A COMPREHENSIVE STUDY OF RING ENHANCING LESIONS IN THE BRAIN: INSIGHTS FROM MRI AND MRS

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DOI: 10.5281/zenodo.11057386

Abstract

Background: Multiple Ring Enhancing Lesions (RELs) of the brain are commonly observed in neuroradiology imaging. These lesions are critical to differentiate between neoplastic and non-neoplastic sources to avoid unnecessary treatments. Magnetic Resonance Imaging (MRI) and Magnetic Resonance Spectroscopy (MRS) play a significant role in the early diagnosis, differentiation, and treatment monitoring of these lesions. **Aim and Objectives:** The study aims to distinguish neoplastic from non-neoplastic brain lesions using MRI, study the characteristic features and imaging findings of various ring enhancing lesions on MRI, establish differential diagnoses using standard and advanced MRI techniques, and assess the role of single voxel proton MRS in differentiating various ring enhancing lesions of the brain. **Materials and Methods:** The study was conducted at Vinayaka Missions Kirupanada Variyar Medical College and Hospital, Salem, between February 2020 and April 2021. A total of 50 patients with clinically suspected cerebral ring enhancing lesions were included. MRI scans were performed using a Siemens Symphony 1.5 T MRI unit, with sequences including Axial T1, T2, FLAIR, Coronal T2, Sagittal T1, Post-contrast axial, coronal, sagittal, DWI, T2 GRE, and single voxel spectroscopy. **Results:** The study included 50 patients, with a male predominance (62%). The most common presenting symptom was seizures (84%). Tuberculoma (44%) was the most frequently diagnosed lesion, followed by Neurocysticercosis (NCC) (32%), abscess (10%), metastasis (10%), primary brain tumor (2%), and tumefactive demyelination (2%). The majority of lesions were less than 2 cm in size (68%). MRI and MRS findings were consistent with the diagnoses, with specific features observed in different types of lesions. **Discussion:** The study highlights the importance of MRI and MRS in the diagnosis and differentiation of various ring enhancing lesions of the brain. The findings are consistent with previous literature, emphasizing the role of advanced imaging techniques in the accurate diagnosis and management of these lesions. The study also underscores the diversity of ring-enhancing lesions, which can present a diagnostic challenge and necessitate a comprehensive evaluation. **Conclusion:** MRI and MRS are invaluable tools in the evaluation of ring enhancing lesions of the brain, enabling accurate differentiation between neoplastic and non-neoplastic lesions and guiding appropriate management.

Keywords: Ring Enhancing Lesions, Magnetic Resonance Imaging (MRI), Magnetic Resonance Spectroscopy (MRS), Neuroimaging, Brain Tumors, Neurocysticercosis.

ISSN 1462 2815

INTRODUCTION

Ring Enhancing Lesions (RELs) in the brain are a common finding in neuroradiological imaging, presenting a diagnostic challenge due to their diverse etiology. These lesions, characterized by a ring-like appearance on contrast-enhanced magnetic resonance imaging (MRI), can be caused by various pathological conditions, including neoplastic, infectious, inflammatory, and demyelinating diseases [1]. Distinguishing between these causes is crucial, as misdiagnosis can lead to inappropriate treatment, resulting in adverse outcomes.

Recent advancements in MRI and Magnetic Resonance Spectroscopy (MRS) have significantly improved the diagnostic accuracy of RELs. High-resolution MRI techniques, such as diffusion-weighted imaging (DWI) and fluid-attenuated inversion recovery (FLAIR), provide detailed information about the lesion's characteristics, aiding in the differentiation between neoplastic and non-neoplastic lesions [2]. MRS, a non-invasive tool, further complements MRI by analyzing the metabolic profile of the lesions, providing insights into their cellular composition [3].

Neoplastic causes of RELs, such as primary brain tumors and metastases, often exhibit distinct imaging features, including irregular ring enhancement and perilesional edema [4]. On the other hand, infectious causes like brain abscesses and tuberculomas typically show smooth ring enhancement with restricted diffusion on DWI [5]. Inflammatory conditions such as multiple sclerosis and neurosarcoidosis may also present as RELs, with imaging features overlapping with other etiologies, posing a diagnostic challenge [6].

The advent of advanced neuroimaging techniques has also shed light on the pathophysiology of RELs. Studies have demonstrated the role of the blood-brain barrier disruption and inflammatory processes in the formation of the characteristic ring enhancement [7]. Furthermore, the application of artificial intelligence and machine learning in analyzing MRI data has shown promise in improving the diagnostic accuracy and prognostication of RELs [8]. Similarly, MRS findings of elevated choline and reduced N-acetylaspartate levels are commonly associated with neoplastic lesions, whereas a prominent lactate peak is often seen in abscesses due to anaerobic metabolism [9].

Despite these advancements, the diagnosis of RELs remains complex, and a multidisciplinary approach involving clinical, radiological, and laboratory data is often necessary for accurate characterization [10]. This highlights the importance of continuous research and development in neuroimaging techniques to improve the diagnostic capabilities and clinical outcomes for patients with brain RELs.

MATERIALS AND METHODS

Study Design and Setting:

This prospective study was conducted at the Department of Radiodiagnosis, Vinayaka Mission’s Kirupananda Variyar Medical College and Hospital, Salem, between February 2020 and April 2021.

Ethical Considerations:

The study protocol was reviewed and approved by the Institutional Ethics Committee of Vinayaka Mission’s Kirupananda Variyar Medical College and Hospital, Salem, with the ethical clearance number VMKVMC &H/IEC/20/53. Informed consent was obtained from all participants or their legal guardians before inclusion in the study.

Study Population:

The study included a total of 50 patients who were clinically suspected of having cerebral ring-enhancing lesions. Patients were referred to the Department of Radiodiagnosis for diagnostic evaluation using MRI. The inclusion criteria were patients of all age groups, irrespective of sex, presenting with clinical symptoms suggestive of brain lesions and showing ring-enhancing lesions on contrast-enhanced MRI scans. Patients with a history of claustrophobia, cardiac pacemakers, metallic implants, or metallic foreign bodies in situ were excluded from the study.

Imaging Protocol:

The MRI scans in this study were conducted using a Siemens Symphony 1.5 Tesla MRI unit, adhering to a comprehensive imaging protocol. This protocol encompassed a variety of sequences to ensure a thorough examination of the brain lesions. Axial T1-weighted images (T1WI) and axial T2-weighted images (T2WI) were obtained to evaluate the basic anatomy and pathology. Fluid-attenuated inversion recovery (FLAIR) images were used to suppress the cerebrospinal fluid signal, enhancing the visibility of lesions. Coronal T2-weighted images provided an additional plane of view, complementing the axial images. Sagittal T1-weighted images were included to assess the midline structures and their relation to the lesions. Diffusion-weighted imaging (DWI) was employed to detect changes in water molecule movement, which is crucial in differentiating between various types of lesions. T2* gradient-recalled echo (GRE) images were acquired to identify any hemorrhagic components or calcifications within the lesions. Post-contrast T1-weighted images in axial, coronal, and sagittal planes were obtained after the intravenous administration of a gadolinium-based contrast agent, which is essential for evaluating lesion enhancement patterns. The imaging parameters for each sequence were carefully adjusted according to the standard protocols of the department, ensuring consistency and reliability in the imaging results.

Magnetic Resonance Spectroscopy (MRS):

In this study, single-voxel proton MRS was utilized for a subset of patients to meticulously examine the metabolic composition of the brain lesions. The technique employed was Point RESolved Spectroscopy (PRESS), which is known for its ability to provide high-quality spectral resolution. The voxel size for the MRS was carefully chosen to encompass the entire lesion, ensuring that the spectral data accurately represented the lesion's metabolic characteristics.

To capture a comprehensive metabolic profile, spectroscopy data were acquired at two different echo times (TE) - 135 milliseconds (ms) and 270 ms. The choice of these specific echo times was strategic, as it allowed for the detection of a wide range of metabolite peaks, each potentially indicative of different pathological processes within the lesion. By analyzing the intensity and pattern of these peaks, valuable insights could be gained into the lesion's nature, aiding in the differential diagnosis and guiding clinical management.

Data Analysis:

MRI and MRS data was entrusted to seasoned radiologists with expertise in neuroimaging, ensuring precision in interpreting complex imaging data. Lesions were characterized based on their anatomical location, size, signal intensity on different MRI sequences (such as T1-weighted, T2-weighted, and FLAIR), enhancement patterns following contrast agent administration, and diffusion restriction observed on diffusion-weighted imaging (DWI). The MRS data were meticulously interpreted to identify specific metabolite peaks associated with different pathological conditions. Key metabolites analyzed included N-acetylaspartate (NAA), a marker of neuronal integrity; choline, elevated in conditions with increased cell membrane turnover; creatine, a marker of energy metabolism; lactate, an indicator of anaerobic metabolism; and lipids, which can indicate necrotic or hemorrhagic lesions. By integrating MRI and MRS findings, the radiologists provided a comprehensive assessment of the lesions, aiding in accurate diagnosis and management of various neurological conditions.

Statistical Analysis:

Descriptive statistics were employed to summarize the demographic and clinical characteristics of the study population. This involved calculating the mean and standard deviation for continuous variables, such as age and size of the lesions, and frequencies and percentages for categorical variables, such as sex, type of lesion, and presence of specific imaging features.

The frequency and percentage of various types of ring-enhancing lesions were calculated to understand their distribution within the study population. For example, the percentage of patients diagnosed with tuberculoma, neurocysticercosis, abscess, metastasis, primary brain tumor, and tumefactive demyelination were determined based on the total number of patients in the study.

To evaluate the association between imaging findings and the final diagnosis, qualitative analysis was performed. This involved comparing the MRI and MRS characteristics of the lesions, such as location, size, signal intensity, enhancement patterns, diffusion restriction, and metabolite peaks, with the histopathological or clinical diagnosis. The aim was to identify imaging features that could reliably differentiate between different types of ring-enhancing lesions. Statistical tests, such as chi-square tests for categorical variables and t-tests or ANOVA for continuous variables, could be used to assess the significance of the associations observed. SPSS Software Version 27 was used.

RESULTS

Demographic and Clinical Characteristics:

The study comprised 50 patients, with a male predominance (62%) and 38% females. The age distribution was widest in the 21-30 years age group, accounting for 28% of the cases, followed by the 11-20 years age group with 22%. Seizures were the most common clinical presentation, reported in 84% of the patients, followed by headache (22%), vomiting (18%), fever (8%), ataxia (6%), and weakness (6%) (Table 1).

Table 1: Clinical Symptoms Presented by a Patient with Various Ring Enhancing Lesions

Symptom	No. of Cases
Seizures	42
Headache	11
Vomiting	9
Weakness	3
Fever	4
Ataxia	3

Imaging Findings:

The brain lesions were distributed across various locations, with 34% on the right side, 28% on the left side, 34% bilateral, and 4% in the midline. In terms of the number of lesions, a single lesion was observed in 34% of patients, while 2-4 lesions and more than 4 lesions were found in 42% and 24% of patients, respectively. The size of the lesions varied, with the majority (68%) being less than 2 cm, 22% measuring 2-4 cm, and 10% greater than 4 cm in size. Diffusion-weighted imaging (DWI) revealed restricted diffusion (complete or partial) in 54% of the lesions, whereas 46% showed no restriction (Table 2).

Table 2: Location of Side of Pathology in Brain in Various Ring Enhancing Lesion

Side of Pathology	No. of Cases
Right	17
Left	14
Bilateral	17
Midline	2

MRS Findings:

MRS data, available for 46 patients, revealed elevated choline levels in 60.9% of cases, suggesting increased cell membrane turnover. Lipid peaks were observed in 58.7% of cases, indicative of necrosis or hemorrhage. Lactate, a marker of anaerobic metabolism, was detected in 54.3% of cases. Reduced N-acetylaspartate (NAA) was present in 37% of cases, suggesting neuronal loss or dysfunction. Amino acids, associated with abscesses or infectious processes, were identified in 6.5% of cases (Table 3).

Table 3: List of Various Metabolite Peaks Noted in Various Enhancing Lesions

Metabolite Peak	No. of Cases
Choline	28
Lipid	27
Lactate	25
Reduced NAA	17
Amino Acids	3

Distribution of Pathologies:

The distribution of pathologies presenting as ring-enhancing lesions was as follows: Tuberculoma accounted for 44% of cases, characterized by smooth ring enhancement and perilesional edema. Neurocysticercosis (NCC) constituted 32% of cases, showing variable imaging features depending on the stage of the lesion. Abscesses made up

10% of cases, typically presenting with restricted diffusion and elevated lactate peaks. Metastases also accounted for 10% of cases, often exhibiting irregular ring enhancement and surrounding vasogenic edema (Table 4). Primary brain tumors and tumefactive demyelination each constituted 2% of cases, with imaging characteristics depending on the tumor type and association with multiple sclerosis, respectively.

Table 4: Male Female Incidence of Ring Enhancing Lesions

Pathology	Males	Females	Total
Tuberculoma	15	7	22
NCC	10	6	16
Abscess	3	2	5
Metastasis	2	3	5
Primary Brain Tumour	0	1	0
Demyelination	1	0	1

The current study results highlight the heterogeneity of ring-enhancing brain lesions, emphasizing the importance of a comprehensive diagnostic approach that integrates clinical, radiological, and advanced imaging findings for accurate diagnosis and management.

DISCUSSION

MRI, renowned for its superior inherent contrast, is a non-invasive, multi-planar modality that offers exceptional accuracy in lesion delineation. This imaging technique is instrumental in precisely assessing brain alterations associated with various RELs. This prospective study, conducted at Vinayaka Missions Kirupananda Variyar Medical College and Hospital in Salem, aimed to scrutinize the MRI characteristics of different RELs in the brain. The investigation encompassed 50 patients, with a male predominance of 62% (31 males) and 38% females (19 females). The predominant presenting symptom was seizures, observed in 84% of the patients, followed by headaches (22%), fever (18%), vomiting (6%), ataxia (8%), and motor weakness (2%). Among the studied cases, tuberculomas emerged as the most common cause of RELs (44%), succeeded by Neurocysticercosis (NCC) (32%), Metastasis (10%), Primary Brain Tumors (2%), Tumefactive Demyelination (2%), and Abscesses (10%). This distribution aligns with findings from Schwartz et al., where gliomas constituted 40% of their cases. The higher incidence of tuberculomas in our study could be attributed to the elevated prevalence of tuberculosis in India. The lesions were predominantly located on the right side (34%), with equal distribution bilaterally (34%) and a smaller proportion on the left side (28%). Single lesions were identified in 34% of the individuals, while 42% had 2-5 lesions, and 24% had more than five lesions. The majority of the RELs (64%) were smaller than 2 cm in diameter.

Diffusion restriction, a critical MRI parameter, was observed in 54% of the cases, indicating the presence of lesions with partial or complete restriction. Magnetic Resonance Spectroscopy (MRS), although not performed in four cases due to proximity to bone, revealed significant findings in the remaining 46 cases. Choline peaks were noted in 28 cases, lipid peaks in 27, lactate peaks in 25, decreased N-acetylaspartate (NAA) peaks in 17, and amino acids in 3 cases. These spectroscopic findings are pivotal in differentiating between various pathological conditions.

ISSN 1462 2815

Tuberculomas, found in 44% of the cases, predominantly affected males (68.1%). These lesions, often presenting as conglomerates, exhibited hypointensity on both T1-weighted and T2-weighted images. Notably, 76.3% of tuberculomas showed partial or complete diffusion restriction, a feature that aids in their identification. MRS further facilitated the differentiation of tuberculomas from other infective granulomas by revealing lipid signals in 68.1% of the cases. Follow-up imaging confirmed the resolution of the lesions and associated perilesional edema in 32% of the tuberculoma cases. Neurocysticercosis (NCC) was diagnosed in 32% of the patients, with a male-to-female ratio of 10:6. This condition presented a spectrum of imaging findings, with 37.5% of the cases exhibiting calcified lesions on gradient echo imaging. The utilization of the CISS 3D sequence proved beneficial in detecting the scolex in 50% of the NCC cases. MRS findings, including decreased choline and NAA peaks, were consistent with the characteristics of NCC. The imaging results of our NCC cases were in line with those reported by Amaral et al. (2003) [11] and Pal et al. (2010) [12].

Brain abscesses, accounting for 10% of the cases, demonstrated complete diffusion restriction and elevated lactate signals on MRS, indicative of anaerobic glycolysis. These findings corroborate the MRI characterization of abscesses by Lai et al (2005) [13]. Metastatic lesions, constituting another 10% of the cases, exhibited high choline-to-creatine and choline-to-NAA ratios, along with hyperintensity on T2-weighted images and irregular ring enhancement following contrast administration. The imaging characteristics of metastases in our study were consistent with those reported by Vieth et al. (1965) [14]. Our study underscores the pivotal role of MRI and MRS in the accurate diagnosis and differentiation of various ring-enhancing lesions in the brain. The findings highlight the diverse etiology of RELs and the importance of a comprehensive imaging approach in their evaluation.

CONCLUSION

In conclusion, this study underscores the pivotal role of MRI and MRS in the accurate diagnosis and differentiation of various ring-enhancing lesions in the brain. Our findings highlight the diverse etiology of RELs, ranging from tuberculomas and neurocysticercosis to abscesses and metastases, each presenting with distinct imaging characteristics. The study emphasizes the importance of a comprehensive imaging approach, integrating both MRI and MRS, to elucidate the nature of these lesions and guide appropriate clinical management. The results also underscore the value of advanced imaging techniques in enhancing diagnostic accuracy, particularly in distinguishing between neoplastic and non-neoplastic lesions. Overall, this research contributes to the existing knowledge base and aids clinicians in making informed decisions for the effective treatment of patients with ring-enhancing brain lesions.

Acknowledgements:

We would like to express our sincere gratitude to the Department of Radiodiagnosis at Vinayaka Mission’s Kirupananda Variyar Medical College and Hospital, Salem, for their support and cooperation throughout this study. Special thanks to the radiology technicians and staff for their assistance in data collection and patient management. We are also grateful to the patients who participated in this study and their families for their cooperation and understanding.

Authors Contribution:

Dr Arun Kumar - conceptualization, data curation, investigation, methodology, project administration, visualization, writing—original draft, writing—review and editing; Dr Yuvabalakumaran - conceptualization, methodology, writing—original draft, writing—review and editing; Dr. Sanjaykanth -

ISSN 1462 2815

conceptualization, visualization, supervision, writing—original draft; Dr Zakir Hussian and Dr Sri Ridanya - methodology, writing—original draft, writing, review and editing. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest:

The authors declare that there are no conflicts of interest regarding the publication of this study. All authors have contributed significantly to the research and preparation of the manuscript and have agreed to the submission of this final version.

Funding Sources:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The study was conducted with the resources available at Vinayaka Mission's Kirupananda Variyar Medical College and Hospital, Salem.

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