Comparative study on magnetization transfer contrast and fluid attenuated inversion recovery sequence in intracranial tuberculoma and neurocysticercosis

Dr Utham K Sanjayan[1*], Dr G. Raj Kumar[2], Dr Lavanya Raj Kumar[3]

[1]Postgraduate Student, Department of Radiology, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam-603103, Tamil Nadu, India.
Email: uthamsanjayan1@gmail.com | ORCID ID: 0009-0003-3130-3733

[2]Assistant Professor, Department of Radiology, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam-603103, Tamil Nadu, India.
Email: rajrad64@gmail.com | ORCID ID: 0000-0002-0564-3967

[3]Assistant Professor, Department of Radiology, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam-603103, Tamil Nadu, India.
Email: dr.lavanya23@gmail.com | ORCID ID: 0000-0002-9674-309X

***Corresponding Author: Dr Utham K Sanjayan, Final year postgraduate, Department of Radiology, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam-603103, Tamil Nadu, India.**
Email: uthamsanjayan1@gmail.com | ORCID ID: 0009-0003-3130-3733

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ABSTRACT

Background

Intracranial tuberculoma (ICT) and neurocysticercosis (NCC) are two major infectious granulomatous diseases having radiological similarities, thus pose a significant challenge in accurate diagnosis. Advanced techniques like Magnetization Transfer Contrast (MTC) and Fluid-Attenuated Inversion Recovery (FLAIR) have emerged as potential tools for enhanced lesion characterization.

Objective

1. To compare the MTC and FLAIR sequences in differentiating intracranial tuberculomas and neurocysticercosis, assessing lesion contrast, edema patterns, and overall diagnostic accuracy.

Methods

A cross-sectional study was conducted on 80 patients clinically suspected of having ICT or NCC. MRI scans were performed using conventional sequences alongside MTC and FLAIR imaging. The lesions were evaluated for signal intensity, lesion count, perilesional edema, and scolex visibility. The Magnetization Transfer Ratio (MTR) was calculated for better differentiation between the two conditions. Interobserver agreement was analyzed using Cohen's kappa statistic.

Results

Among the participants, 50% have ICT and 50% with NCC. MTC imaging demonstrated superior lesion contrast in ICT, whereas FLAIR imaging was more effective in highlighting perilesional edema in NCC. The mean FLAIR signal intensity was significantly higher in ICT cases ($p = 0.003$), distinguishing it from NCC. The kappa value of 0.800 indicated a high level of interobserver agreement in diagnosis.

Conclusion

While MTC improves lesion contrast, FLAIR is more effective in detecting perilesional edema and inflammatory changes. Combining these advanced imaging techniques with conventional MRI enhances diagnostic precision and aids in appropriate clinical management.

Keywords: Comparative study, Intracranial tuberculoma, Neurocysticercosis, Magnetization Transfer Contrast, Fluid-Attenuated Inversion Recovery.

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Introduction:

Intracranial infections are a significant cause of morbidity and mortality, particularly in developing regions where infectious diseases remain prevalent. Among these, intracranial tuberculoma (ICT) and neurocysticercosis (NCC) are two of the most common parasitic and granulomatous infections affecting the central nervous system (CNS) [1]. These conditions pose a diagnostic challenge due to their overlapping clinical and radiological

presentations, necessitating advanced neuroimaging techniques for accurate differentiation.

Magnetic resonance imaging (MRI) plays a crucial role in the diagnosis of ICT and NCC, with conventional sequences such as T1-weighted, T2-weighted, and post-contrast imaging being routinely used. However, these conventional sequences often fail to provide definitive differentiation due to similarities in lesion morphology and enhancement patterns. Advanced imaging modalities such as Magnetization Transfer Contrast (MTC) and Fluid-Attenuated Inversion Recovery (FLAIR) sequences have emerged as valuable tools for improved lesion characterization in infectious and inflammatory CNS pathologies [2].

Magnetisation Transfer contrast imaging is an unparalleled contrast mechanism in MRI, established by the use that target alterations in the basic relaxation characteristics of water protons, therefore revealing influence on MRI findings.[3,4,5] Fluid-attenuated inversion recovery (FLAIR) is a specialised inversion recovery pulse sequence characterised by an extended repetition time (TR) and echo time (TE), together with an inversion time (TI) that effectively nullifies signals from CSF. Intravenous magnetic resonance (MR) contrast agents are often used to enhance the identification and characterisation of lesions in CNS diseases. [6,7]

MTC enhances the visibility of lesions by selectively suppressing background tissue signal, thereby improving contrast between lesions and surrounding brain parenchyma. This sequence is particularly useful in detecting subtle parenchymal involvement and distinguishing granulomas with high proteinaceous content [8]. On the other hand, FLAIR imaging is highly sensitive in detecting perilesional edema and lesion-associated inflammatory changes by nullifying cerebrospinal fluid (CSF) signals, making it a key sequence in evaluating infectious CNS lesions. Despite the growing utilization of MTC and FLAIR sequences in neuroimaging, limited studies have directly compared their diagnostic utility in differentiating ICT from NCC. Given the distinct pathophysiological characteristics of these infections, assessing the comparative efficacy of these imaging techniques is essential for refining diagnostic accuracy and guiding appropriate clinical management [9].

This study aims to evaluate and compare the MTC and FLAIR sequences in differentiating intracranial tuberculoma and neurocysticercosis, with an emphasis on lesion contrast, edema assessment. By systematically analyzing imaging findings, this research seeks to enhance the radiological approach for distinguishing these two conditions, ultimately aiding in more effective treatment planning and patient outcomes.

AIM AND OBJECTIVES:

- To determine the difference in MTC and FLAIR techniques in lesions suggestive of ICT and NCC on conventional Magnetic Resonance Imaging sequences.
- To study the imaging features of intracranial tuberculoma and neurocysticercosis on axial non-contrast Magnetization Transfer Imaging.

Methodology: A cross sectional study done after obtaining institutional ethical committee clearance, (IHEC/) in patients referred to the department of Radio diagnosis, suspected to have either intracranial tuberculoma and neurocysticercosis on conventional Magnetic Resonance Imaging, in a tertiary health care centre in Chengalpattu, Tamil Nadu from the period of March 2024 to March 2025.

INCLUSION CRITERIA

- All patients suspected to have either intracranial tuberculoma and neurocysticercosis on conventional MRI sequence
- Patient providing informed consent for the study

EXCLUSION CRITERIA:

- Patient having history of claustrophobia
- Patient having history metallic implants insertion, cardiac pacemaker and metallic foreign body in situ
- All patient with previous history of contrast allergy
- Patient not providing consent

Sample size: 80 patients, 40 with ICT and 40 with NCC

Sampling method: Patients who fulfil the inclusion criteria will be allocated consecutively to the study. Informed consent letters will be obtained from the patient or guardian in their regional language after explaining the study in detail to them. Purposive sampling method was used.

Procedure: Using a pretested semistructured questionnaire data was collected. It includes data on detailed clinical evaluation followed by neuroimaging on a high-field strength MRI scanner. Prior to imaging, the procedure and its purpose were clearly explained to all patients or their attendants, and informed consent was obtained in accordance with institutional ethical guidelines.

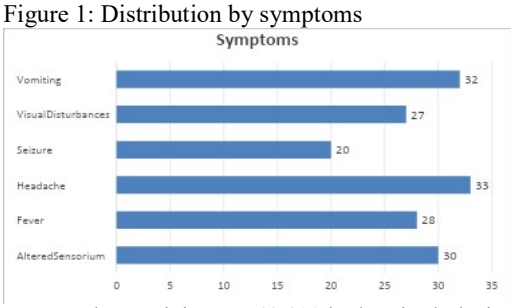
MRI were performed using a 1.5 Tesla system with a standard head coil. Patients were positioned supine and head was secured to minimize motion artifacts. Routine brain MRI sequences, including T1-weighted, T2-weighted, and FLAIR sequences, were obtained in axial, coronal, and sagittal planes for initial assessment. Following the standard protocol, Magnetization Transfer Contrast (MTC) imaging was then performed without the use of intravenous contrast. For MTC sequences, an off-resonance radiofrequency saturation pulse was applied before image acquisition to selectively suppress signals from macromolecule-bound protons, thereby enhancing contrast between lesions and surrounding parenchyma.

Subsequently, Fluid Attenuated Inversion Recovery (FLAIR) imaging was performed using inversion recovery parameters designed to nullify cerebrospinal fluid (CSF) signal. Slice thickness, repetition time (TR), echo time (TE), and inversion time (TI) were optimized to achieve uniform image quality and adequate lesion visualization. Identical slice positioning was maintained across sequences to facilitate direct comparison. The total imaging duration per patient averaged 30–40 minutes. All obtained images were analysed for Regions of interest (ROIs) by two experienced radiologists. Each lesion was categorized based on its imaging features into either ICT or NCC. Comparison between MTC and FLAIR sequences was performed in differentiating intracranial tuberculoma from neurocysticercosis.

Statistical analysis: All the data collected will be entered into an excel sheet according to the grading of degeneration of spine according to age and sex and will be analysed under IBM-SPSS version 25.0. relevant prevalence will be calculated and tabulated. The quantitative variable will be expressed in frequency and percentage. Inter-observer agreement was assessed using Cohen's Kappa statistic. $P < 0.05$ was considered as statistically significant.

Results: In the study, 50% participants were having ICT and 50% NCC. The most commonly reported symptom was headache (41.3%), followed by altered sensorium (37.5%), vomiting (40.0%), fever (35.0%), visual disturbances (33.8%), and seizures (25.0%) (shown in figure 1).

Figure 1: Distribution by symptoms



Among the participants, 43.8% had a single lesion, while 56.3% had multiple lesions. The most common lesion locations were the frontal region (13.8%), cortex (12.5%), parietal lobe (10.0%), cerebellum (8.8%), deep grey matter (8.8%), grey matter junction (8.8%), temporal lobe (8.8%), brain stem (7.5%), occipital lobe (7.5%), thalamus (7.5%), and white matter (6.3%). Ring enhancement was present in 50.0% of cases and absent in the remaining 50.0%. The scolex was observed in 25.0% of cases of NCC, while it was absent in 75.0% of cases. Among the cases, 35.0% exhibited hyperintense signals, 31.3% showed isointense signals, and 33.8% had hypointense signals. In T2-weighted images, hypointense signals were seen in 42.5% of cases, hyperintense in 33.8%, and isointense in 23.8%. FLAIR signal intensity patterns were mixed in 36.3% of cases, suppressed in 32.5%, and hyperintense in 31.3%. Restricted diffusion was observed in 46.3% of cases, while 53.8% did not show restriction.

The study recorded choline peak ratios in 37.5% of cases, lactate peaks in 35.0%, and lipid peaks in 27.5%. MTC signal intensity was hypointense in 23.8% of cases, isointense in 55.0%, and hyperintense in 21.3%. The kappa statistic for inter-observer agreement in diagnosing ICT and Neurocysticercosis was 0.800, indicating a strong level of agreement between the two observers. (shown in table 1 and figure 2)

Figure 2; Location of lesion

Table 1: Distribution by characteristics of lesion

Characteristics of lesion	**Sub group**	**Frequency**	**Percent**
Lesion Count	Single	35	43.8
	Multiple	45	56.3
Ring Enhancement	Absent	40	50.0
	Present	40	50.0
T1SignalIntensity	Hypointense	27	33.8
	Isointense	25	31.3
	Hyperintense	28	35.0
T2SignalIntensity	Hypointense	34	42.5
	Isointense	19	23.8
	Hyperintense	27	33.8
FLAIR Signal	Suppressed	26	32.5
	Hyperintensed	25	31.3
	Mixed	29	36.3
Diffusion-Weighted Imaging	Restricted	37	46.3
	Not Restricted	43	53.8

Magnetic Resonance Spectroscopy	Choline peak Ratio	30	37.5
	Lactate Peak	28	35.0
	Lipid Peak	22	27.5
MTC signal intensity	Hypointense	19	23.8
	Isointense	44	55.0
	Hyperintense	17	21.3
Discrepancy between Observers	No	72	90.0
	Yes	8	10.0

In the study, the mean age of participants in the ICT group was 33.53 years (SD = 16.05), while in the NCC group, it was 33.05 years (SD = 15.48). The difference was not statistically significant (t = 0.135, p = 0.893). The Mean Transfer Ratio (MTR) of lesions was slightly higher in the ICT group (20.7453, SD = 1.52668) compared to the NCC group (20.6825, SD = 1.52859) which was not statistically significant (t = 0.18, p = 0.8).

The FLAIR signal intensity was significantly higher in the ICT group (mean = 289, SD = 23.38) than in the NCC group (mean = 253.85, SD = 67.53). This difference was statistically significant (t = 3.111, p = 0.003). The MT signal intensity was lower in the ICT group (mean = 395.20, SD = 32.073) compared to the Neurocysticercosis group (mean = 404.55, SD = 27.313), but this difference was not statistically significant (t = -1.404, p = 0.164).

The MTR of white matter was slightly lower in the ICT group (mean = 29.5560, SD = 3.50701) than in the Neurocysticercosis group (mean = 30.7193, SD = 3.39721), but this difference was not statistically significant (t = -1.507, p = 0.136). The MTR of grey matter was slightly higher in the ICT group (mean = 30.7918, SD = 3.04593) compared to the Neurocysticercosis group (mean = 29.8, SD = 3.76), but this difference was not statistically significant (t = 1.279, p = 0.205).

Overall, the FLAIR signal intensity was the only parameter that showed a statistically significant difference between the ICT and NCC groups. (shown in table 2)

Table 2: Comparison of ICT and NCC Group

Students t test						
Diagnosis	**N**	**Mean**	**SD**	**Std. Error Mean**	**t value**	**p value**
Age	ICT	40	33.53	16.054	2.538	.135	.893
	NCC	40	33.05	15.482	2.448		
MTR of Lesion	ICT	40	20.7453	1.52668	.24139	.184	.855
	NCC	40	20.6825	1.52859	.24169		
FLAIR Signal Intensity	ICT	40	289.000	23.3809	3.6968	3.111	.003*
	NCC	40	253.850	67.5337	10.6780		
MT Signal Intensity	ICT	40	395.20	32.073	5.071	-1.404	.164
	NCC	40	404.55	27.313	4.319		
MTR of White Matter	ICT	40	29.5560	3.50701	.55451	-1.507	.136
	NCC	40	30.7193	3.39721	.53715		
MTR of Grey Matter	ICT	40	30.7918	3.04593	.48160	1.279	.205
	NCC	40	29.8130	3.76336	.59504		

The study evaluated the agreement between two observers in diagnosing ICT and NCC. Observer 1 diagnosed 40 cases of ICT and 40 cases of NCC. Observer 2 agreed on 35 (87.5%) ICT cases but classified 5 (12.5%) of them as NCC. Similarly, Observer 2 agreed on 37 (92.5%) cases of NCC but classified 3(12.5%) cases as ICT. Overall, as per observer 2 out of 80 ICT and NCC comprised 47.5% and 52.5% cases, respectively. The inter-observer agreement was assessed using Cohen's Kappa statistic, which yielded a kappa value of 0.800. This indicates a strong level of agreement between the two observers. The standard error for the kappa value was 0.067, and the approximate t-value was 7.164, with a statistically significant p-value of 0.000, confirming the reliability of the agreement.

A kappa value of 0.800 suggests substantial agreement, meaning that the diagnostic classification between the two observers was highly consistent. The Monte Carlo significance also confirms the robustness of this agreement.

Table 3: Observer Agreement in Diagnosis

Observer 1 Diagnosis	Observer 2 Diagnosis		Total
	ICT	NCC	
ICT	35	5	40
	87.5%	12.5%	100.0%
NCC	3	37	40
	7.5%	92.5%	100.0%
Total	38	42	80
	47.5%	52.5%	100.0%

Measure of Agreement (Kappa Statistics)

		Value	Asymp. Std. Error[a]	Approx. ICT	P value.	Monte Carlo Sig. Sig.	99% Confidence Interval Lower Bound	99% Confidence Interval Upper Bound
Measure of Agreement	Kappa	.800	.067	7.164	.000	.0000[c]	0.000	.000
N of Valid Cases		80						

Discussion

Both intracranial tuberculoma and neurocysticercosis are serious neurological disorders with comparable clinical presentations and imaging properties. As a result, comparing imaging sequences to distinguish between the two disorders is extremely important for clinicians. Thus this study was designed to compare advanced techniques like magnetization transfer contrast and fluid attenuated inversion recovery sequence in intracranial tuberculoma and neurocysticercosis.

In our study majority of the participants were aged less than 20 years (27.5%), followed by those aged above 49 years (20.0%), 40-49 years (18.8%), 30-39 years (17.5%), and 20-29 years (16.3%) and 51.3% of the participants were male, while 48.8% were female. A study by S. Saxena et al [10] included 28 patients, 8 males and 20 females, with ages ranging from 6 to 38 years. Asht M. Mishra et al [11] included thirty-three consecutive patients (22 males and 11 females, 1.5–65 years old, mean age _ 25 years).

Our study reported common symptoms as headache (41.3%), followed by altered sensorium (37.5%), vomiting (40.0%), fever (35.0%), visual disturbances (33.8%), and seizures (25.0%). A compilation of 913 children from 6 retrospective case series of CNS tuberculosis identifies common presenting symptoms to be fever (72%), altered mental status (62%), vomiting (61%), seizure (47%), and headache (37%)[12].

In our study 43.8% had a single lesion, while 56.3% had multiple lesions. A notable study by Saxena et al[10], evaluated 28 patients with brain tuberculomas and found that T1-weighted MTC imaging detected a higher number of lesions compared to FLAIR imaging. Specifically, 209 lesions were identified on T1-weighted MTC images, whereas only 163 lesions were detected using FLAIR sequences.

In the current study the scolex was observed in 25.0% of cases of neurocysticercosis, while it was absent in 75.0% of cases. In a study by Lucato et al., Fluid-Attenuated Inversion Recovery (FLAIR) sequences demonstrated higher sensitivity for scolex detection compared to other MRI sequences [13]. Another study Verma, A et al [14] reported that on conventional MRI, the visibility of lesions and scolex was 82.4% and 60%, respectively.

In our study among the cases analyzed, 35.0% exhibited hyperintense T1 signal intensities, 31.3% displayed isointense signal intensities, and 33.8% presented with hypointense signal intensities. Degenerating cysts commonly present with hyperintense signals on T1-weighted imaging, a finding that is presumably attributable to the increased protein concentration within the cystic fluid [15]. A study by Mahajan et al [16] reported that while most NCC lesions appeared hypointense on T1-weighted images, some exhibited hyperintense signals, attributed to increased proteinaceous content or calcification.

Our study recorded choline peak ratios in 37.5% of cases, lactate peaks in 35.0%, and lipid peaks in 27.5%. Patra et al [17] found elevated choline levels are often associated with increased cellular turnover and membrane synthesis. In a study comparing MRS findings in NCC and tuberculomas, 63.6% of patients exhibited a raised choline/creatine ratio greater than 1.2. Pandit et al[18] found that lactate accumulation indicates anaerobic metabolism within lesions. The same study reported raised lipid-lactate peaks in 54.5% of cases.

In our study the results of the independent samples t-test comparing two groups—ICT and NCC—

across various variables like age, (t = 0.135, p = 0.893), MTR of lesions (t = 0.184, p = 0.855), MT signal intensity (t = -1.404, p = 0.164), MTR of white matter (t = -1.507, p = 0.136), or MTR of grey matter (t = 1.279, p = 0.205) shows no significant difference. However, a significant difference was found in the FLAIR signal intensity, with ICT showing higher values (289.00 ± 23.38) compared to NCC (253.85 ± 67.53), with a t-value of 3.111 and a p-value of 0.003, indicating that FLAIR signal intensity significantly differentiates the two groups. These findings suggest that FLAIR signal intensity may be a potential distinguishing factor between ICT and NCC. J. Naveen, et al[19] found that the mean MTR for tuberculomas was 25.42 ± 0.81, while degenerative neurocysticercosis (NCC) cysts showed an MTR of 23.38 ± 1.22. The difference in MTR between these groups was not statistically significant. Saxena, S et al[10] found that lesion detection was more effective with T1-weighted magnetization transfer contrast (MTC) imaging, which identified 209 lesions compared to 163 lesions detected by FLAIR imaging, thereby demonstrating the higher sensitivity of MTC in identifying brain tuberculomas.

In our study multiple lesions were more common (56.3%), with single lesions observed in 43.8% of cases. Ring enhancement, a characteristic imaging feature, was equally present in 50.0% of cases. The presence of scolex, a distinguishing feature of NCC, was observed in 25.0% of cases, reinforcing the utility of conventional MRI in definitive diagnosis. A study by Naveen, et al[19] found that multiple lesions were observed in 56.3% of cases, while single lesions were present in 43.8%. Ring enhancement, a characteristic imaging feature, was equally present in 50.0% of cases. The presence of the scolex, a key distinguishing feature of neurocysticercosis (NCC), was identified in 25.0% of cases, underscoring the value of conventional MRI in the definitive diagnosis of NCC. This study demonstrated that interobserver agreement was strong (kappa = 0.800, p < 0.001), indicating high reproducibility in differentiating tuberculoma and NCC using MTC and FLAIR sequences. Observer discrepancies were minimal (10%), further validating the reliability of these imaging modalities. A study by Naveen, et al[19] The study demonstrated strong interobserver agreement (kappa = 0.800, p < 0.001), highlighting the high reproducibility of differentiating tuberculoma and neurocysticercosis (NCC) using Magnetization Transfer Contrast (MTC) and Fluid-Attenuated Inversion Recovery (FLAIR) sequences. Observer discrepancies were minimal, at only 10%, further reinforcing the reliability and consistency of these imaging modalities in diagnosing these conditions. These findings underscore the effectiveness of MTC and FLAIR MRI sequences in differentiating between intracranial tuberculomas and neurocysticercosis, highlighting specific imaging features and the high reliability of these modalities.

Clinical Implications and Future Directions

Given the high interobserver agreement, these findings suggest that combining FLAIR with conventional imaging markers like lesion morphology, ring enhancement, and the presence of scolex enhances diagnostic accuracy. Future studies with larger cohorts and advanced imaging modalities such as quantitative MTR analysis, and longitudinal follow-up of lesion progression could refine diagnostic protocols. Additionally, correlation with biopsy findings and treatment response could strengthen the understanding of imaging biomarkers in intracranial infections.

Conclusion

This study highlights the significant role of FLAIR imaging in differentiating ICT and NCC, with higher signal intensity in ICT. While MTC imaging provides useful tissue characterization, its diagnostic impact remains limited due to overlapping values. A multimodal imaging approach, integrating FLAIR, MTC, and conventional MRI, remains the best strategy for accurate differentiation between these two conditions. Further research into quantitative imaging techniques could enhance diagnostic precision and clinical decision-making.

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