ORIGINAL RESEARCH

Features of Ring-Enhancing Brain Lesions: A Correlative Study between MRI and MR Spectroscopy

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ABSTRACT

Background:This study aimed to examine and pinpoint distinctive alterations in multiple ring-enhancing lesions within the brain using conventional MRI and proton MR spectroscopy. The objective was to facilitate early diagnosis, treatment, response assessment, and reduce complications in patients with such lesions.**Methods**:his descriptive study involved 100 patients clinically suspected of having ring-enhancing lesions. These patients were referred to the Department of Radiodiagnosis and underwent scanning using a 1.5 Tesla MRI over a span of two years.**Results**:Among the 100 patients examined, the diagnoses were distributed as follows: 38 cases of neurocysticercosis, 32 cases of tuberculomas, 16 cases of intracranial abscess, 8 cases of metastasis, 6 cases of primary brain neoplasms, and 2 cases of tumefactive demyelination. Notably, neurocysticercosis emerged as the most prevalent pathology, with seizures being the predominant complaint among patients.**Conclusion**:Among the 100 patients examined, the diagnoses were distributed as follows: 38 cases of neurocysticercosis, 32 cases of tuberculomas, 16 cases of intracranial abscess, 8 cases of metastasis, 6 cases of primary brain neoplasms, and 2 cases of tumefactive demyelination. Notably, neurocysticercosis emerged as the most prevalent pathology, with seizures being the predominant complaint among patients.

Keywords:MRspectroscopy,brain,ringenhancinglesions,Neurocysticercosis,Tuberculosis

INTRODUCTION

Magnetic Resonance Imaging (MRI) stands as a pivotal diagnostic tool, offering a nuanced perspective in the early identification of various pathological conditions within the brain. Its ability to accentuate the contrast between grey and white matter facilitates a detailed examination of the cerebral landscape.[1] Notably, this imaging modality excels in delineating features such as tumor ischemia, infarction, edema, multiple sclerosis plaques, and the presence of infections, abscesses, and hemorrhages.One of the distinct advantages of MRI lies in its inherent sensitivity, allowing for a comprehensive visualization of all brain regions without necessitating the reformatting of images. This broad scope contributes significantly to the holistic understanding of the intricate structures and potential abnormalities within the brain.Moreover, MRI proves instrumental in the accurate diagnosis of conditions characterized by ring-enhancing lesions.[2] This is particularly crucial in cases where differentiating between various pathologies is paramount. Magnetic Resonance Spectroscopy (MRS), a complementary technique to MRI, emerges as a vital adjunct in this diagnostic journey.

MRS serves as a sophisticated tool, particularly adept at unraveling the complexities associated with infectious etiologies such as intracranial abscesses, and non-infectious lesions like primary intraparenchymal neoplasms, demyelination, lymphoma, and cerebral metastasis. By scrutinizing the quantity and ratio of tissue metabolites—such as lipid, choline, amino acids, and N-acetyl aspartate—MRS provides a nuanced understanding of the nature and characteristics of these lesions.In the context of lesions located in the sub-cortical areas and at the grey-white matter interface, whether situated superficially or deeply within the brain parenchyma, the combined power of MRI and MRS offers a comprehensive diagnostic approach, aiding clinicians in unraveling the intricacies of neurological

conditions and paving the way for informed and targeted therapeutic interventions.

The clinical presentation of lesions often presents a diagnostic challenge due to the lack of specific symptoms. In the pursuit of reaching a conclusive diagnosis, longitudinal studies have underscored the invaluable role of proton MR spectroscopy (H-MRS).[3] Not only does H-MRS serve as a critical tool in monitoring disease progression, but it also plays a pivotal role in gauging the efficacy of treatment interventions. Furthermore, the insights gained from MR Spectroscopy extend to prognostic considerations, enhancing our understanding of the potential trajectory of the condition.In the realm of contemporary medical imaging, MR localization procedures have evolved to become predominantly image-guided. Leveraging 1H MR images to guide the precise placement of Regions of Interest (ROIs) for Radiofrequency (RF) excitation, these procedures often include a spectroscopy component, emphasizing the integral role of molecular-level information in diagnosis and monitoring.Two primary methodological approaches are prominent in the clinical setting when it comes to volume localization. The first involves single-voxel localization, concentrating on signals emanating from a well-defined region of tissue.[4] The second approach entails the simultaneous acquisition of signal data from multiple regions, each method utilizing magnetic field gradients to provide spatial information while selectively offering detailed insights into the molecular composition of tissues.Examining a standard MR spectrum reveals metabolite peaks at various positions on the X-axis. Lipids appear at 0.9 and 1.3 ppm, lactate at 1.3 ppm (manifesting as a doublet), N-acetyl aspartate peak (NAA) at 2.0 ppm, choline peak (Cho) at 3.2 ppm, creatine peak (Cr) at 3.0 ppm, and Myo-inositol peak (mI) at 3.6 ppm. Notably, the alignment of mI, Cr, Cho, and NAA peaks forms a distinctive 45-degree angle to the X-axis, recognized as Hunter's angle.This nuanced perspective is further enriched by considering variations in echo time (TE), alterations in voxel location from peripheral cortex to midbrain, and changes in repetition time (TR), all of which contribute to fluctuations in Hunter's angle. Embracing these sophisticated spectroscopic techniques provides a profound understanding of the biochemical underpinnings of tissues, thereby refining our ability to characterize and comprehend the intricacies of various neurological conditions.[5,6]

MATERIALS AND METHODS

The study in question was characterized as a descriptive investigation encompassing a cohort of 100 patients, carried out diligently over a span of two years. During this comprehensive two-year period, the research delved into various aspects, seeking to unravel the intricacies of the subjects under scrutiny. The descriptive nature of the study implies a meticulous examination of the characteristics, patterns, and phenomena associated with the selected patient population, with the overarching goal of shedding light on the nuances within the scope of the investigation.

The extended duration of the study, spanning two years, implies a thorough and prolonged engagement with the subjects, providing a more comprehensive understanding of the factors and variables at play. This extended timeframe facilitates a nuanced analysis of temporal changes, trends, and variations within the patient cohort.

In essence, the study design reflects a commitment to a thorough exploration of the subject matter over a substantial period, with the intent of capturing a holistic view of the phenomena under investigation. This temporal dimension not only enhances the reliability and depth of the findings but also allows for a more robust interpretation of the data collected throughout the course of the research endeavor.

RESULTS

All patients under consideration were specifically referred to the Department of Radiology due to a strong suspicion of intracranial space-occupying lesions. In a meticulous retrospective analysis, all individuals with ring-enhancing lesions of the brain, as identified through MR imaging with gadolinium contrast injection, were included in the study. This inclusive approach encompassed individuals of all age groups, without any discrimination based on gender.However, to ensure the integrity of the study and the safety of participants, certain exclusion criteria were applied. Patients with a history of claustrophobia, metallic foreign bodies or implants in situ, cardiac pacemakers, contrast allergies, and those with compromised kidney function were excluded from the study. These exclusions aimed at minimizing potential complications and ensuring the well-being of the participants throughout the course of the investigation.Additionally, to augment the diagnostic process and enhance the overall understanding of the cases, supportive investigations were initiated. This included a comprehensive set of examinations such as a complete blood count, cerebrospinal fluid (CSF) analysis, tuberculin test and/or chest X-ray, ELIZA test, radiographs of extremities to detect intramuscular cysticercosis, visual evoked potential (VEP), and biopsy. These ancillary investigations were deemed essential for correlating the imaging findings with clinical examinations, thereby providing a more holistic and informed perspective on the nature of the intracranial lesions under investigation.

Table 1: The brain metabolites that correspond to various pathological processes.

Chemical Compound	Chemical (PPM)	Comments
N-Acetyl Aspartate (NAA)	2.0	Neuronal Marker.
Creatine/Phosphocreatine	3.0,3.9	Supplier Of Phosphate To Convert Adp. Energy Metabolism.
Choline (Cho)	3.2	Cell Membrane Marker.
Myo–Inositol(Ml)	3.6	Glial Cell Marker, Osmolyte Hormone Receptor Mechanisms
Glutamate (Glu) Glutamine (Gln) (Glu+Gln=Glx)	2.1-2.5	An Excitatory Neuro Transmitter And Regulator
Lipids (Lip)	0.9-1.4	Cell Break Down/ Brain Destruction Indicator.
Lactate(Lac)	1.3	Degradation Of Pyruvate In The Anaerobic Glycolysis Pathway

Table 2: Incidence of various pathologies presenting as Ring enhancing lesion

Pathologies	Number
Neurocysticercosis	38
Tuberculomas	32
Abscesses	14
Metastasis	8
Primaryneoplasm	6
Demyelination	2

Figure 1: Incidence of various pathologies presenting as Ring enhancing lesion

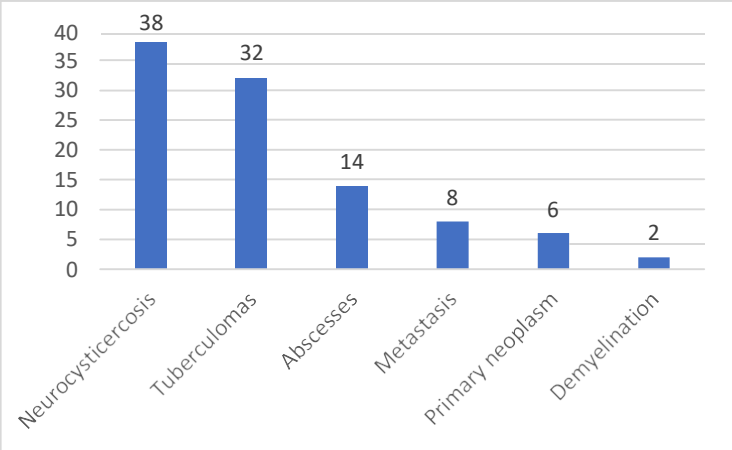

Table 3: MRI characteristics of various ring enhancing pathologies and their supportive findings that help to reach a conclusive diagnosis.

Radiological diagnosis	No. of patients	Most common Complaint	T1WI	T2WI	DWI (Restriction)	MR Spectroscopy peak	Supportive findings to confirm the diagnosis
Neurocysticercosis	38	Seizures	Hypointense	Hyperintense	No	Choline, Lactate, succinate	Extremity Radiographs and/or ELISA positive for cysticercosis
Tuberculoma	32	Seizures, neurologic deficit	Hypointense	Hyperintense	No	Lipid, Lactate	Past history of TB and/or Seizure stoppage in 4 weeks after starting Anti-tubercular therapy
Abscess	14	Fever, headache	Hypointense	Hyperintense rim	Yes	Amino acids- e.g.: leucine, valine etc.	High TLC count with improvement on Antibiotics
Metastasis	8	Seizures	Hypo to Isointense	Hyperintense	Yes	Choline, lactate	Primary neoplasm: In lungs- 3 patients In breast-1 patient
Primary neoplasm	6	Headache	Hypointense	Heterogeneously hyperintense	Yes	High Choline/Creatinine ratio, reduced NAA	Biopsy proven High grade glioma in all patients.
Tumefactive demyelination	2	Seizures	Hypointense	Iso to hypointense rim	No	Variable,Choline, NA/Creat. higher	Low CBV on perfusion imaging

DISCUSSION

In our comprehensive assessment involving 200 patients, the presence of neurocysticercosis was distinctly identified in 76 cases, with a discernable distribution among genders – 48 cases in males and 28 in females. A nuanced categorization revealed that 32 patients exhibited a singular lesion, while 44 presented with multiple lesions. Notably, all observed cases manifested as intraparenchymal forms of neurocysticercosis, with the intriguing occurrence of spinal and subarachnoid cysticercosis noted in one case each. The utilization of CISS 3D sequences emerged as an invaluable tool in detecting scolex, a characteristic feature in 14 cases.[7]Upon delving into the metabolic landscape, Magnetic Resonance Spectroscopy (MRS) uncovered specific metabolic signatures. Notably, a distinct Choline peak at 3.2 ppm, a succinate peak at 2.4 ppm, and a reduced peak of N-acetyl aspartate (NAA) were observed, providing valuable insights into the biochemical composition of the lesions. The implementation of gradient echo imaging played a pivotal role in identifying calcified lesions, observed in 14 cases, constituting 36.8% of the cohort.Radiological imaging further unveiled consistent patterns across the lesions – all showcased low or isointense signals on T1-weighted images and manifested hyperintensity on T2-weighted images. Intriguingly, 22 lesions exhibited inversion on FLAIR, hinting at contents akin to cerebrospinal fluid (CSF). A particularly noteworthy observation was the strong ring enhancement coupled with an adjacent perilesional edematous component, identified in 24 cases, indicative of active lesions.A distinctive aspect of our study was the absence of any intraventricular neurocysticercosis cases, a feature potentially attributed to the study's limited sample size. This stands in contrast to the findings of Martinez et al., who reported intraventricular neurocysticercosis in 22% of cases. Our study advocates for the superiority of Magnetic Resonance Imaging (MRI) over Computed Tomography (CT) in detecting parenchymal neurocysticercosis, aligning with the conclusions drawn by Suss Raetal et al. Importantly, the characteristics identified in our study parallel those reported in the study conducted by Amaral LL et al., reinforcing the consistency of features associated with parenchymal neurocysticercosis. Overall, our findings contribute to the growing body of evidence supporting the diagnostic prowess of MRI in unraveling the diverse manifestations of neurocysticercosis.[8]

In our comprehensive study involving 100 cases, tuberculomas emerged as a notable diagnostic entity, accounting for 32% of the total cases. Within this subset, 32 individual cases were identified, with a gender distribution of 10 males to 6 females. The varied presentation of tuberculomas included instances of singular lesions noted in 8 cases and multiple lesions observed in an additional 8 cases. The morphological characteristics of multiple tuberculomas exhibited a conglomeration pattern, portraying diverse signal intensities on both T1-weighted (T1W) and T2-weighted (T2W) images. Notably, some lesions demonstrated a low signal on both sequences, while others exhibited a high signal on T2W images, adding to the radiological complexity of these cases.Diffusion characteristics revealed no or partial restriction in 28 cases, further contributing to the heterogeneous nature of tuberculomas. Importantly, all tuberculomas exhibited a nodular or irregular ring-like enhancement, a crucial feature aiding in their distinctive identification.[9,10] Magnetic Resonance Spectroscopy (MRS) played a pivotal role in enhancing the diagnostic precision by consistently revealing a lipid peak in all 32 cases. This lipid peak, characteristic of tuberculomas, proved to be instrumental in distinguishing them from other infective granulomas, thereby contributing to the specificity of the diagnostic process.The application of MRS also enabled the assessment of the Choline to Creatinine ratio, a parameter that emerged as a consistent discriminator between neurocysticercosis (NCC) and tuberculomas. Specifically, the ratio consistently fell below 1.1 in all NCC cases and exceeded 1.2 in all tuberculoma cases. This aligns closely with the findings reported in studies conducted by Kumar et al. and Jayasunder et al., reaffirming the reliability and reproducibility of this parameter in the differential diagnosis of these two conditions.In summary, our study underscores the radiological diversity of tuberculomas and emphasizes the crucial role of MRS in their accurate identification. The Choline to Creatinine ratio further contributes to the diagnostic acumen, aligning with established findings in the literature and enhancing the overall understanding of these intracranial lesions.[11]

In our comprehensive investigation involving 100 patients, the identification of abscesses proved to be a salient finding, encompassing 14% of the total cases. This subset included 10 males and 4 females, reflecting a diverse distribution. A nuanced exploration of these cases revealed that a majority, specifically 57.1%, presented with a solitary abscess, while the remaining 6 cases exhibited the presence of multiple abscesses. An intriguing aspect was the medical history of one patient, who had a notable background of congenital heart disease - tetralogy of Fallot.The radiological characterization of these abscesses unveiled distinct features on various imaging sequences. On T1-weighted (T1W) images, all abscesses displayed hypointensity, accompanied by the noteworthy presence of a hyperintense ring around the lesion in 12 cases. In the realm of T2-weighted (T2W) images, the abscesses manifested hyperintensity, juxtaposed with a hypointense rim encircling the lesion. A notable commonality across all cases was the observation of absolute diffusion restriction, elucidated by consistently low apparent diffusion coefficient (ADC) values. This radiological signature, indicative of restricted water movement

within the abscess, added a crucial dimension to the diagnostic profile.Further enriching the metabolic landscape, high lactate levels were uniformly identified in all 14 patients.[12] This finding suggested an anaerobic glycolytic process within the abscess. Additionally, in 6 cases, the presence of specific amino acids—valine, leucine, and isoleucine—were detected, further contributing to the intricate metabolic characterization of these lesions. These metabolic features align closely with descriptions provided by Halmes et al. in the context of MR characterization of abscesses.Crucially, our findings underwent a meticulous correlation with structural features, including central necrosis, peripheral edematous changes, and the characteristic peripheral enhancing capsule of the abscess. This integrative approach enhanced the diagnostic precision, providing a comprehensive understanding of the radiological and metabolic features associated with these lesions.Noteworthy parallels were drawn between our observations and findings reported in studies conducted by Leuthardt EC et al. and Shukla-Dave A et al., underscoring the consistency of radiological characteristics associated with abscesses across diverse patient cohorts. In summary, our study contributes to the evolving understanding of abscesses, shedding light on their varied presentations and reinforcing the importance of a multi-faceted diagnostic approach in the clinical setting.

CONCLUSION

The integration of Magnetic Resonance Imaging (MRI) alongside Magnetic Resonance Spectroscopy (MRS) stands as a crucial and primary research tool in the field of neurodiagnosis. This combined approach is particularly indispensable in regions with a high prevalence of certain conditions, and in developing countries like India, where neurological disorders such as Neurocysticercosis (NCC) and tuberculomas are prevalent.NCC and tuberculomas often present as ring-enhancing lesions in the brain, posing a diagnostic challenge due to the similarity in their radiological appearance. The utilization of MR spectroscopy in conjunction with routine MRI scans emerges as a powerful strategy to achieve accurate diagnosis and delineate the characteristic features of these lesions.MR spectroscopy allows for a detailed analysis of the quantity and ratio of tissue metabolites within the lesions. This comprehensive metabolic profiling aids in distinguishing between different pathological entities, providing valuable insights into the underlying biochemical composition. For instance, in the case of NCC, characteristic features such as the presence of lipid peaks and specific metabolite ratios can be indicative of this parasitic infection. Similarly, tuberculomas exhibit distinct metabolic patterns, which can include alterations in choline, creatinine, and lipid peaks, aiding in their differentiation from other lesions.In summary, the use of MRI with MR spectroscopy is pivotal in neurodiagnosis, especially in regions with a high incidence of specific neurological conditions. In the context of developing countries like India, where diseases like NCC and tuberculomas are prevalent, this combined approach serves as a cornerstone in advancing our ability to accurately diagnose and characterize these lesions, ultimately improving patient care and outcomes.

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