Section: Radiodiagnosis

Original Research Article

ROLE OF MAGNETIC RESONANCE IMAGING IN THE EVALUATION OF INTRACRANIAL TUBERCULOSIS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Intracranial tuberculosis (TB) is a severe form of extrapulmonary tuberculosis associated with high morbidity and mortality. Early diagnosis remains challenging due to nonspecific clinical features and limited sensitivity of microbiological tests. Magnetic resonance imaging (MRI) plays a pivotal role in detecting and characterizing intracranial TB lesions. The objective is to evaluate the role of MRI in intracranial tuberculosis, analyze various imaging presentations, classify tuberculomas based on morphology, and correlate MRI findings with cerebrospinal fluid (CSF) parameters.

Materials and Methods: This cross-sectional study was conducted in the Department of Radiodiagnosis, Rohilkhand Medical College & Hospital, Bareilly, over one year. A total of 144 patients with clinical suspicion of intracranial tuberculosis underwent MRI using a 1.5 Tesla scanner. Imaging findings were analyzed and correlated with CSF parameters including lymphocytic pleocytosis, protein, glucose, ADA, and PCR for Mycobacterium tuberculosis. Statistical analysis was performed using SPSS version 23.0.

Results: The majority of patients were aged 11–30 years. Fever (69.4%) and headache (50.7%) were the most common clinical symptoms. MRI revealed iso- to hypointense lesions on T1-weighted images in 55.2% and hyperintense lesions on T2-weighted images in 63% of cases. Diffusion restriction was present in 87% of patients, ring enhancement in 53.2%, and meningeal enhancement in 48.7%. CSF analysis showed lymphocytic pleocytosis in 61% and elevated protein, low glucose, positive PCR, or raised ADA in 60.4%. Meningeal enhancement demonstrated significant association with lymphocytic pleocytosis ($p = 0.02$), elevated CSF protein ($p = 0.001$), positive PCR for MTB ($p = 0.01$), and raised ADA ($p = 0.01$).

Conclusion: MRI is an indispensable diagnostic modality for intracranial tuberculosis, capable of detecting diverse parenchymal and meningeal manifestations. Meningeal enhancement on MRI shows strong correlation with CSF inflammatory markers and serves as a reliable indicator of disease severity. MRI should be routinely employed in all suspected cases of CNS tuberculosis.

Keywords: Intracranial tuberculosis, MRI, tuberculoma, tuberculous meningitis, diffusion restriction, CSF correlation.

INTRODUCTION

Tuberculosis (TB) remains a major global public health problem, particularly in low- and middle-income countries, where it contributes significantly to morbidity and mortality. Although pulmonary tuberculosis is the most common form, central nervous system tuberculosis (CNS-TB) represents

one of the most severe manifestations of extrapulmonary TB and is associated with high rates of neurological sequelae and death if diagnosis or treatment is delayed.[1,2] CNS involvement accounts for approximately 5–10% of extrapulmonary tuberculosis cases, with a higher burden observed in TB-endemic regions such as India.[3]

CNS tuberculosis encompasses a wide pathological spectrum, including tuberculous meningitis, parenchymal tuberculomas, tuberculous abscesses, cerebritis, ventriculitis, and spinal arachnoiditis.[4] Hematogenous dissemination from a primary pulmonary focus leads to the formation of subependymal or meningeal "Rich foci," which may rupture into the subarachnoid space, resulting in basal meningitis, vasculitis, hydrocephalus, and infarction.[5] Alternatively, localized granulomatous immune responses give rise to tuberculomas within the brain parenchyma.[6] The diverse pathological mechanisms underlying CNS-TB account for the wide variety of imaging appearances observed on magnetic resonance imaging (MRI).

Early diagnosis of intracranial tuberculosis remains challenging due to nonspecific clinical manifestations and limited sensitivity of microbiological confirmation methods, particularly in CSF analysis.[7] In this context, neuroimaging plays a critical role in diagnosis, disease characterization, and treatment planning. While computed tomography (CT) can detect gross abnormalities, MRI offers superior soft-tissue contrast, multiplanar capability, and enhanced sensitivity for early meningeal inflammation, parenchymal lesions, and ischemic complications.[8,9]

MRI has therefore emerged as the imaging modality of choice for suspected CNS tuberculosis. Contrast-enhanced MRI can demonstrate basal meningeal enhancement, tuberculomas, infarctions, and hydrocephalus more accurately than CT.[10] Advanced MRI techniques such as diffusion-weighted imaging (DWI), susceptibility-weighted imaging (SWI), perfusion imaging, and magnetic resonance spectroscopy further improve diagnostic accuracy and aid in differentiating tuberculous lesions from neoplasms, pyogenic abscesses, and other infectious or inflammatory conditions.[11-13]

Tuberculomas represent the most frequent parenchymal manifestation of intracranial TB. Their MRI appearance varies depending on the stage of granuloma evolution. Non-caseating granulomas typically appear T1 isointense and T2 hyperintense with homogeneous enhancement, whereas solid caseating granulomas show T2 hypointensity due to dense cellularity and caseation. Caseating granulomas with central liquefaction demonstrate ring enhancement and central T2 hyperintensity.[14,15] Calcified lesions may show blooming on SWI sequences.[16]

Despite the extensive literature describing MRI patterns of CNS tuberculosis, there remains limited evidence correlating imaging findings with CSF parameters in a systematic manner, particularly from Indian populations.[17] This study was therefore undertaken to evaluate the role of MRI in intracranial tuberculosis, analyze the spectrum of imaging presentations, classify tuberculomas based on morphology, and correlate MRI findings with CSF parameters.

MATERIALS AND METHODS

A cross-sectional study was conducted in the Department of Radiodiagnosis, Rohilkhand Medical College & Hospital, Bareilly, after approval from the Institutional Ethics Committee. A total of 144 patients with clinical suspicion of intracranial tuberculosis were included in the study. All patients who were clinically suspected of having central nervous system tuberculosis were considered eligible for inclusion. Patients with contraindications to magnetic resonance imaging, such as implanted pacemakers or metallic implants, were excluded from the study.

MRI Protocol

All MRI examinations were performed on a 1.5 Tesla Siemens Magnetom Sempra scanner. Sequences included:

- T1-weighted, T2-weighted, and FLAIR images
- Diffusion-weighted imaging (DWI) with ADC maps
- Susceptibility-weighted imaging (SWI)
- Post-contrast T1-weighted images following gadolinium administration (0.1 mmol/kg)

Lesions were assessed for number, location, signal intensity, diffusion restriction, blooming, ring enhancement, and meningeal enhancement.

CSF Analysis

CSF parameters analyzed included:

- Lymphocytic pleocytosis
- Protein
- Glucose
- PCR for Mycobacterium tuberculosis
- Adenosine deaminase (ADA)

Statistical Analysis: Data were analyzed using SPSS version 23.0. Descriptive statistics were used, and associations were tested using appropriate statistical tests. A p-value <0.05 was considered statistically significant.

RESULTS

The present cross-sectional study assessed the diagnostic role of MRI in intracranial tuberculosis and examined the correlation between radiological findings and cerebrospinal fluid (CSF) parameters among 144 patients with clinical suspicion of the disease.

[Figure 1] depicted that the highest number of patients belonged to the 11–20 years (26.6%) and 21–30 years (24.7%) age groups.

[Figure 2] showed that females constituted 48.7% and males 44.8% of the study population.

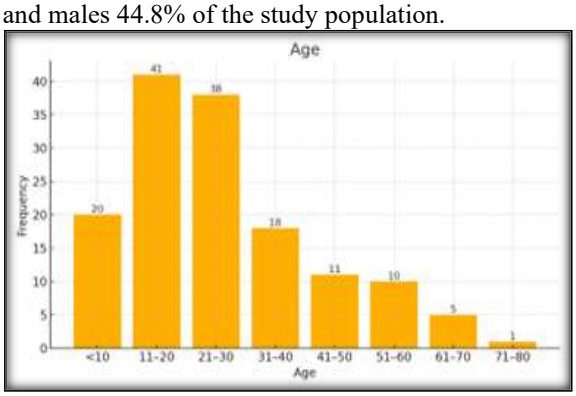


Figure 1: Distribution of Patients According to Age

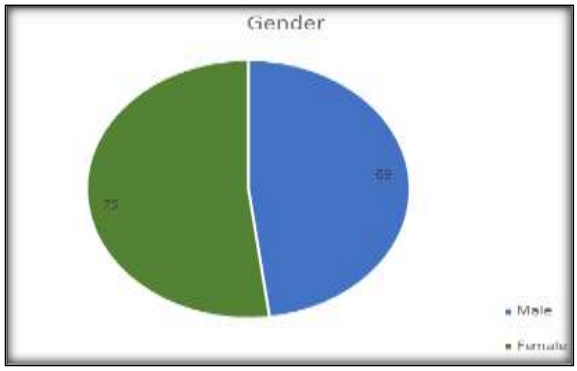


Figure 2: Distribution of patients according to Gender

Table 1: Distribution of patients according to Clinical Presentation

Clinical Presentation	Present (n)	Present (%)	Absent (n)	Absent (%)	Total
Fever	100.0	69.44	44.0	30.56	144.0
Headache	73.0	50.69	71.0	49.31	144.0
Vomating	47.0	32.64	97.0	67.36	144.0
Weakness	27.0	18.75	117.0	81.25	144.0
Altered sensorium	29.0	20.14	115.0	79.86	144.0
Seizures	45.0	31.25	99.0	68.75	144.0
weight loss	29.0	20.14	115.0	79.86	144.0

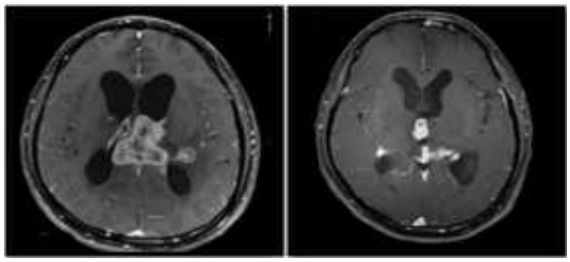
[Table 3] illustrated that fever was the most common clinical presentation (69.44%), followed by headache (50.69%), seizures (31.25%) and vomiting (32.64%). Altered sensorium and weight loss were seen in 20.14% of cases. Overall, systemic and neurological symptoms were prominent, consistent with CNS infections.

MRI findings demonstrated:

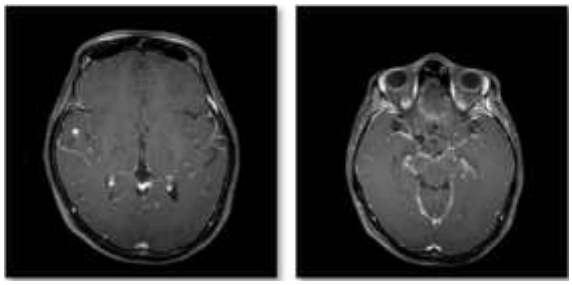
- Iso- to hypointense lesions on T1-weighted images in 55.2%
- Hyperintense lesions on T2-weighted images in 63%
- Diffusion restriction in 87%
- Ring enhancement in 53.2%
- Meningeal enhancement in 48.7%
- Blooming on SWI in 11%

CSF analysis revealed lymphocytic pleocytosis in 61% of patients. Elevated protein, low glucose, PCR positivity, or raised ADA were present in 60.4%.

Statistically significant associations were observed between meningeal enhancement and CSF lymphocytic pleocytosis, protein elevation, PCR positivity, and raised ADA ($p < 0.05$).

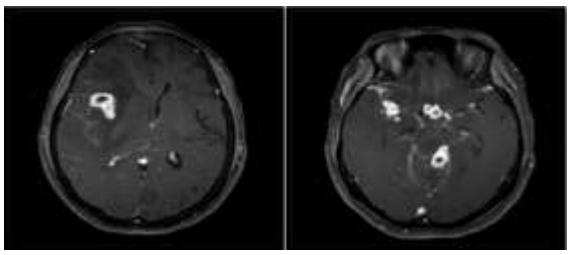


Intraventricular tuberculoma with hydrocephalus. (a) Contrast-enhanced T1-weighted image displaying ring-like enhancement at the body of the corpus callosum and demonstrating enlargement of the lateral ventricle. (b) Contrast-enhanced T1-weighted image revealing the intraventricular tuberculoma at the third ventricle and enlargement of the third ventricle.



Non-caseating tuberculoma with meningitis

Contrast-enhanced T1-weighted image displaying homogeneous nodular enhancement at the right temporal lobe. (b) Contrast enhanced T1-weighted image demonstrating basal cistern enhancement



Caseating tuberculoma with meningitis. (a) Contrast-enhanced T1-weighted image displaying ring-like enhancement at the external capsule and right frontalis region. (b) Contrast-enhanced T1-weighted image demonstrating basal cistern enhancement.

DISCUSSION

The present cross-sectional study evaluated the role of MRI in intracranial tuberculosis and correlated imaging findings with CSF parameters in 144 clinically suspected cases. The age distribution in our study showed a predominance of patients in the 11–20 and 21–30 year age groups, indicating that intracranial tuberculosis primarily affects adolescents and young adults in TB-endemic regions. Similar age distributions have been reported in studies from South Asia and Southeast Asia, where early exposure and primary infection contribute to CNS involvement.[18,19]

Gender distribution in our cohort was nearly equal, with a slight female predominance. This finding is consistent with recent regional studies suggesting improved healthcare access and diagnostic reach among females compared to earlier reports that demonstrated male predominance in tuberculosis.[20,21]

Fever, headache, seizures, and vomiting were the most common presenting symptoms in our patients, reflecting the classical clinical spectrum of CNS tuberculosis. These findings align with previous studies by Dian et al. and Dahal et al., who reported fever and headache as predominant symptoms, with seizures occurring in approximately one-third of cases due to cortical irritation from tuberculomas.[22,23]

MRI signal characteristics in our study were consistent with established descriptions of tuberculous granulomas. The majority of lesions were iso- to hypointense on T1-weighted images and hyperintense on T2-weighted images, reflecting varying stages of granuloma maturation. Similar imaging patterns have been documented by Khatri et al. and Ma et al., who emphasized the heterogeneity of MRI appearances in intracranial tuberculosis.[14,24]

Diffusion restriction was observed in 87% of patients, underscoring the high diagnostic value of DWI in detecting caseating necrosis and associated vasculitic infarctions. Previous studies have reported diffusion restriction as a key imaging feature in tuberculomas and tuberculous abscesses, helping differentiate them from neoplastic lesions.[11,25]

Blooming on SWI was noted in 11% of cases, suggesting calcification or hemorrhage, which typically indicates chronic or healed lesions. Similar low frequencies of blooming have been reported in cohorts dominated by active disease.[16,26] Ring enhancement, observed in over half of our patients, remains a classical feature of caseating tuberculomas and has been widely described in the literature.[14,24]

Meningeal enhancement was present in 48.7% of cases, indicating a significant burden of tuberculous meningitis. Although this proportion is lower than that reported in studies focusing exclusively on TB meningitis, it reflects the inclusion of patients with isolated parenchymal disease in our cohort.[22,23]

CSF analysis revealed lymphocytic pleocytosis and elevated protein in the majority of patients, consistent with chronic granulomatous inflammation.[27] The most important finding of our study was the strong association between meningeal enhancement and CSF inflammatory markers, including lymphocytic pleocytosis, elevated protein, positive PCR for Mycobacterium tuberculosis, and raised ADA levels. These findings are consistent with prior reports demonstrating that basal meningeal enhancement is the strongest radiological correlate of CSF abnormalities in tuberculous meningitis.[22,28]

Although other MRI features such as diffusion restriction, blooming, and ring enhancement showed statistically significant associations with CSF protein levels, the correlations were weaker. This observation highlights the heterogeneous nature of CNS tuberculosis, where parenchymal disease may exist independently of meningeal inflammation and CSF abnormalities.[17,29]

Overall, our findings reinforce MRI as an indispensable diagnostic modality in intracranial tuberculosis. Multiparametric MRI enables comprehensive assessment of lesion morphology, disease extent, and associated complications, and its correlation with CSF parameters enhances diagnostic confidence and clinical decision-making.

CONCLUSION

MRI is an essential and highly sensitive tool in the evaluation of intracranial tuberculosis. It effectively demonstrates parenchymal, meningeal, and vascular involvement and provides valuable correlation with CSF inflammatory markers. Meningeal enhancement on MRI is the most reliable indicator of disease severity and CSF abnormality. Routine use of MRI in suspected cases of CNS tuberculosis can facilitate early diagnosis, guide management, and reduce neurological morbidity.

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