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DIVERSE APPEARANCES OF RING-ENHANCING LESIONS ON MAGNETIC RESONANCE SPECTROSCOPY: A COMPREHENSIVE REVIEW

Radio-Diagnosis

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ABSTRACT

Introduction The evaluation of brain ring-enhancing lesions (RELs) using magnetic resonancespectroscopy (MRS) presents a critical area of study in neuroimaging and neurology.Our study aimsto assess the role of MRS in evaluating varying ring enhancing lesions of the brain. **Material and Methods** Between November 2023 and May 2024, a prospective observational study was conducted at a specialized tertiary care hospital. Before the study commenced, approval was obtained from the Institutional Ethics Committee, and informed consent was secured from all participating patients. The sample size of 24 for this study was determined based on confidence limits 20%, a power of 0.8, and a significance level of 0.05.11Patients presenting with seizures and headaches, incidentally diagnosed with ring-enhancing brain lesions through CT and contrast MR tests, were eligible to participate. Exclusions were made for patients with claustrophobia, metallic implants, cardiac pacemakers, chronic kidney disorders, schizophrenia, and pregnant women, ensuring data reliability and safety. **Results** The study on ring-enhancing brain lesions using magnetic resonance spectroscopy (MRS) revealed varied metabolite profiles aiding in differential diagnosis, such as elevated choline in metastasis and NCC, decreased levels in glioblastoma, and lipid peaks in meningioma and tuberculoma. Choline/creatinine ratios were informative for low-grade glioma. These findings underscore MRS's role as an adjunct to conventional imaging for precise characterization and treatment planning of such lesions.**Conclusion** Magnetic Resonance Spectroscopy (MRS) serves as a valuable asset in diagnosing ring-enhancing brain lesions, aiding in distinguishing lesions that present with similar features such as tuberculoma and neurocysticercosis

KEYWORDS

Metabolites, Neurocysticercosis, Tuberculoma, ring enhancing lesions

Introduction

The evaluation of brain ring-enhancing lesions (RELs) using magnetic resonance spectroscopy (MRS) presents a critical area of study in neuroimaging and neurology[1]. RELs pose diagnostic challenges due to their diverse etiologies, including infections, neoplasms, inflammatory processes, and vascular abnormalities. Conventional magnetic resonance imaging (MRI) alone may not always provide conclusive characterization, often necessitating additional investigations like contrast-enhanced MRI, computed tomography (CT), and invasive procedures such as biopsy. However, these approaches may be limited in terms of diagnostic precision, invasiveness, and potential risks.

MRS stands out as a non-invasive technique that offers valuable insights into tissue chemistry. Its lack of ionizing radiation makes it patient-friendly, and it generates information in the form of high-quality spectra rather than images. MRS can measure metabolites such as N-acetylaspartate (NAA), lactate, phosphocreatine, choline-containing compounds, and adenosine triphosphates, providing quantifiable data that enhances specificity and sensitivity compared to MRI.[2-4]Despite numerous studies on differentiating ring-enhancing lesions, distinguishing between tuberculoma and neurocysticercosis remains a challenge due to their similar appearance on conventional MRI.[5,6]

The justification for this study encompasses several key aspects. Firstly, MRS has the potential to improve diagnostic precision by providing biochemical insights into the composition of RELs, reducing diagnostic uncertainty, and guiding appropriate treatment strategies[7]. Secondly, it offers a non-invasive means of serially monitoring RELs over time, facilitating the tracking of treatment responses and disease progression[8]. Thirdly, the cost-effectiveness of MRS, despite potential initial costs, can be justified by the savings from avoiding unnecessary invasive procedures, repeated imaging studies, and incorrect treatments[9,10].

Furthermore, this study contributes to research and innovation in neuroimaging and neuropathology, fostering the integration of advanced imaging techniques like MRS into routine clinical practice. It aims to validate the reliability and specificity of MRS parameters in differentiating between infectious, neoplastic, and other etiologies of RELs, ultimately improving patient outcomes through accurate diagnosis, personalized treatment plans, and optimized disease management. Overall, the study on brain REL evaluation using MRS addresses a critical need for enhanced diagnostic capabilities and patient-centered care in neurology, paving the way for advancements in understanding and managing complex intracranial lesions. Our study aimsto assess the role of MRS in evaluating varying ring enhancing lesions of the brain.

Material and Methods

Between November 2023 and May 2024, a prospective observational study was conducted at a specialized tertiary care hospital. Before the study commenced, approval was obtained from the Institutional Ethics Committee, and informed consent was secured from all participating patients. The sample size of 24 for this study was determined based on confidence limits 20%, a power of 0.8, and a significance level of 0.05.[11]Patients presenting with seizures and headaches, incidentally diagnosed with ring-enhancing brain lesions through CT and contrast MR tests, were eligible to participate. Exclusions were made for patients with claustrophobia, metallic implants, cardiac pacemakers, chronic kidney disorders, schizophrenia, and pregnant women, ensuring data reliability and safety.

MRI scans were conducted using the MR Philips Achieva, featuring an ultracompact, superconducting magnet with a magnetic field strength of 1.5 Tesla (T). Various sequences were performed, including conventional spin echo sequences (axial T1, T2, and FLAIR), coronal T2, sagittal T1, post-contrast axial, coronal, and sagittal sequences, DWI, and T2 GRE spectroscopy with echo times (TE) of 20 and 144 milliseconds.The MRS procedure utilized the same instrument, with a preference for single voxel MRS for its quicker and easier operation compared to multi-voxel MRS. Voxel placement was meticulously done to encompass the lesion, its edges, and surrounding normal brain

tissue within a single voxel for comprehensive spectroscopic analysis. Small lesions near bone structures were excluded from spectroscopy to ensure accurate results and avoid interference.

Statistical analysis

Results

Table 1: Distribution of age among the study participants (N=24)

Slno	Variable	Frequency	Percentage
1	Age		
	13-20	4	16.7
	21-40	7	29.2
	41-60	8	33.3
	61-80	5	20.8
2	Gender		
	Male	12	50
	Female	12	50
3	Location		
	Cerebrum and cerebellum	2	8.3
	Left frontal	2	8.3
	Left fronto temporal lobe	1	4.2
	Left parietal	1	4.2
	Left posterior temporal	1	4.2
	Left temporal lobe	1	4.2
	Left thalamus	1	4.2
	Right capsuloganglionic	2	8.3
	Right frontal	5	20.8
	Right frontoparietal	1	4.2
	Right occipital	1	4.2
	Right parietal	4	16.7
	Right temporal	2	8.3
4	Number of lesions		
	Single	12	50
	Two	4	16.7
	Multiple	8	33.3
5	T2		
	Hyperintense	18	75
	Hypointense	2	8.3
	Iso-hyperintense	2	8.3
	Mixed signal	2	8.3
6	T2 FLAIR		
	Complete suppression	6	25.0
	Incomplete suppression	18	75.0
7	DWI		
	Hyperintense	17	70.8
	Hypointense	7	29.2

The Table 1 provided offers insights into the characteristics of patients with ring-enhancing brain lesions, highlighting several key variables and their corresponding frequencies and percentages. Regarding age distribution, the majority of patients fall within the age groups of 41-60 years (33.3%) and 61-80 years (20.8%), indicating a higher incidence of these lesions in older individuals. In terms of gender, there is an equal distribution between males (50%) and females (50%), suggesting no significant gender predilection for these lesions.Regarding the location of the lesions, the most common sites are the right frontal lobe (20.8%) and the left frontal lobe (8.3%), with a notable proportion also found in the right capsuloganglionic area (8.3%). This distribution across various brain regions underscores the diverse anatomical involvement of ring-enhancing lesions. The number of lesions varies, with single lesions being the most common (50%), followed by multiple lesions (33.3%) and two lesions (16.7%).Regarding imaging characteristics, the majority of lesions exhibit hyperintensity on T2-weighted images (75%), indicating increased fluid content or edema. T2 FLAIR sequences show complete suppression in a quarter of cases (25%) and incomplete suppression in the remaining (75%), suggesting varying degrees of fluid attenuation and contrast enhancement. Diffusion-weighted imaging (DWI) demonstrates hyperintensity in the majority of cases (70.8%), indicative of restricted diffusion commonly seen in acute infarcts or inflammatory processes.

Among the diagnoses, neurocysticercosis (NCC) and tuberculoma are the most prevalent, each accounting for approximately 29.2% of cases. This finding underscores the importance of considering infectious etiologies, particularly in regions where neurocysticercosis and tuberculosis are endemic. Glioblastoma multiforme and metastasis each represent 16.7% of cases, indicating a significant proportion of neoplastic lesions in this cohort. Cerebral abscess, low-grade glioma, and meningioma constitute smaller percentages at 8.3% each, highlighting the diversity of pathologies associated with ring-enhancing brain lesions.

Figure 1: Distribution of diagnosis among the study participants (N=24)

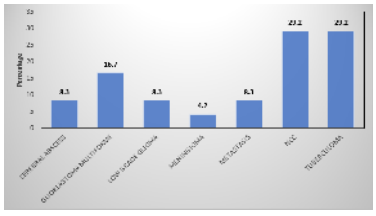


Table 2: Distribution of metabolite levels among the study participants (N=24)

Slno	Metabolite	Cerebral abscess	Glioblastoma multiforme	Low grade glioma	Meningioma	Metastasis	NCC	Tuberculoma	P value
1	Choline Normal Decreased Elevated	0 (0) 2 (100) 0 (0)	0 (0) 0 (0) 4 (100)	0 (0) 0 (0) 2 (100)	0 (0) 1 (100) 0 (0)	0 (0) 0 (0) 2 (100)	1 (16.7) 0 (0) 5 (83.3)	4 (57.1) 0 (0) 3 (42.9)	0.001
2	NAA Normal Low	0 (0) 2 (100)	0 (0) 4 (100)	0 (0) 2 (100)	1 (100) 2 (100)	0 (0) 0 (0)	0 (0) 2 (100)	1 (14.3) 6 (100)	0.05
3	Lipid Small peak 0.9-1.3ppm 1.3-2.00 ppm Nil	0 (0) 0 (0) 2 (100) 0 (0)	0 (0) 0 (0) 0 (0) 4 (100)	0 (0) 1 (50) 1 (50) 0 (0)	0 (0) 0 (0) 1 (100) 0 (0)	0 (0) 2 (100) 0 (0) 0 (0)	1 (16.7) 0 (0) 0 (0) 5 (83.3)	0 (0) 6 (85.7) 0 (0) 1 (14.3)	0.001
4	Choline / creatinine ratio <1 1-2 2-4 Normal	0 (0) 0 (0) 2 (100) 0 (0)	0 (0) 0 (0) 0 (0) 4 (100)	0 (0) 2 (100) 0 (0) 0 (0)	0 (0) 0 (0) 1 (100) 0 (0)	0 (0) 0 (0) 2 (100) 0 (0)	0 (0) 0 (0) 0 (0) 6 (100)	2 (28.6) 2 (28.6) 3 (42.9) 0 (0)	0.003
5	Amino acid Single peak Multiple peak Nil	1 (50) 1 (50) 0 (0)	0 (0) 0 (0) 4 (100)	0 (0) 1 (50) 1 (50)	1 (100) 0 (0) 0 (0)	0 (0) 0 (0) 2 (100)	0 (0) 6 (100) 0 (0)	0 (0) 1 (14.3) 6 (85.7)	0.001

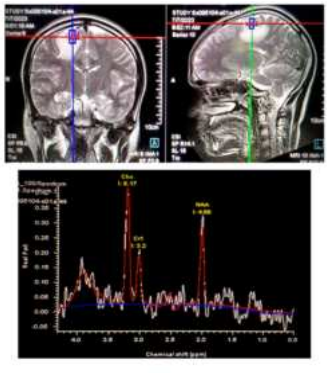
The data table 2 presents the analysis of metabolite levels and ratios in different types of brain lesions, including cerebral abscess, glioblastoma multiforme, low-grade glioma, meningioma, metastasis, neurocysticercosis (NCC), and tuberculoma, along with corresponding p-values for significance.Choline levels varied significantly across the lesion types, with elevated levels observed in metastasis (100%) and NCC (83.3%), while decreased levels were noted in glioblastoma multiforme (100%) compared to normal levels in cerebral abscess, low-grade glioma, meningioma, and tuberculoma. This variation highlights the potential of choline as a marker for distinguishing between different lesion types ($p = 0.001$).N-Acetylaspartate (NAA) levels were predominantly low in glioblastoma multiforme (100%) compared to normal levels in cerebral abscess, low-grade glioma, meningioma, and tuberculoma. This difference suggests that NAA levels could aid in differentiating glioblastoma multiforme from other lesions ($p = 0.05$).Lipid peaks were observed in varying degrees across different lesions, with small peaks noted in meningioma (100%) and tuberculoma (83.3%), while no lipid peaks were observed in cerebral abscess, low-grade glioma, and metastasis. This variability in lipid peaks could be indicative of different pathological processes within these lesions ($p = 0.001$).Choline/creatinine ratios were elevated in low-grade glioma (42.9%) compared to normal levels in other lesion types, indicating a potential marker for distinguishing low-grade glioma from other lesions ($p = 0.003$).Amino acid peaks showed multiple peaks in

metastasis (100%) and NCC (85.7%), while single peaks were observed in cerebral abscess, low-grade glioma, and meningioma. This diversity in amino acid peaks may reflect underlying differences in the metabolic profiles of these lesions (p = 0.001).

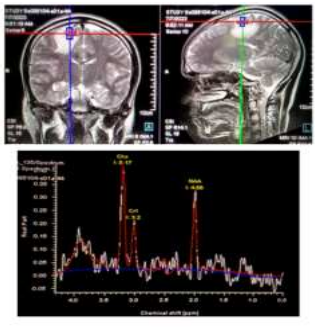
Discussion

The findings from this study provide valuable insights into the demographic characteristics, anatomical distribution of lesions, imaging characteristics, and metabolic profiles of various ring-enhancing brain lesions.Starting with the demographic analysis, the age distribution indicates a higher incidence of these lesions in older individuals, particularly in the age groups of 41-60 years and 61-80 years. This observation aligns with existing literature, which suggests that age-related factors such as immune status and comorbidities may contribute to the development of these lesions[4,7]. Interestingly, there is an equal distribution between males and females, indicating no significant gender predilection for these lesions in this cohort.The anatomical distribution of lesions reveals a diverse pattern, with the most common sites being the right frontal lobe, left frontal lobe, and right capsuloganglionic area. This diverse distribution underscores the complex anatomical involvement of ring-enhancing lesions, which can arise from various underlying pathologies across different brain regions. The predominance of single lesions further highlights the varied presentation of these lesions, with multiple and two lesions representing a smaller proportion but still significant in clinical context.

Moving on to imaging characteristics, the majority of lesions exhibit hyperintensity on T2-weighted images, indicative of increased fluid content or edema. The variability in T2 FLAIR sequences, with complete suppression in some cases and incomplete suppression in others, suggests differing degrees of fluid attenuation and contrast enhancement within these lesions. Diffusion-weighted imaging (DWI) findings of hyperintensity indicate restricted diffusion, commonly associated with acute infarcts or inflammatory processes, further adding to the diagnostic clues provided by imaging modalities.Analyzing the specific types of lesions, neurocysticercosis (NCC) and tuberculoma emerge as the most prevalent, emphasizing the significance of considering infectious etiologies, especially in regions where these infections are endemic. Glioblastoma multiforme and metastasis represent a notable proportion of neoplastic lesions, reflecting the diverse pathological spectrum associated with ring-enhancing brain lesions. The presence of cerebral abscess, low-grade glioma, and meningioma highlights the complexity and diversity of underlying pathologies contributing to these lesions.



Case representation of neurocysticercosis: a) MR Spectroscopy of the lesion in right high frontal lobe cortex shows multiple amino acid peak with elevated choline peak at 3.2 ppm and mildly reduced NAA at 2.0 ppm, However, no significant lipid lactate peak is seen.



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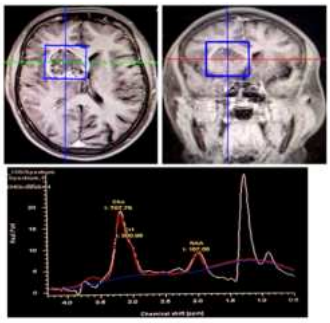
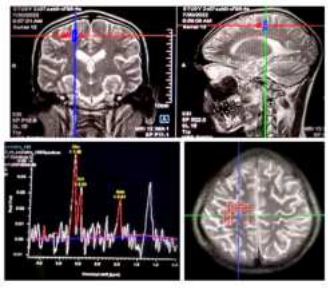
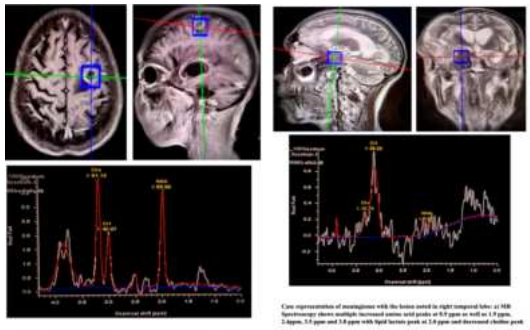


Case representation of glioblastoma multiforme with the lesion noted in right capsuloganglionic region a) MR Spectroscopy shows elevated choline and reduced NAA.



Case representation of tuberculoma in right high parietal lobe: a) MR Spectroscopy shows elevated choline peak at 3.2 ppm and lipid peak at 0.9-1.3 ppm with decreased NAA.

Various metabolites identified by MRS play a crucial role in discerning the nature of ring-enhancing brain lesions. Tuberculoma and neurocysticercosis, despite their clinical and neuroimaging similarities, present a diagnostic challenge for radiologists. The differentiation and characterization of these lesions rely on the distinct metabolite peaks they exhibit. Tuberculomas typically show lipid peaks and a choline/creatine ratio of >1. On the other hand, neurocysticercosis is characterized by elevated lactate, succinate, and choline levels alongside minimal or absent lipid peaks. In our study the metabolic analysis reveals significant variations in choline levels, N-acetylaspartate (NAA) levels, lipid peaks, choline/creatinine ratios, and amino acid peaks across different lesion types. These variations serve as potential markers for distinguishing between different lesion types, aiding in their accurate diagnosis and classification[13]. The statistical significance of these metabolic differences underscores their clinical relevance and potential utility as diagnostic biomarkers. In a study by Rajshree et al[12]patients diagnosed with tuberculoma displayed higher lipid peak levels, possibly attributed to lipid fractions in tuberculosis bacilli, as indicated in previous research. These patients also exhibited increased lipid/lactate peaks and decreased choline/NAA peaks, aligning with typical tuberculoma profiles. Conversely, neurocysticercosis cases showed heightened lactate, succinate, and choline levels with negligible lipid peaks[14]. Notably, primary brain tumors showcased elevated choline peaks, while cerebral abscesses exhibited lactate and amino acid peaks.The significance of choline/creatine ratio emerged, particularly in distinguishing low and high-grade tumors. A ratio >2.0 indicated high-grade neoplasms, with our study highlighting this trend in primary brain tumors and tuberculomas. These findings align with existing literature, emphasizing the utility of metabolite analysis, especially choline/creatine ratios, in characterizing brain lesions and guiding clinical decisions.[14,15]



Case representation of cerebral metastasis in left parietal lobe: a) MR spectroscopy shows increased choline and lactate peak with relatively low NAA peak.

Case representation of meningioma with the lesion noted in right temporal lobe: a) MR Spectroscopy shows multiple increased amino acid peaks at 0.9 ppm as well as 1.9 ppm, 2.4ppm, 3.0 ppm and 3.8 ppm with lipid lactate peak at 2.0 ppm and decreased choline peak

Conclusion

Magnetic Resonance Spectroscopy (MRS) serves as a valuable asset in

diagnosing ring-enhancing brain lesions, aiding in distinguishing lesions that present with similar features such as tuberculoma and neurocysticercosis. Nonetheless, additional research is essential to establish MRS as the primary diagnostic tool for these conditions. In the meantime, MRS sequences can be utilized as supplementary measures alongside conventional techniques.

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