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Diagnostic Utility of Magnetisation Transfer Ratio (MTR) in Differentiating Tuberculoma from Neurocysticercosis in Ring-Enhancing Brain Lesions: A Cross-Sectional MRI-Based Study

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ABSTRACT

Introduction: Intracranial ring-enhancing lesions are a frequent imaging finding in patients presenting with seizures or other neurological symptoms. In regions like India, tuberculoma and neurocysticercosis (NCC) are the most common causes, often sharing overlapping features on MRI. Accurate differentiation is essential, as NCC typically responds to antiparasitic and antiepileptic therapy, while tuberculoma requires long-term antitubercular treatment. Traditional MRI sequences may not provide sufficient distinction. Magnetisation Transfer Imaging (MTI), particularly through Magnetisation Transfer Ratio (MTR) measurement, offers a quantitative tool that reflects underlying tissue composition, helping differentiate between infectious etiologies.

Aim and Objective: To assess the effectiveness of MRI using Magnetisation Transfer Ratio (MTR) in accurately differentiating tuberculoma from neurocysticercosis in patients presenting with ring-enhancing lesions on brain imaging.

Materials & Methods: This was a cross-sectional, observational study conducted over 1.5 years at Sree Balaji Medical College and Hospital, Chennai. Thirty patients with ring-enhancing brain lesions and clinical suspicion of CNS granulomas were evaluated. MRI was performed with MTR sequences, and values were compared between tuberculoma and NCC subtypes (colloid vesicular, granular nodular, vesicular). ANOVA and post-hoc statistical tests were applied to determine significance.

Results: The mean MTR for tuberculoma was 18.4 ± 2.46. Among NCC subtypes, colloid vesicular showed 11.3 ± 1.13, granular nodular 21.5 ± 1.57, and vesicular 13.9 ± 4.5. ANOVA indicated significant intergroup differences ($p < 0.00001$), while post-hoc analysis validated key pairwise distinctions, supporting MTR's role in lesion differentiation.

Conclusion: MTR is a reliable, non-invasive imaging biomarker that significantly improves diagnostic accuracy in distinguishing tuberculoma from different NCC stages, facilitating appropriate treatment planning in endemic regions.

Keywords: *Magnetisation Transfer Ratio; MRI; Neurocysticercosis; Tuberculoma; Ring-enhancing lesions*

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1. INTRODUCTION

Enhancing lesions observed in brain imaging are indicative of abnormal areas where the blood-brain barrier is disrupted, where vascularity is altered, or where pathological tissue activity occurs. These lesions are typically visualized using contrast-enhanced imaging modalities, especially Magnetic Resonance Imaging (MRI) and, in some settings, Computed Tomography (CT). The detection of such lesions plays a critical role in diagnosing a wide spectrum of neurological diseases, as the number, shape, enhancement pattern, and location of these lesions can hint at the underlying pathology, which may include infections, neoplasms, inflammatory disorders, or vascular anomalies (1).

Solitary enhancing lesions in the brain often point toward localized pathology. Infections such as neurocysticercosis (NCC), particularly prevalent in endemic regions, commonly appear as ring-enhancing lesions accompanied by surrounding edema. Brain abscesses can present with similar radiological characteristics, typically showing a central hypodense area due to liquefied necrosis. Neoplastic conditions, including high-grade gliomas like glioblastoma multiforme, may also manifest as solitary irregular enhancing masses with perilesional edema and mass effect. Inflammatory demyelinating conditions such as multiple sclerosis may demonstrate enhancing plaques in the acute phase, while neuromyelitis optica can initially present with solitary lesions. Moreover, subacute infarcts and vascular malformations like cavernomas may enhance on imaging, further broadening the differential (2).

Multiple enhancing lesions are often suggestive of systemic or disseminated diseases. Infectious causes in immunocompromised individuals include tuberculosis, presenting as multiple ring-enhancing tuberculomas, and opportunistic infections like toxoplasmosis, which typically affects basal ganglia or corticomedullary junctions in patients with HIV/AIDS. Metastatic brain disease is another common cause of multifocal enhancing lesions, especially from primary malignancies such as lung, breast, and melanoma. Primary CNS lymphoma, particularly in immunosuppressed individuals, can present as multiple homogeneously enhancing lesions. Inflammatory disorders like multiple sclerosis show multifocal enhancing plaques often in periventricular or juxtacortical regions. Vascular etiologies such as multiple cavernomas or embolic infarctions may also manifest with multifocal enhancement. Furthermore, drug-induced leukoencephalopathy or radiation necrosis can mimic infectious or neoplastic lesions. Imaging clues such as ring versus homogeneous enhancement, the presence of perilesional edema, diffusion restriction, and MR spectroscopy findings can help refine the differential diagnosis. For instance, restricted diffusion is a hallmark of pyogenic abscesses and lymphoma, while homogeneous enhancement is more characteristic of lymphoma than of necrotic tumors or infections (3, 4).

Clinical correlation is indispensable in interpreting brain imaging findings. The presence of fever, immunodeficiency, previous tuberculosis, cancer history, neurological deficits, or seizure activity can guide clinicians toward the appropriate diagnosis. Advanced imaging techniques like MR spectroscopy, perfusion imaging, and PET scans, along with cerebrospinal fluid (CSF) analysis and histopathological confirmation through biopsy, are valuable adjuncts. Treatment protocols vary significantly based on the etiology—ranging from antimicrobial agents for infectious lesions to surgery, radiation, or chemotherapy for neoplastic conditions. A comprehensive diagnostic approach combining imaging, clinical, and laboratory parameters is essential to ensure effective and accurate management of patients with enhancing brain lesions (5, 6).

Differentiating between infectious and neoplastic brain lesions is of paramount importance, given their contrasting pathophysiological mechanisms and therapeutic strategies. Infections of the central nervous system (CNS) involve immune-mediated inflammation triggered by bacteria, viruses, fungi, or parasites. This is distinctly different from the unregulated cellular proliferation seen in neoplastic diseases such as glioblastoma or metastases. Although both conditions can produce similar clinical presentations—such as headache, seizures, and altered mental status—accurate diagnosis is essential, as treatment for one may be contraindicated in the other. Administering corticosteroids or chemotherapy in a patient with undiagnosed infection can have catastrophic consequences. Therefore, accurate and early distinction between these entities significantly affects patient outcomes and reduces the risk of inappropriate management (7, 8).

The burden of acute symptomatic seizures due to CNS lesions varies significantly between developing and developed countries, largely due to differences in disease prevalence and diagnostic capabilities. In low-income regions, infections such as neurocysticercosis (NCC), tuberculomas, bacterial meningitis, and cerebral malaria are common triggers, with NCC especially prevalent in areas with poor sanitation and pig exposure. Limited access to CT or MRI often delays diagnosis, increasing the risk of chronic epilepsy. Conversely, in high-income nations, seizures are more commonly caused by non-infectious conditions like stroke, brain tumors, or trauma, with timely imaging and intervention ensuring better outcomes. Diagnosing tuberculoma versus NCC in resource-limited settings is particularly challenging due to overlapping symptoms and imaging features, compounded by limited access to advanced imaging and low diagnostic specificity of available tests, leading to empirical treatments that may delay appropriate therapy (9, 10).

Co-infection with both tuberculoma and neurocysticercosis (NCC) can occur, especially in endemic regions, complicating

diagnosis due to overlapping symptoms and imaging findings. Limited access to specialists and advanced diagnostics in low-resource areas further hampers differentiation. MRI remains essential for distinguishing these lesions, with tuberculomas showing ring enhancement, diffusion restriction, and lipid-lactate peaks, while NCC presents stage-specific features like scolex and choline-lactate elevation. Recognizing key differences in morphology, enhancement patterns, and MR spectroscopy findings is crucial. This study aims to assess MRI features and Magnetisation Transfer Ratio (MTR) to differentiate tuberculoma from NCC in a tertiary care hospital setting (11).

This study aims to assess tuberculoma and neurocysticercosis using magnetic resonance imaging (MRI) at a tertiary care hospital and to distinguish between the two based on magnetisation transfer ratio (MTR). The objectives are to identify and evaluate the specific MRI characteristics of neurocysticercosis and tuberculoma lesions and to differentiate their ring-enhancing features using MTR, providing a non-invasive and accurate imaging approach for improved diagnosis and management in clinical settings where these infections are prevalent.

2. MATERIALS AND METHODS

This hospital-based, cross-sectional observational study was conducted over 1.5 years (August 2023 to February 2025) at the Department of Radiodiagnosis, Sree Balaji Medical College and Hospital, Chennai, in collaboration with Neurology and General Medicine departments. It aimed to evaluate and differentiate intracranial ring-enhancing lesions diagnosed as tuberculoma and neurocysticercosis (NCC) using MRI, focusing on Magnetisation Transfer Ratio (MTR). Patients with seizures or neurological symptoms suggestive of CNS granulomas and ring-enhancing lesions on imaging were included via convenient sampling. Ethical approval was obtained, informed consent was secured, and standard MRI contraindications and calcified granulomas were part of the exclusion criteria.

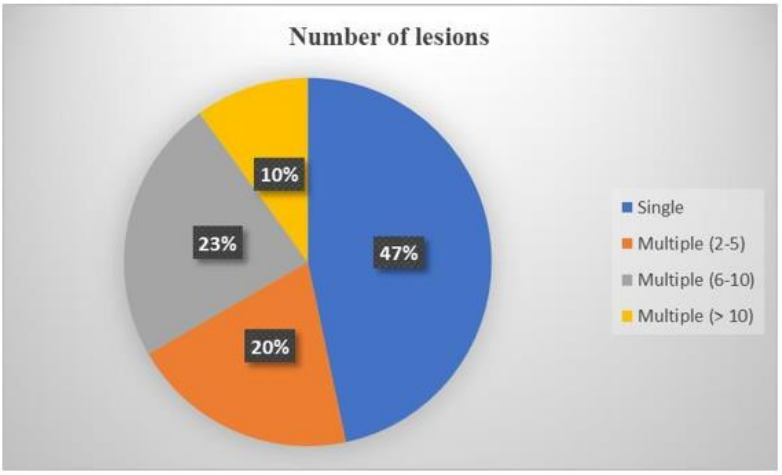
3. RESULTS

The table presents baseline characteristics of 30 patients. The mean age was 42.16 years with a standard deviation (SD) of 14.39, indicating a moderately wide age distribution. Males constituted 63.33% of the sample, while females made up 36.67%. The average Magnetisation Transfer Ratio (MTR) was 16.41 with an SD of 4.35, reflecting inter-individual variability in lesion characteristics.

Table 1: Distribution of Age groups in the study population

Age Group (in years)	No. of patients	Percentage
15-30	8	26.7
31-40	5	16.7
41-50	9	30.0
51-60	5	16.7
> 60	3	10.0

The majority of patients (30%) in the study were aged 41–50 years, followed by 26.7% in the 15–30-year group. The age distribution shows a concentration of cases in the middle age group, suggesting higher disease incidence in this demographic. Only 10% of patients were older than 60 years, indicating lower representation in the elderly. This age pattern may reflect disease epidemiology or healthcare-seeking behavior.



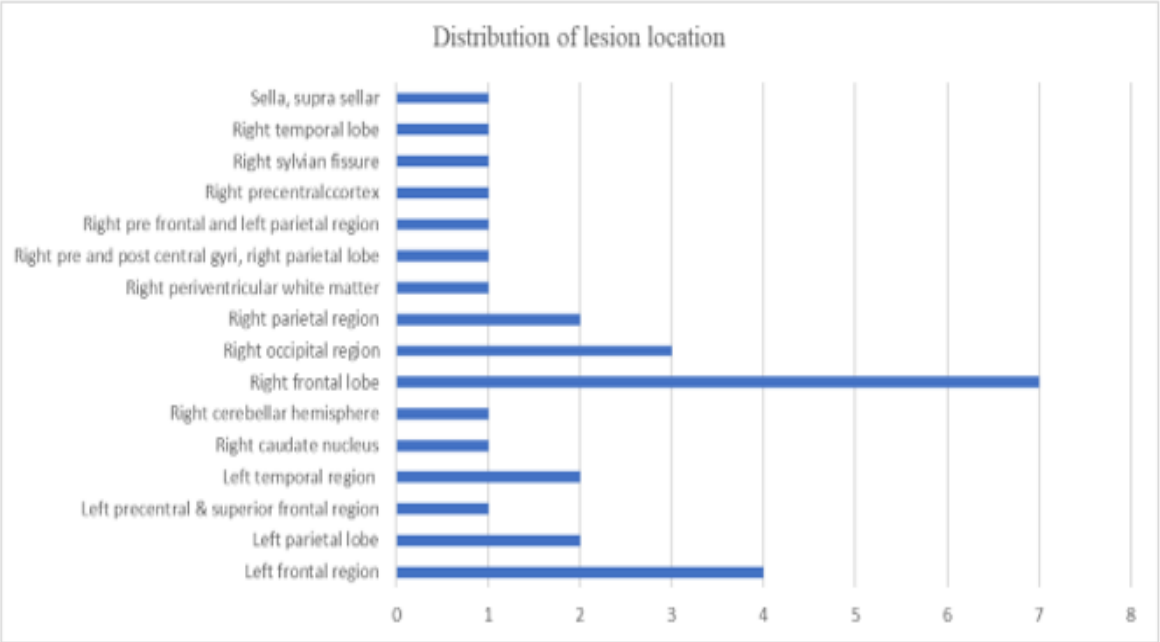
Graph 1: Distribution of number of lesions

The pie chart shows that 47% of patients had a single lesion, while the remaining 53% had multiple lesions. Among those with multiple lesions, 23% had 6–10 lesions, 20% had 2–5 lesions, and 10% had more than 10 lesions. This indicates that although single lesions are more common, a significant proportion present with multifocal involvement.

Table 2: Distribution of Perilesional Edema

Perilesional Edema	No. of patients	Percentage
None	3	10
Mild	9	30
Moderate	10	33.33
Significant	7	23.33
Severe	1	3.33

The majority of patients (33.33%) exhibited moderate perilesional edema, followed by mild edema in 30% and significant edema in 23.33% of cases. Only 10% showed no edema, and severe edema was rare (3.33%). This suggests that most lesions are associated with some degree of perilesional inflammatory response.



Graph 2: Distribution of location of lesions

The chart shows that the **right frontal lobe** is the most common site of lesions (7 cases), followed by the **left frontal lobe** and **right occipital region** (4 cases each). Lesions were distributed across multiple brain regions, indicating heterogeneity in lesion localization. This suggests a predilection for frontal involvement, particularly on the right side.

Table 3: Mean MTR of ring enhancing lesions

Diagnosis	N	Mean	SD	SE	Min	Max	95% Confidence interval for mean	
							Lower	Upper
Tuberculoma	14	18.4	2.46	0.65	15.1	23.8	17.1114	19.6886
NCC-CV	7	11.3	1.13	0.42	9.8	12.7	10.4629	12.1371
NCC-GN	4	21.5	1.57	0.78	19.4	23.2	19.9614	23.0386
NCC-V	5	13.9	4.5	2.02	10.2	21.8	9.9556	17.8444

The table shows that the **mean Magnetisation Transfer Ratio (MTR)** was highest in **NCC-GN (21.5)** and lowest in **NCC-CV (11.3)**. **Tuberculoma** lesions had a relatively high mean MTR (18.4), with narrow confidence intervals suggesting consistent values. **NCC-V** had a wider standard deviation and standard error, indicating greater variability in MTR. These differences may aid in differentiating lesion types based on MTR values.

Table 4: ANOVA tests showing difference in MTR values between different diagnosis

	Sum of squares	df	Mean square	F
Between Groups	400.807	3	133.602	20.465
Within Groups	176.261	27	6.52	
Total	577.068	30		

The ANOVA table shows a statistically significant difference in MTR values among different diagnostic groups. The **F-value is 20.465**, which is much greater than 1, indicating substantial variability between groups compared to within groups. With a **between-group mean square of 133.602** and **within-group mean square of 6.52**, the result suggests that the type of lesion significantly influences MTR values. This supports the utility of MTR in differentiating between tuberculoma and neurocysticercosis subtypes.

Table 5: Multiple Comparisons of MTR values

Diagnosis (I)	**Diagnosis (J)**	**Mean Difference**	**Std. Error**	**95% Confidence interval for mean**	
				Lower	Upper
Tuberculoma	NCC-CV	7.1	0.784	5.5634	8.6366
	NCC-GN	-3.1	1.024	-5.1069	-1.0931
	NCC-V	4.5	2.1171	0.3505	8.6495
NCC-CV	Tuberculoma	-7.1	0.784	-8.6366	-5.5634
	NCC-GN	-10.2	0.8937	-11.9516	-8.4484
	NCC-V	-2.6	2.0573	-6.6322	1.4322
NCC-GN	Tuberculoma	3.1	1.024	1.0931	5.1069
	NCC-CV	10.2	0.8937	8.4484	11.9516
	NCC-V	7.6	2.1601	3.3662	11.8338
NCC-V	Tuberculoma	-4.5	2.1171	-8.6495	-0.3505
	NCC-CV	2.6	2.0573	-1.4322	6.6322
	NCC-GN	-7.6	2.1601	-11.8338	-3.3662

The table displays post-hoc pairwise comparisons of MTR values between diagnoses. Statistically significant differences (confidence intervals not including 0) are observed between **Tuberculoma vs. NCC-CV (mean diff: 7.1)**, **NCC-CV vs. NCC-GN (−10.2)**, and **NCC-GN vs. NCC-V (7.6)**, suggesting meaningful MTR differences. However, comparisons like **Tuberculoma vs. NCC-V** and **NCC-CV vs. NCC-V** are not significant, as their confidence intervals include zero. These findings reinforce MTR's potential to differentiate specific lesion subtypes.

Table 6: Group Statistics

Final Diagnosis	N	Mean	SD	SE (Mean)
NCC	16	14.66	4.94	1.235
Tuberculoma	14	18.4	2.46	0.658

The table shows group statistics comparing MTR values between **NCC** and **Tuberculoma** cases. The mean MTR is significantly higher in Tuberculoma (18.4 ± 2.46) than in NCC (14.66 ± 4.94), with lower standard error in Tuberculoma (0.658 vs. 1.235). This suggests more consistent MTR values in Tuberculoma and supports its diagnostic distinction from NCC using MTR.

4. DISCUSSION

Enhancing brain lesions are commonly seen in CT imaging, especially among patients with seizures. In India and similar endemic regions, these lesions are often due to neurocysticercosis (NCC) or tuberculoma, both of which share overlapping imaging features, making diagnosis challenging . NCC, caused by *Taenia solium*, leads to granuloma formation that appears as ring-enhancing lesions, similar to tuberculomas from CNS tuberculosis. While NCC is often self-limiting and treated with antiepileptics, tuberculomas require prolonged antitubercular therapy. This distinction is crucial for guiding management strategies (12).

Although CT and conventional MRI are widely used, advanced imaging techniques such as Magnetization Transfer Imaging (MTI) and Magnetization Transfer Ratio (MTR) offer improved differentiation. Studies show that MTR values

are significantly lower in NCC lesions than in tuberculomas due to differences in tissue composition—tuberculomas having dense cellular and fibrotic structures, whereas NCC lesions are more cystic. Gupta et al. demonstrated the diagnostic value of MTR in distinguishing between tuberculous and pyogenic abscesses as well as between NCC and tuberculoma (13).
In the present study of 30 patients, the mean age was 42.16 years, with most lesions found in the 41–50 age group, mirroring findings by Joy et al. (mean age 42.85 ± 14.76). However, Rana A et al. found a younger age distribution in their cohort. Supratentorial regions—particularly the frontal lobe—were the most common lesion locations, consistent with reports by Joy et al. (14, 15).

Most patients (53.33%) had multiple lesions. In contrast, Gupta et al. reported a higher number of lesions per patient (107 in 22 patients) and found that MTI improves lesion detection, especially in edematous regions. Perilesional edema was prevalent and varied in severity, as also described by Khatri GD et al. and Muljadi R, who noted edema severity correlates with lesion size and inflammation (13, 16, 17).

In this cohort, NCC constituted 53.33% of cases, and tuberculoma 46.67%. Joy et al. similarly found a higher NCC prevalence (59.52%). Differentiation is difficult on conventional imaging alone; hence, modalities like diffusion-weighted imaging (DWI), magnetic resonance spectroscopy (MRS), and MTR are emphasized. Jacobs MA et al. noted that amino acid peaks on MRS are seen in NCC, while lipid-lactate peaks indicate tuberculoma (14, 18).

Mean MTR values in this study were: tuberculoma – 18.4 ± 2.46, colloid vesicular NCC – 11.3 ± 1.13, granular nodular NCC – 21.5 ± 1.57, and vesicular NCC – 13.9 ± 4.5. These are in agreement with Rajapandian et al. (tuberculoma – 16.6 ± 3.1, vesicular NCC – 10.9 ± 2.8, degenerating NCC – 20.8 ± 3.5) and Kathuria et al., who reported healing NCC lesions with very high MTR values (31.0 ± 2.8) (19, 20).

ANOVA testing showed significant differences in MTR among diagnostic groups, supporting prior findings by Gupta et al. and Guglani B et al. Additionally, Saxena S et al. confirmed variation in MTR between the core and rim of tuberculomas, emphasizing the diagnostic utility of spatial MTR analysis, the evidence supports MTR as a powerful non-invasive imaging biomarker for distinguishing tuberculoma from different stages of NCC, enabling tailored and effective management of intracranial ring-enhancing lesions (21-23).

5. CONCLUSION

This study demonstrates the value of incorporating Magnetisation Transfer Ratio (MTR) into MRI protocols for differentiating tuberculoma from neurocysticercosis (NCC), two common causes of ring-enhancing brain lesions. Conventional imaging often fails to clearly distinguish these conditions due to overlapping features, but MTR provides a quantitative advantage. A significant difference in mean MTR values between tuberculoma and various NCC stages ($p < 0.00001$) was observed, with lesion stage influencing MTR. Magnetic resonance spectroscopy further aided diagnosis. Though limited by sample size and lack of histopathology, the findings support MTR as a non-invasive tool to enhance diagnostic accuracy and guide targeted management.

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