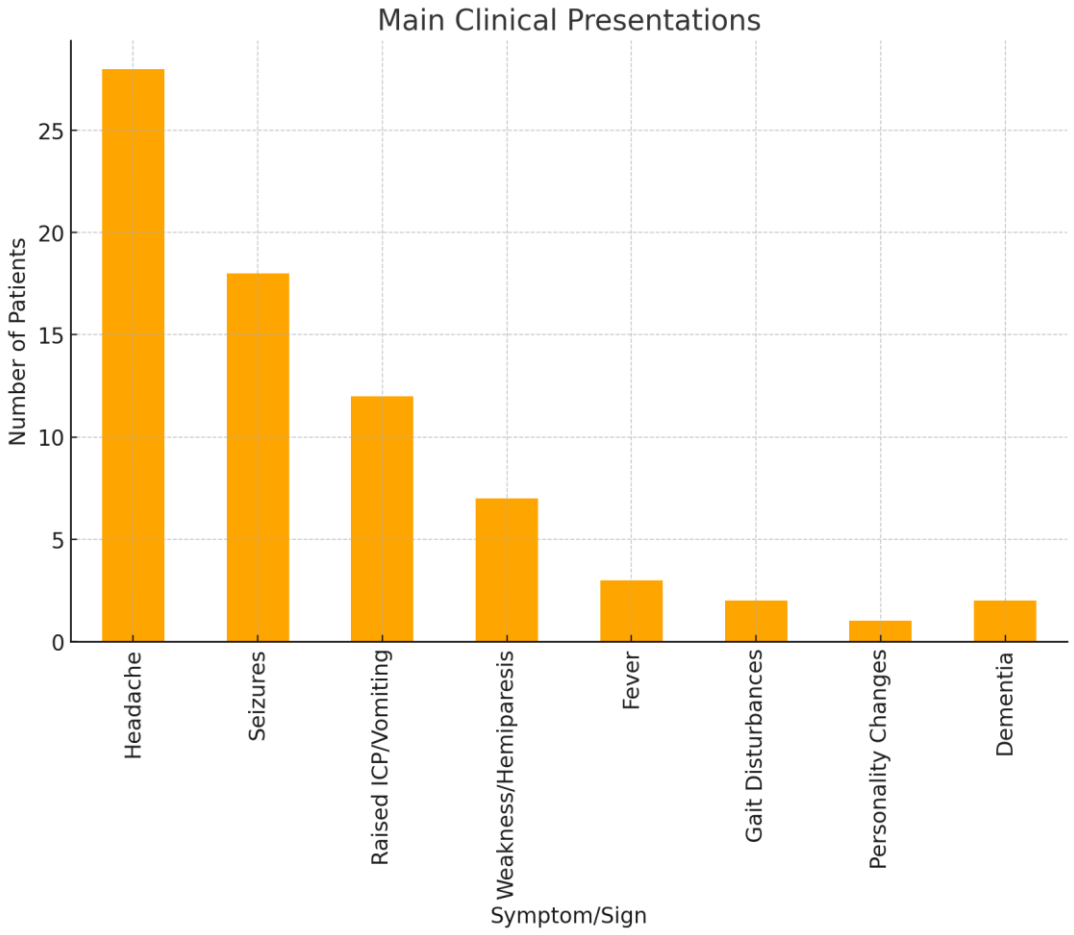

Lesion Classification

Among the 30 patients with valid MRS data, 56% had gliomas, 10% metastases, and 7% meningiomas. Infections accounted for 23%.

Table 3. Lesion Distribution (n=30)

Lesion Type	Number of Patients	Percentage (%)
Gliomas	17	56
Metastases	3	10
Meningioma	2	7
Other Tumors (DNET)	1	3
Pyogenic Abscess	4	13
Tubercular Lesions	3	10
Total	**30**	**100**

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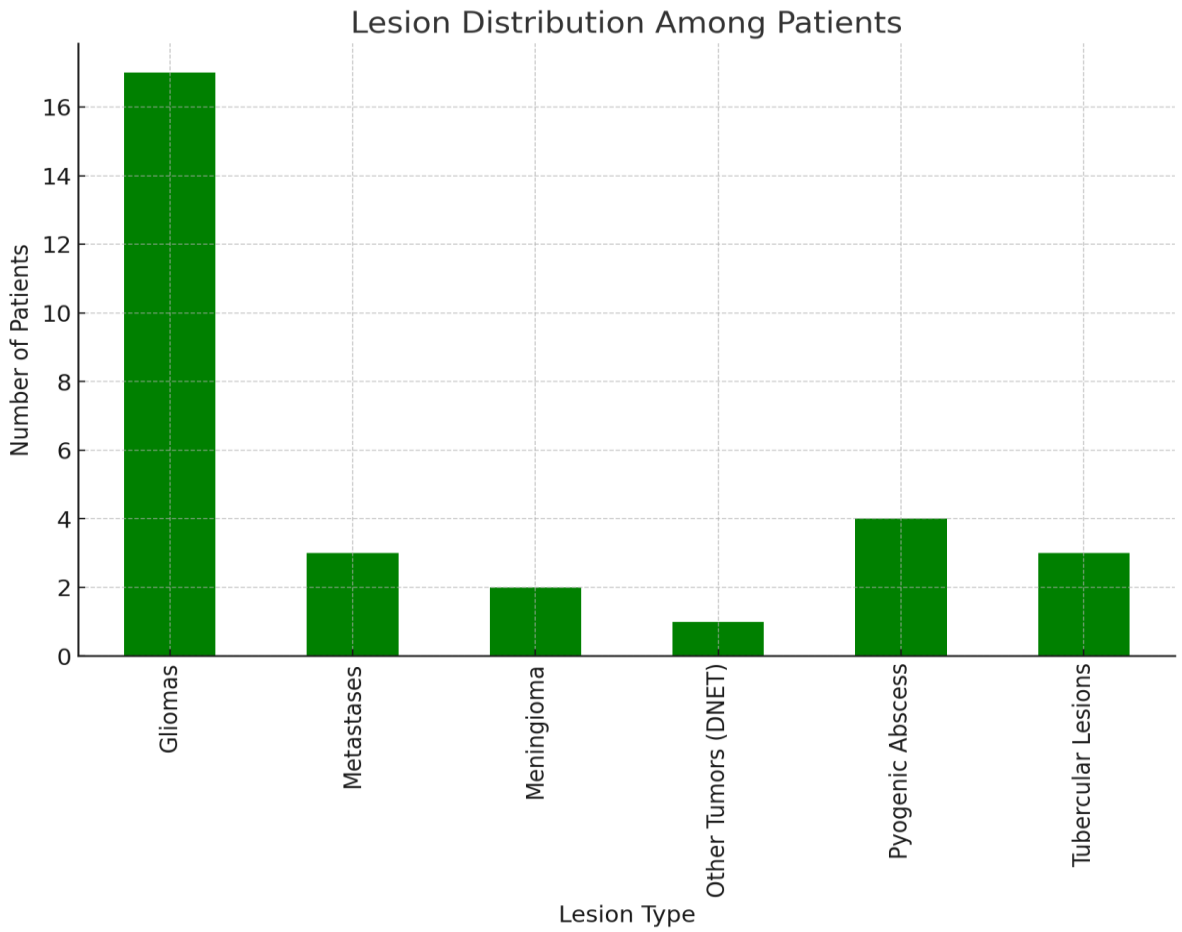

MRS Metabolite Patterns

High-grade gliomas demonstrated markedly high Cho/Cr and Cho/NAA ratios, with conspicuous lactate–lipid complexes. Low-grade gliomas revealed milder increases in Cho/Cr and fewer lactate peaks. Meningiomas displayed elevated Cho/Cr and alanine peaks, while pyogenic abscesses had prominent amino-acid peaks. Tubercular lesions featured strong lipid signals.

Table 4. Notable Metabolite Ratios

Lesion Type	Cho/Cr	Cho/NAA	NAA/Cr	Additional Observations
High-Grade Glioma	6.2	5.8	1.2	Lactate & lipid peaks (necrosis)
Low-Grade Glioma	1.5	1.9	1.6	Occasionally mild lactate elevation
Metastasis	3.5	4.1	1.2	Lactate present in most cases
Meningioma	6.1	10.2	1.8	Alanine peak in approx. 50%
Pyogenic Abscess	1.6	1.2	1.4	Amino-acid peaks, lactate noted
Tubercular Abscess	1.5	1.2	1.3	Dominant lipid resonance

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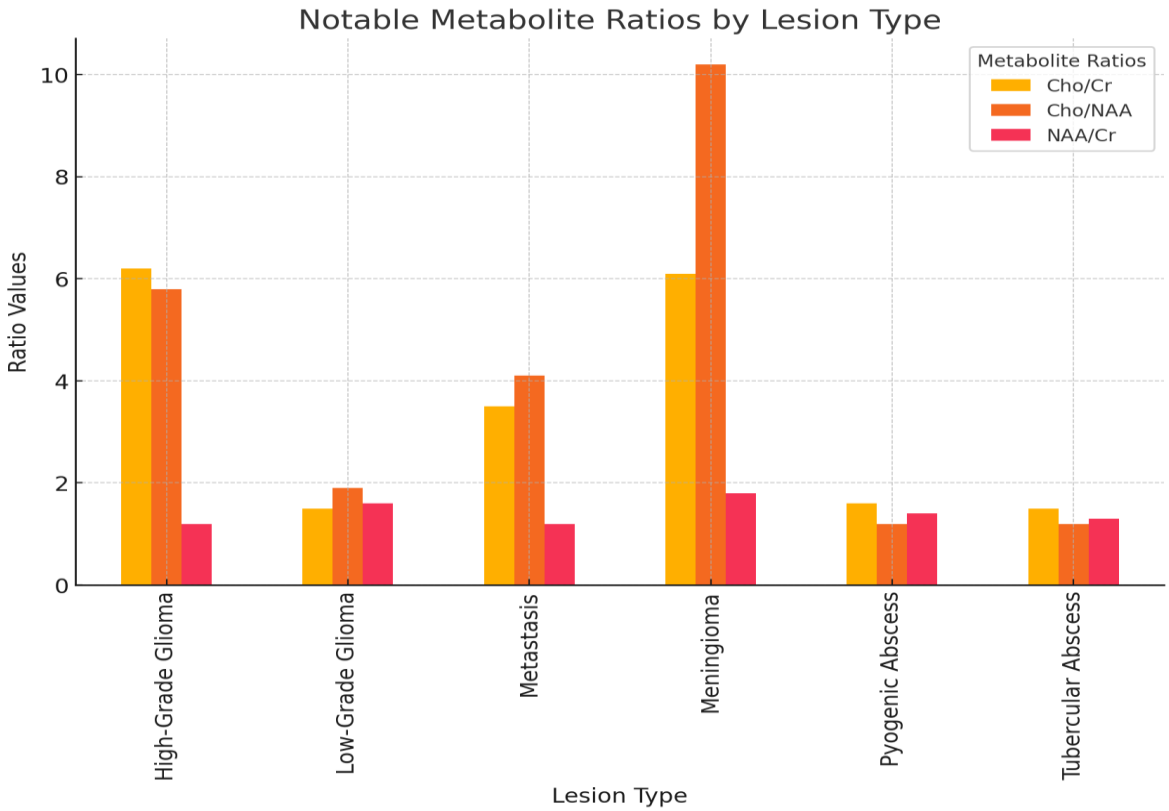
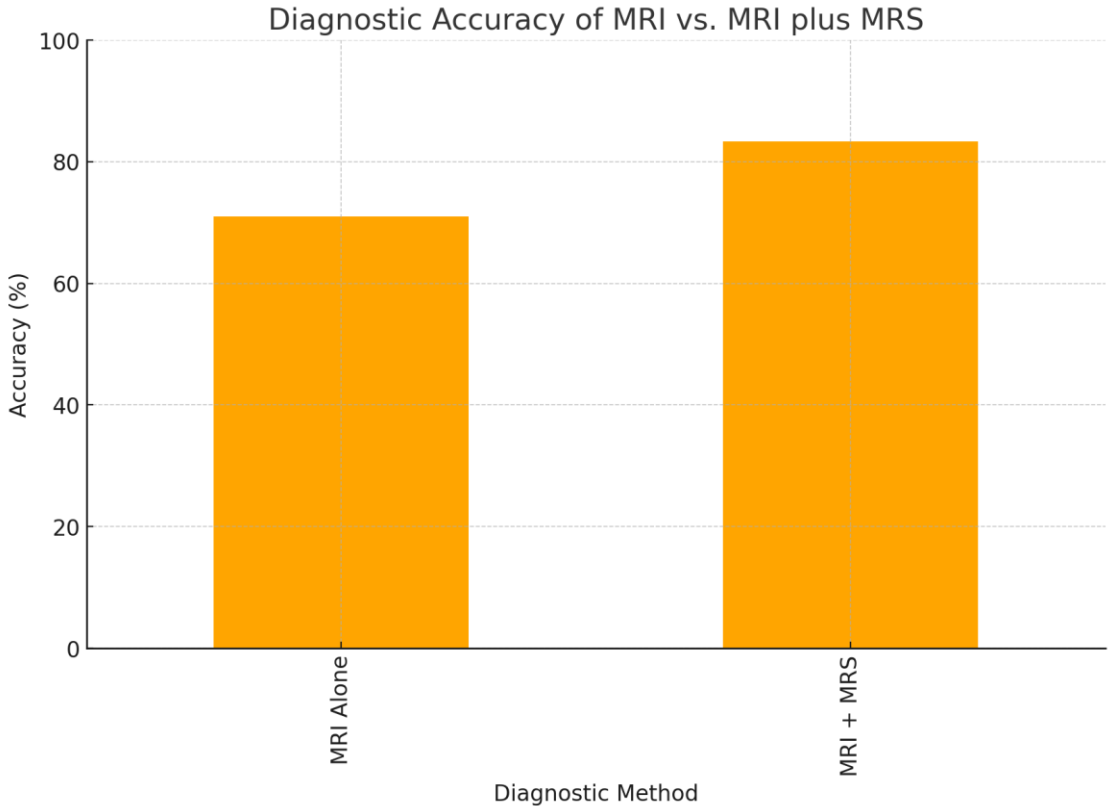


Diagnostic Accuracy

- **MRI alone**: 71%
- **MRI plus MRS**: 83.3%

Hence, supplementing MRI with spectroscopic data noticeably improved the reliability of lesion classification.



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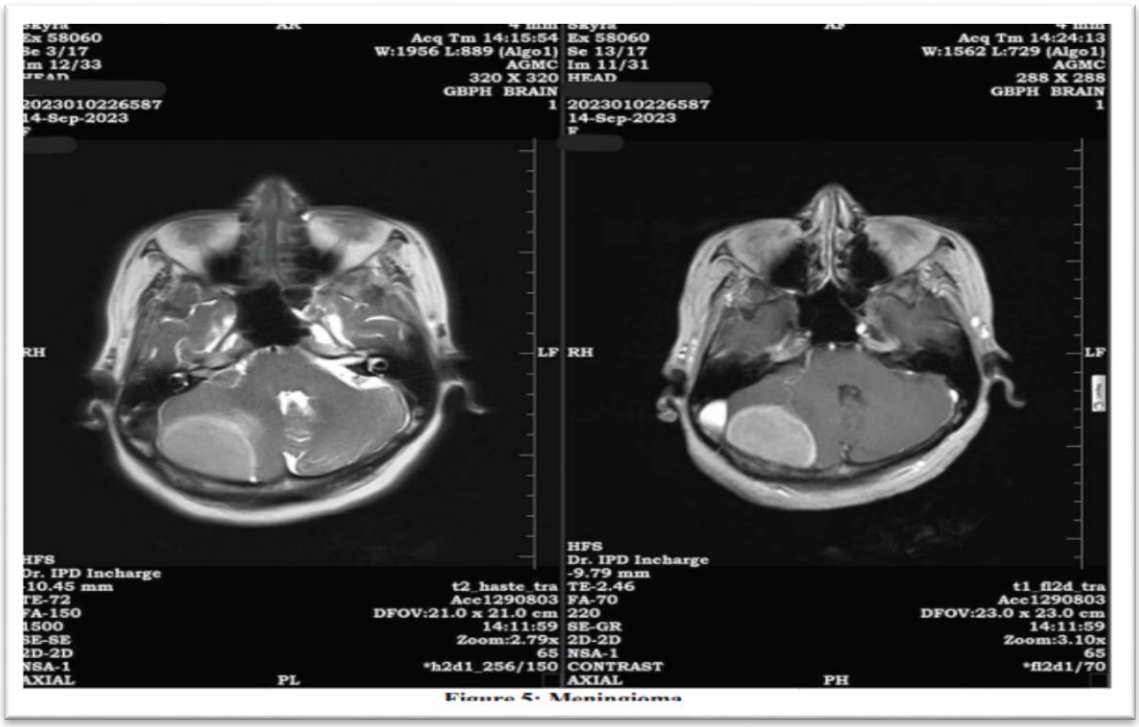
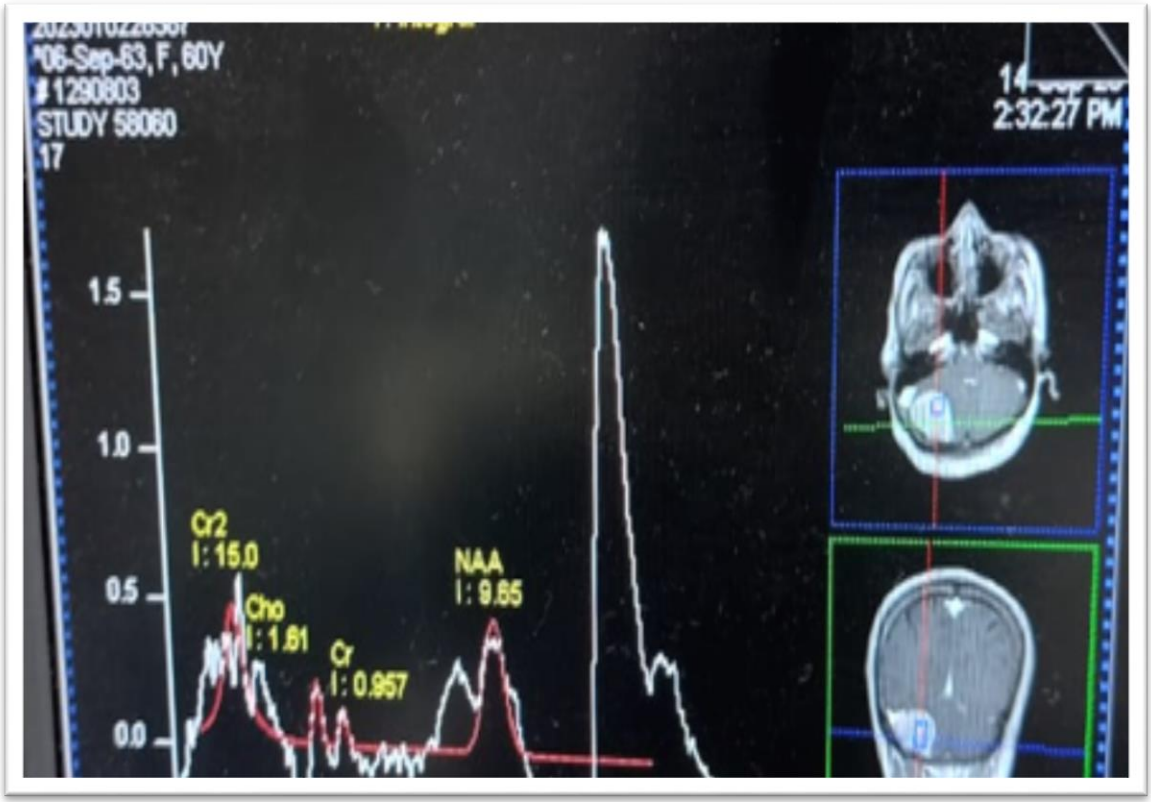


Figure 5: Meningioma



Meningioma: MR spectroscopy shows elevated alanine level

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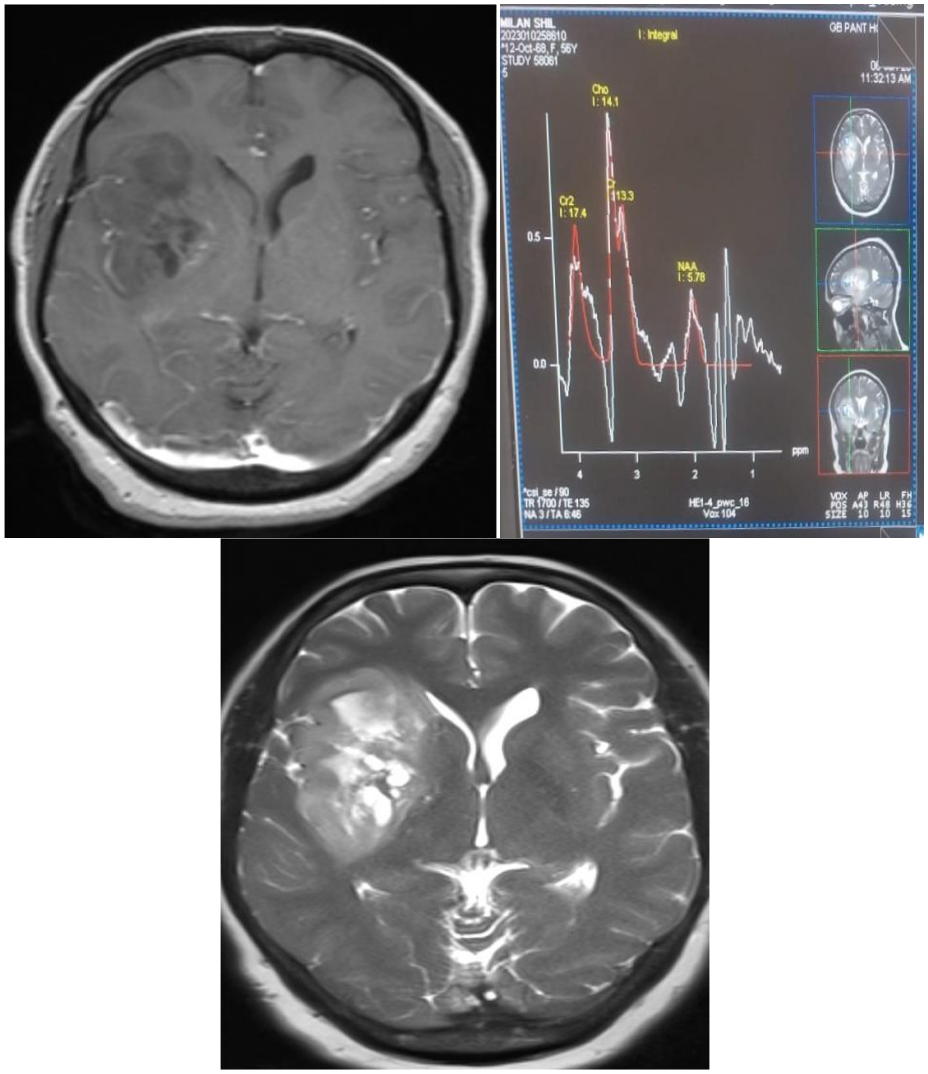
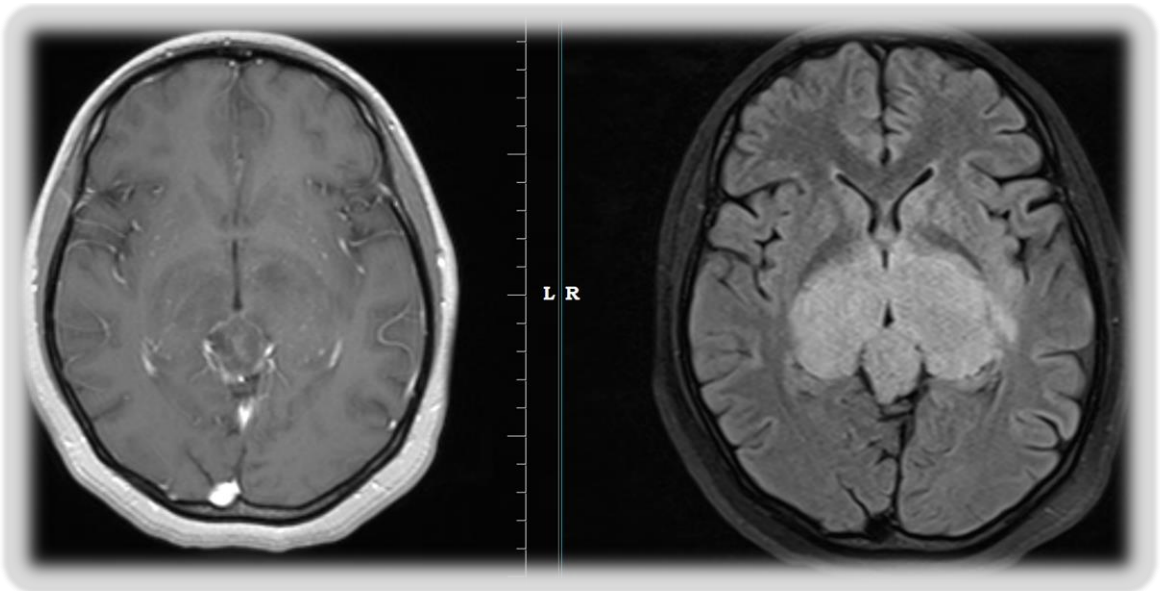


Low grade astrocytoma: MR spectroscopy shows elevated CHO, decreased NAA level and raised CHO/NAA ratio & lactate peak



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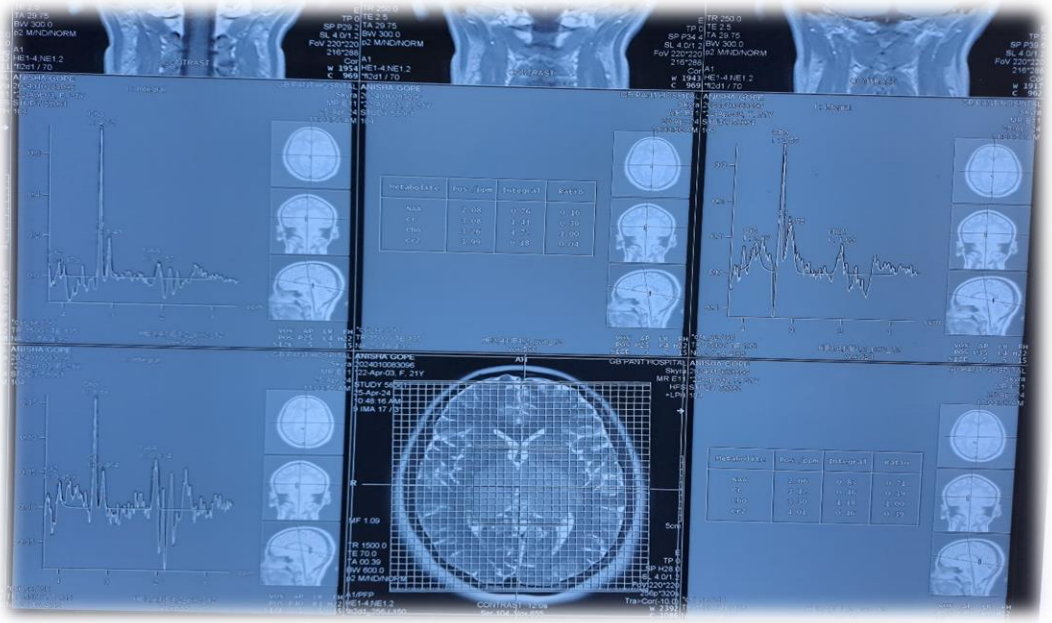
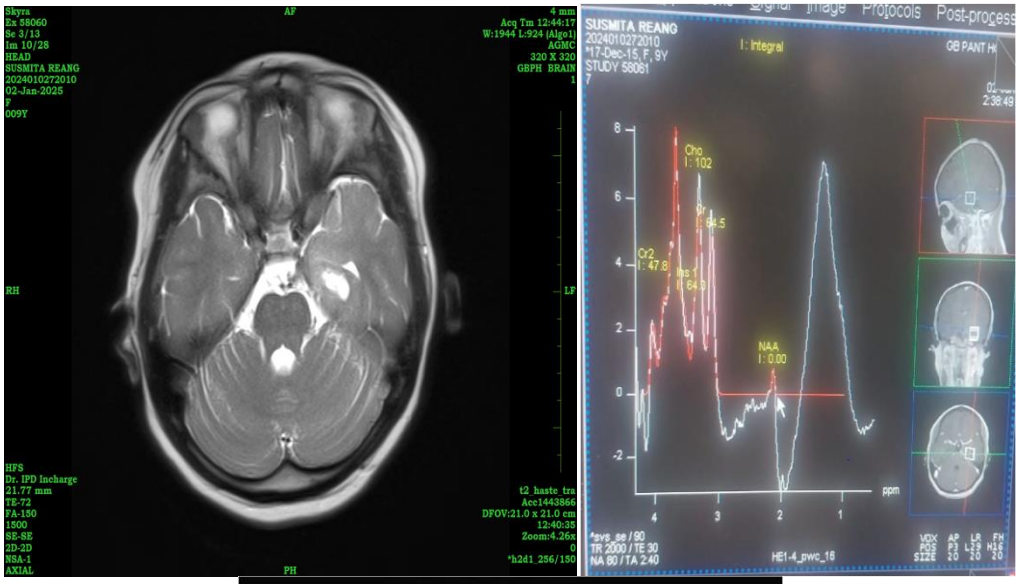
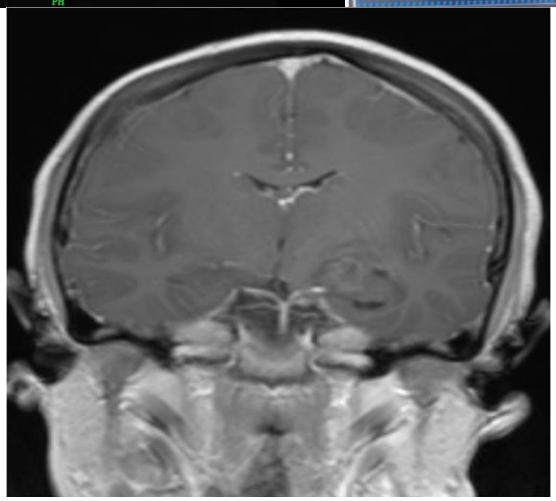


High Grade glioma: On spectroscopy, the enhancing portion shows elevated choline and lactate peaks with decreased NAA levels. CHO/NAA ratio is grossly elevated suggestive of malignant lesion.





DNET (Low grade glioma):MR spectroscopy shows elevated CHO & LAC peaks and raised CHO/NAA ratio with decreased NAA.

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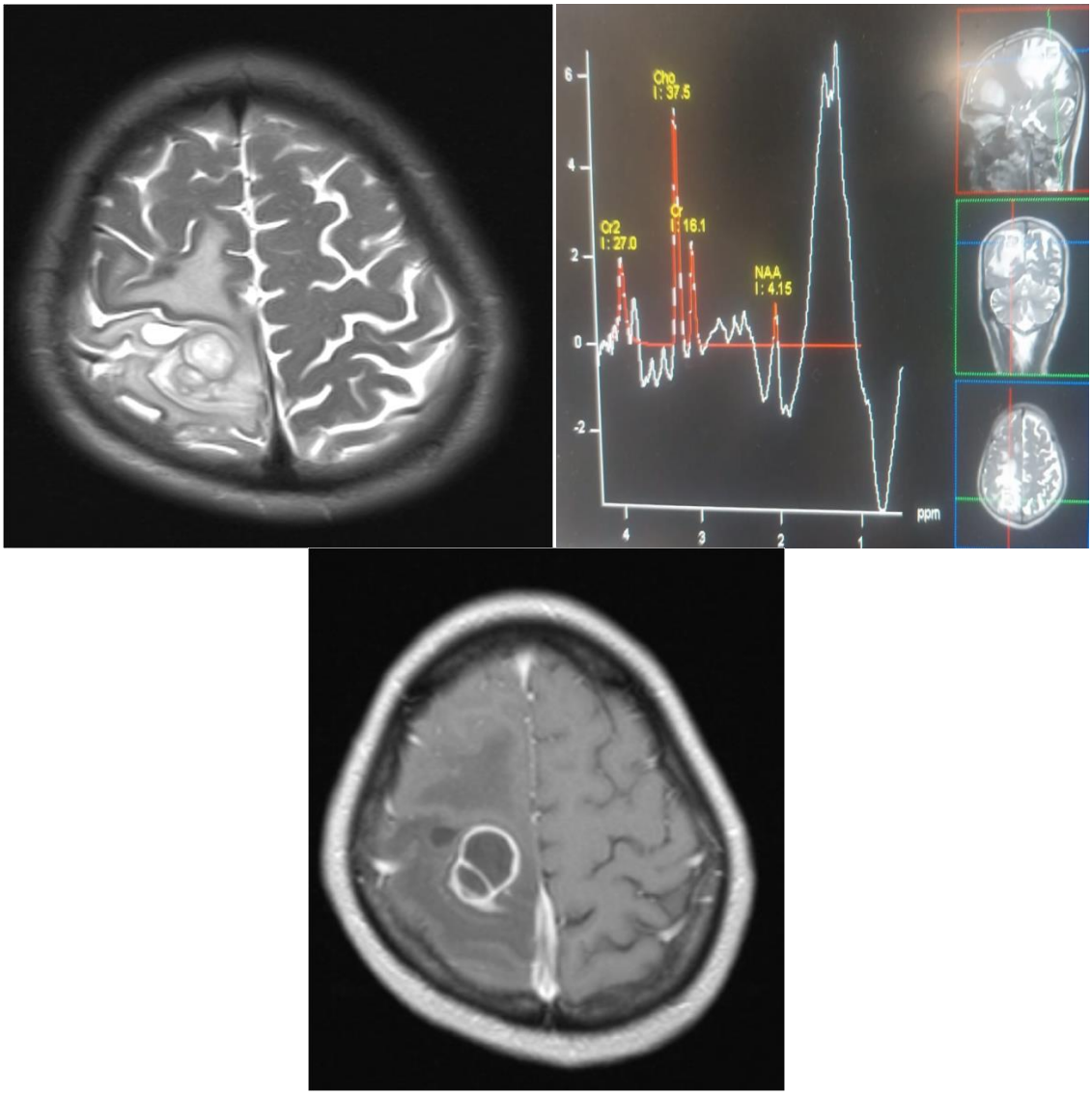

TUBERCULAR ABCESS: MR spectroscopy shows miimaly elevated CHO with decreased NAA & LACTATE-LIPID peak.

DISCUSSION

The incorporation of Magnetic Resonance Spectroscopy (MRS) into standard brain imaging protocols has greatly expanded our capacity to identify and delineate intracranial pathologies [11]. Our study population aligns with previously documented demographic trends, with many cases surfacing in middle age—an interval where both primary brain tumors and infectious etiologies are commonly encountered [12]. Gliomas emerged as the leading primary neoplasm, consistent with established epidemiological data indicating that gliomas represent a substantial fraction of brain tumors in adults [13].

A notable feature of high-grade gliomas was an elevated choline (Cho) peak accompanied by lower N-acetyl aspartate (NAA), reflective of increased membrane turnover and neuronal depletion, respectively [14]. Lactate and lipid resonance peaks further signaled necrotic or hypoxic regions—frequent hallmarks of aggressive gliomas [15]. These metabolic indicators help refine grading, as lower-grade lesions exhibit comparatively modest Cho elevations and lactate production [16].

Meningiomas in this series frequently showed elevated Cho/Cr ratios and, in several cases, an alanine peak—attributes that differentiate these tumors from other intracranial neoplasms and thereby aid in planning surgical intervention [17]. Meanwhile, the differential diagnosis between necrotic tumors and abscesses, a common dilemma in routine MRI, was clarified by spectroscopic findings. Pyogenic abscesses typically revealed amino-acid peaks, correlating with the metabolic byproducts of inflammatory processes, whereas tubercular lesions were dominated by lipid resonances, indicative of caseous necrosis [18,19]. Prompt recognition of these patterns can accelerate accurate treatment, particularly in regions where tubercular infections remain prevalent [20,21].

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Parallel to other research, we found that the additional metabolic data from MRS elevated overall diagnostic accuracy when combined with MRI [22,23]. Beyond merely detecting malignancy or infection, MRS assists in treatment planning and follow-up. For instance, in post-therapy scenarios, it can distinguish tumor recurrence from radiation necrosis, a vital distinction for ensuring timely intervention [24,25]. The technique is also advantageous for directing stereotactic biopsies, targeting metabolically active tumor regions to maximize histological yield [26,27].

Nevertheless, MRS usage can be hampered by technical limitations, such as susceptibility artifacts near cranial bones or air spaces, as evidenced by the suboptimal spectra in nine patients [28]. Additionally, expertise in interpreting spectroscopic signals is essential to confidently differentiate overlapping metabolite patterns [29]. Ongoing advancements in hardware and software, including improved coil designs and advanced post-processing algorithms, aim to overcome these hurdles and further broaden the clinical utility of MRS [30].

In conclusion, our findings highlight the ability of MRS to deliver metabolite-based insights that supplement structural MRI, thereby enhancing diagnostic precision for a variety of intracranial lesions. By integrating metabolic profiles with morphologic assessment, clinicians can reach more informed decisions regarding biopsy, resection, and adjuvant therapy, ultimately fostering improved patient outcomes.

CONCLUSION

Magnetic Resonance Spectroscopy (MRS) considerably strengthens the diagnostic performance of conventional MRI in assessing intracranial space-occupying lesions. Through quantitative and qualitative metabolite analysis, it provides a deeper understanding of the biochemical status of tissues, thus distinguishing malignant tumors from benign entities and infections. In doing so, it refines tumor grading, supports targeted biopsies, and facilitates more precise monitoring of post-therapy alterations. By bridging the gap left by purely anatomical methods, MRS holds promise as a vital component of modern neuroimaging strategies, especially when surgical or histopathological confirmation is challenging.

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