Section: Radiodiagnosis

Original Research Article

THE MANY FACES OF NEUROTUBERCULOSIS: MRI FEATURES ACROSS THE DISEASE SPECTRUM

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ABSTRACT

Background: Neurotuberculosis (neuro-TB), the most severe form of extrapulmonary tuberculosis, remains a major diagnostic challenge because of its diverse intracranial manifestations that often mimic neoplastic and other infectious diseases. Magnetic resonance imaging (MRI) plays a pivotal role in its early detection and characterization. The objective is to describe the spectrum of MRI findings in neurotuberculosis and highlight imaging features that aid accurate diagnosis. **Materials and Methods:** A retrospective observational study was conducted in the Department of Radiodiagnosis, Jorhat Medical College and Hospital, Jorhat, Assam, from January to June 2026. Twenty-eight patients diagnosed with neurotuberculosis on MRI were included in the study. MRI examinations were performed using a 1.5 Tesla GE MRI scanner. The MRI scans were reviewed by senior radiologist. Imaging findings including the pattern of meningeal enhancement, parenchymal lesions, lesion morphology, diffusion restriction, susceptibility changes, contrast enhancement and spectroscopic findings were analysed. Relevant clinical information was obtained from medical records. The diagnosis of neurotuberculosis was established based on characteristic cerebrospinal fluid findings and/or microbiological confirmation, supported by clinical and radiological evidence. **Result:** Tuberculous meningitis was the most common manifestation, occurring in 14 patients (50%), including basal meningitis (n=8), leptomeningitis (n=5) and pachymeningitis (n=1). Parenchymal involvement was present in 14 patients, including 10 tuberculomas (seven caseating and three non-caseating) and four tuberculous abscesses. Hydrocephalus and cerebral infarctions were each observed in two patients. **Conclusion:** Neurotuberculosis demonstrates a wide spectrum of MRI findings. Recognition of characteristic imaging patterns, combined with clinico-radiological correlation, facilitates early diagnosis and appropriate management, particularly in tuberculosis endemic regions.

INTRODUCTION

Tuberculosis (TB) remains a major global health challenge and continues to be one of the leading infectious causes of morbidity and mortality, particularly in low- and middle-income countries. According to the World Health Organization (WHO), India accounts for the highest burden of tuberculosis worldwide. Although pulmonary tuberculosis is the predominant form, central nervous system (CNS) involvement represents one of the most severe manifestations of extrapulmonary disease because of its high mortality and the risk of permanent neurological disability. Early diagnosis and prompt initiation of treatment are therefore essential to improve clinical outcomes.[1]

Neurotuberculosis comprises a wide spectrum of pathological entities resulting from hematogenous dissemination of Mycobacterium tuberculosis to the brain and meninges. It commonly manifests as tuberculous meningitis, intracranial tuberculomas, and tuberculous abscesses, while less frequent manifestations include pachymeningitis, vasculitic infarctions, hydrocephalus, ventriculitis, and cranial nerve involvement. These manifestations may occur individually or coexist in the same patient, reflecting

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the diverse pathological processes of the disease. The considerable overlap in clinical and imaging features with other infectious, inflammatory, and neoplastic disorders often makes neurotuberculosis a diagnostic challenge.[2-4]

Magnetic resonance imaging (MRI) is the imaging modality of choice for evaluating suspected neurotuberculosis because of its superior soft-tissue contrast, multiplanar capability, and high sensitivity for detecting both parenchymal and meningeal abnormalities. Conventional MRI sequences accurately demonstrate granulomatous lesions, meningeal enhancement, edema, and associated complications. Advanced imaging techniques such as diffusion-weighted imaging (DWI), susceptibility-weighted imaging (SWI), and magnetic resonance spectroscopy (MRS) further improve lesion characterization by providing functional and metabolic information, thereby facilitating differentiation from pyogenic abscesses, neurocysticercosis, fungal infections, high-grade gliomas, metastatic lesions, and primary CNS lymphoma.[5-8]

Despite significant advances in neuroimaging, diagnosing neurotuberculosis remains challenging because no single imaging feature is pathognomonic. Accurate diagnosis requires careful integration of imaging findings with clinical presentation, cerebrospinal fluid analysis, microbiological evidence, and epidemiological context. In tuberculosis-endemic countries such as India, familiarity with the complete spectrum of MRI manifestations is essential for reducing diagnostic delays and initiating timely antitubercular therapy.

Most published studies have focused on individual manifestations of neurotuberculosis, particularly tuberculomas or tuberculous meningitis, whereas comprehensive imaging-based case series encompassing the entire disease spectrum remain limited. The present study aims to illustrate the diverse MRI features of neurotuberculosis encountered in routine clinical practice, highlighting characteristic imaging findings across different disease manifestations and emphasizing the pivotal role of MRI in improving diagnostic confidence and facilitating early diagnosis.

MATERIALS AND METHODS

Study Design and Setting: The retrospective observational study was conducted in the Department of Radiodiagnosis, Jorhat Medical College and Hospital, Jorhat, Assam for a period of 6 months from January 2026 to June 2026. Patients diagnosed with neuro-TB were identified from the hospital information system. A total of 28 cases were included in the study who underwent CEMRI Brain in 1.5 Tesla General Electric (GE) MRI scanner.

MR Imaging Protocol: Axial T2, Axial T1, Axial FLAIR, Diffusion weighted Imaging with ADC sequence, Sagittal T2, Axial SWI, Post contrast T1 weighted images were obtained after intravenous administration of gadolinium-based contrast agent (0.1 mmol/kg body weight) and MRS (in specific cases)

Image Analysis: The scans were reviewed by a senior radiologist with 20 years of experience. The following imaging parameters were evaluated. The MRI studies were systematically evaluated for the following imaging characteristics:

- Type of lesion: Tuberculoma, tuberculous abscess, tuberculous meningitis or other manifestations of neurotuberculosis.
- Lesion distribution: Supratentorial or infratentorial location, lobar involvement, basal ganglia, brainstem, cerebellum, ventricular system and meningeal involvement.
- Number of lesions: Solitary or multiple.
- Lesion morphology: Size, shape, margin definition and presence of conglomerate lesions.
- Signal characteristics: Appearance on T1-weighted, T2-weighted and FLAIR sequences.
- Contrast enhancement: Homogeneous, nodular, ring-enhancing, conglomerate ring-enhancing or meningeal enhancement (basal, leptomeningeal or pachymeningeal).
- Diffusion characteristics: Presence or absence of diffusion restriction on DWI with corresponding ADC changes.
- Susceptibility changes: Presence of hemorrhage, calcification or blooming artifacts on SWI.
- MR spectroscopy findings (where performed): Evaluation for lipid-lactate peaks, choline elevation, N-acetylaspartate (NAA) reduction and other metabolite alterations.
- Associated findings: Perilesional edema, mass effect, hydrocephalus, vasculitic infarction, ependymal enhancement, and other intracranial complications.

Relevant clinical information, including patient name, age, gender, symptoms, treatment approach were collected from hospital information system. Imaging findings were subsequently correlated with cerebrospinal fluid (CSF) analysis, microbiological investigations and clinical records to establish the final diagnosis.

Inclusion Criteria

1. Patients of any age or gender.
2. Patients diagnosed with neurotuberculosis who underwent contrast-enhanced MRI (CEMRI) of the brain during the study period.
3. Diagnosis established based on clinical findings, cerebrospinal fluid (CSF) analysis, microbiological confirmation (AFB smear) and clinico-radiological correlation.
4. Patients with complete clinical records and MRI examinations available for retrospective analysis.

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Exclusion Criteria

1. Patients with intracranial lesions due to non-tuberculous etiologies.
2. Patients with isolated spinal tuberculosis without intracranial involvement.
3. Patients with inadequate MRI studies, poor image quality or motion artefacts limiting image interpretation.
4. Patients with incomplete clinical, laboratory or imaging records preventing definitive diagnosis.

RESULTS

A total of 28 patients diagnosed with neurotuberculosis were included in the study. The study population comprised of 21 males (75%) and 7 females (25%), with an age range of 20–64 years (mean age 38 years). The majority of patients belonged to the third and fourth decades of life.

The clinical presentation was variable, with headache, seizures, altered sensorium and focal neurological deficits being the most frequently encountered symptoms.

MRI demonstrated a broad spectrum of intracranial manifestations. Among the 28 patients, tuberculous meningitis was the most common manifestation, observed in 14 patients (50.0%), followed by tuberculomas in 10 patients (35.7%) and tuberculous abscesses in 4 patients (14.3%).

Among the 14 patients with tuberculous meningitis, basal meningitis was the predominant subtype, observed in 8 patients (57.1%), followed by leptomeningitis in 5 patients (35.7%) and pachymeningitis in 1 patient (7.1%). Among the 10 tuberculomas, 7 (70%) were caseating tuberculomas, while 3 (30%) were non-caseating tuberculomas.

Associated complications included hydrocephalus in two patients (14.3%) both occurring in association with basal meningitis, and vasculitic cerebral infarctions in two patients (14.3%), both associated with leptomeningitis.

Table 1: Demographic Characteristics of the Study Population

Variable	Category	Number of Patients (n)	Percentage (%)
Age (years)	20–29	6	21.4
	30–39	10	35.7
	40–49	7	25.0
	50–59	4	14.3
	≥60	1	3.6
	Total	28	100
Gender	Male	21	75.0
	Female	7	25.0
	Total	28	100
Age Range	20–64 years	—	—
Mean Age	38 years	—	—

Table 2: MRI Spectrum of Neurotuberculosis

MRI Manifestation	Number of Patients (n)	Percentage (%)
Parenchymal Manifestations		
Caseating tuberculoma	7	25.0
Non-caseating tuberculoma	3	10.7
Tuberculous abscess	4	14.3
Meningeal Manifestations		
Basal meningitis	8	28.6
Leptomeningitis	5	17.9
Pachymeningitis	1	3.6
Associated Intracranial Complications		
Hydrocephalus	2	7.1
Vasculitic cerebral infarction	2	7.1

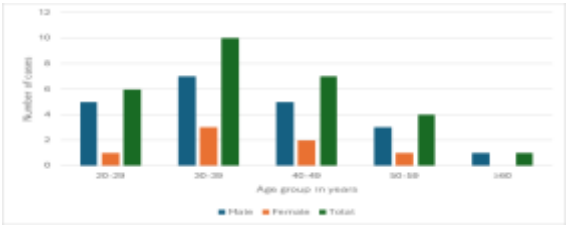

Figure 1: Demographic distribution of the study population

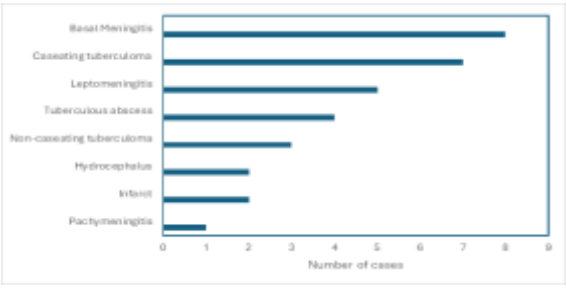

Figure 2: Distribution of MRI manifestations in patients with neurotuberculosis

Representative Cases:

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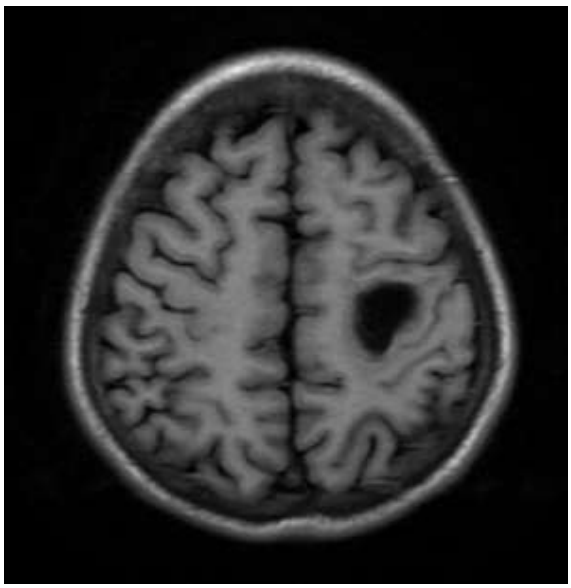

Figure 3a: Axial T1

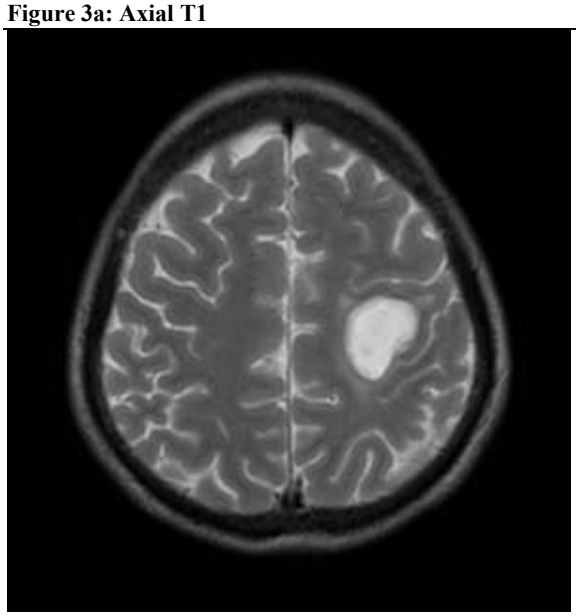

Figure 3b: Axial T2

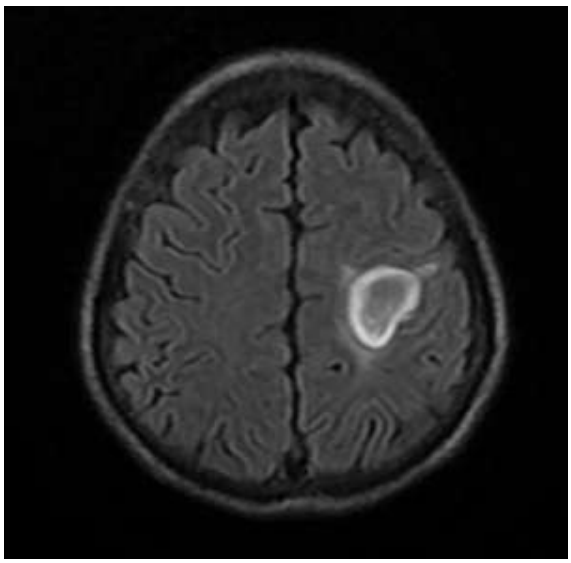

Figure 3c: Axial FLAIR

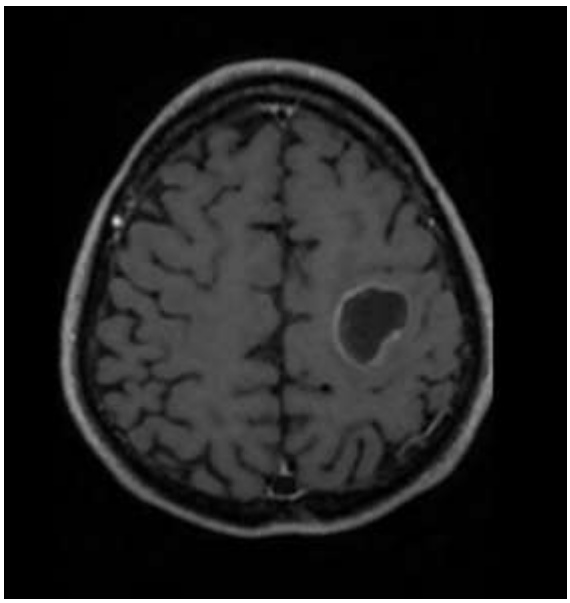

Figure 3d: Axial Post ContrastT1

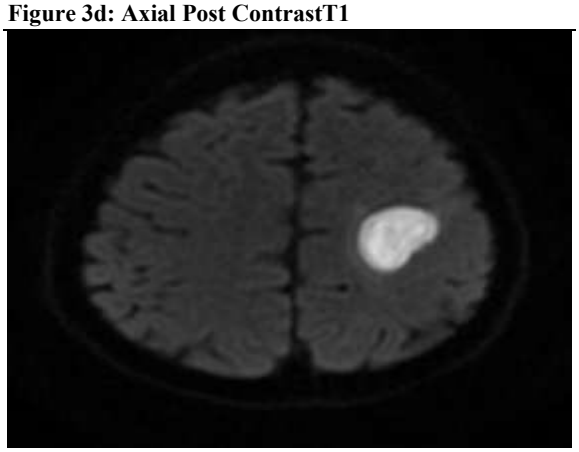

Figure 3e: Axial DWI

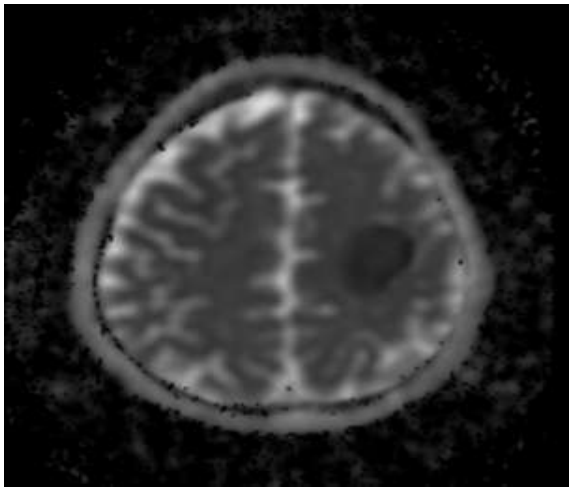

Figure 3f: Axial ADC

Figures 3 (a-f): A 50-year-old male presented with fever, headache, and altered sensorium. CEMRI brain was performed and the MR images of the patient (Figures 3 (a-f), Origin-Department of Radiodiagnosis, Jorhat Medical College and Hospital) revealed a smooth-walled T1 hypointense, T2, FLAIR hyperintense peripherally enhancing lesion in the left parietal lobe with mild surrounding edema. The lesions demonstrated central diffusion restriction on DWI, findings consistent with tuberculous abscesses.

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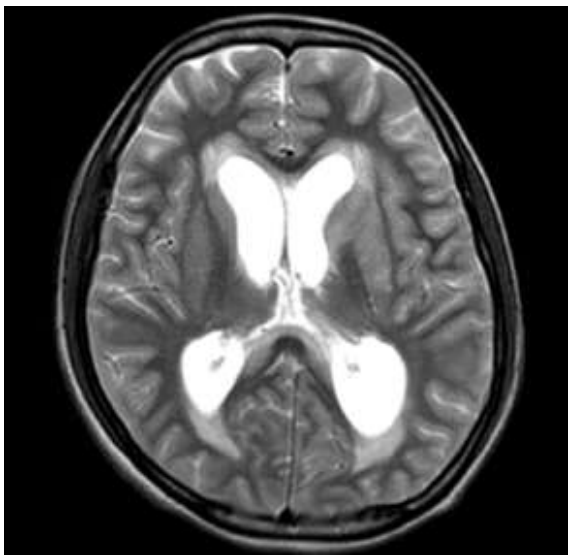

Figure 4a: Axial T2

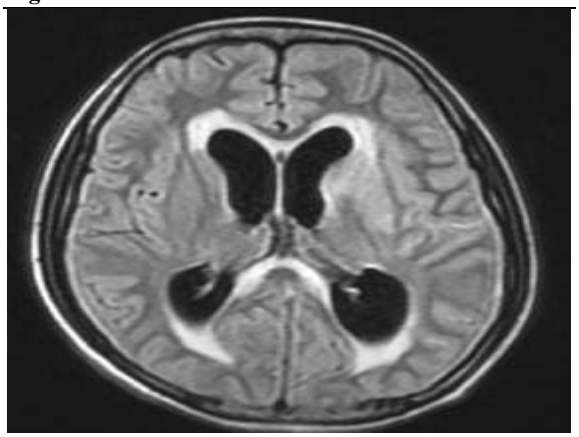

Figure 4b: Axial FLAIR

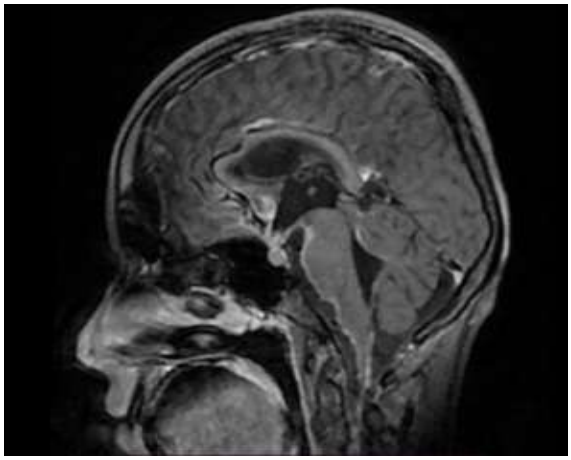

Figure 4c: Sagittal Post contrast T1

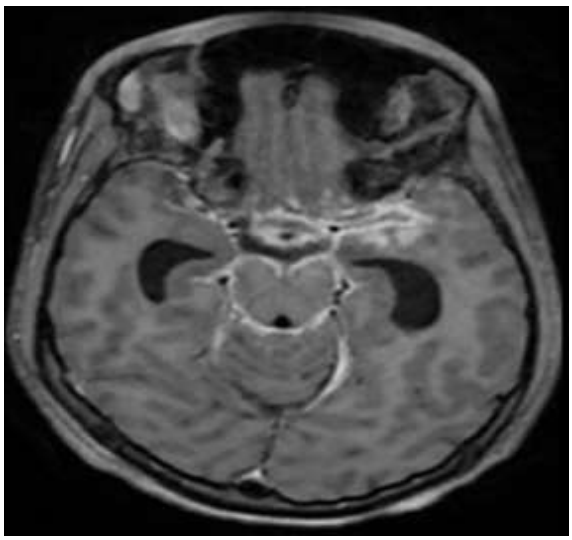

Figure 4d: Axial Post contrast T1

Figures 4 (a-d): A 20-year-old male with pulmonary tuberculosis presented with headache and altered sensorium. MRI was performed to evaluate suspected CNS involvement. Images of contrast-enhanced MRI (Figures 4 (a-d), Origin-Department of Radiodiagnosis, Jorhat Medical College and Hospital) demonstrated diffuse leptomeningeal enhancement involving the peri-mesencephalic and left sylvian cisterns with multiple enhancing exudates. Associated communicating hydrocephalus with transependymal edema were also noted, consistent with basal tuberculous meningitis complicated by hydrocephalus.

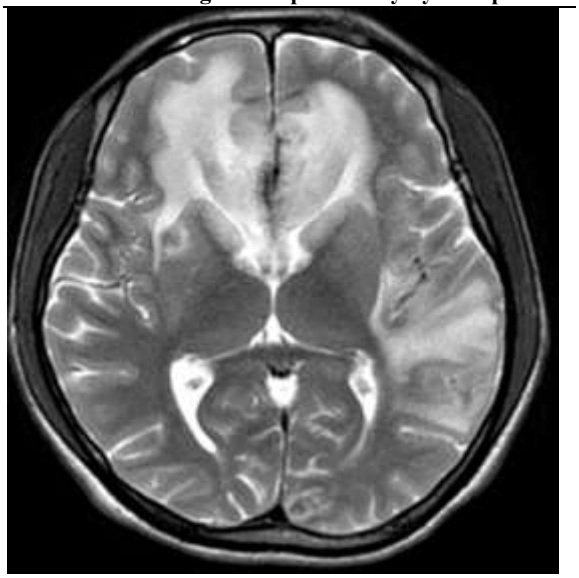

Figure 5a: Axial T2

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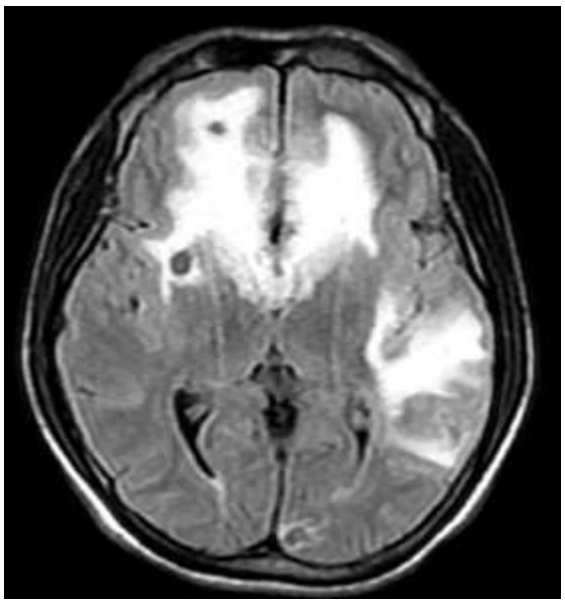

Figure 5b: Axial FLAIR

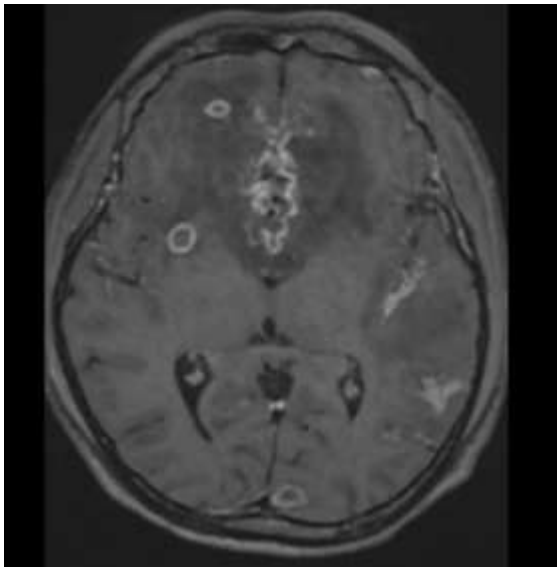

Figure 5c: Axial Post ContrastT1

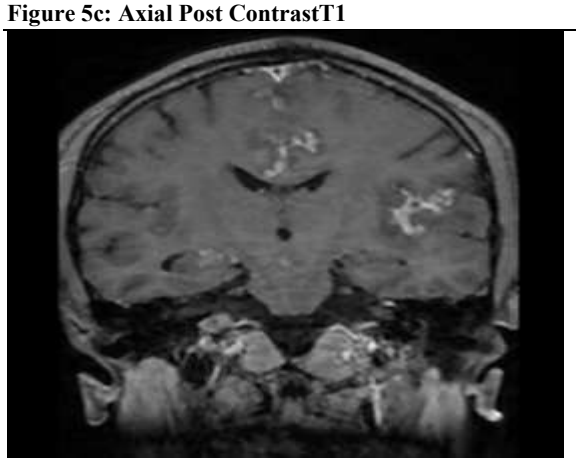

Figure 5d: Coronal Post Contrast T1

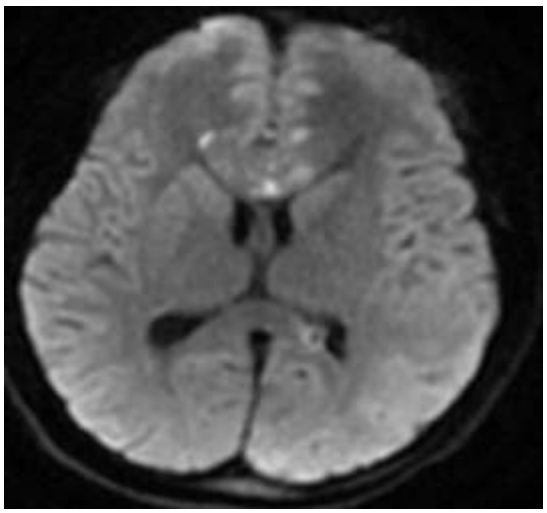

Figure 5e: Axial DWI

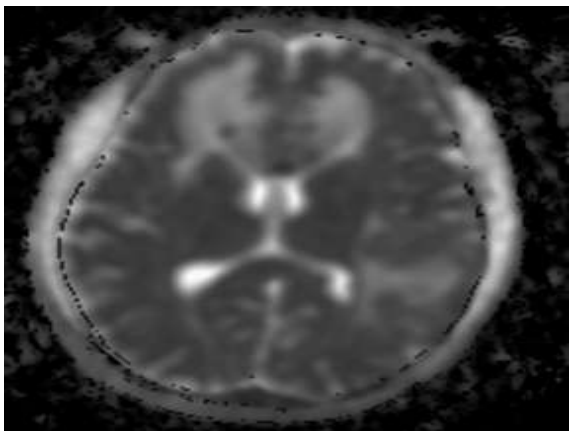

Figure 5f: Axial ADC

Figures 5 (a-f): A 35-year-old male presented with abnormal jerky movements. MRI brain was performed to investigate intracranial lesions. Images of Contrast-enhanced MRI (Figures 5 (a-f), Origin-Department of Radiodiagnosis, Jorhat Medical College and Hospital) demonstrated diffuse leptomeningeal enhancement involving the anterior interhemispheric fissure, cerebral sulci of bilateral frontal lobes and left sylvian fissure with multiple conglomerate ring-enhancing lesions. Associated acute lacunar infarcts and diffuse cerebral edema involving bilateral frontal lobes, left parieto-temporal lobe were present, consistent with tuberculous leptomeningitis with tuberculoma and vasculitic cerebral infarction.

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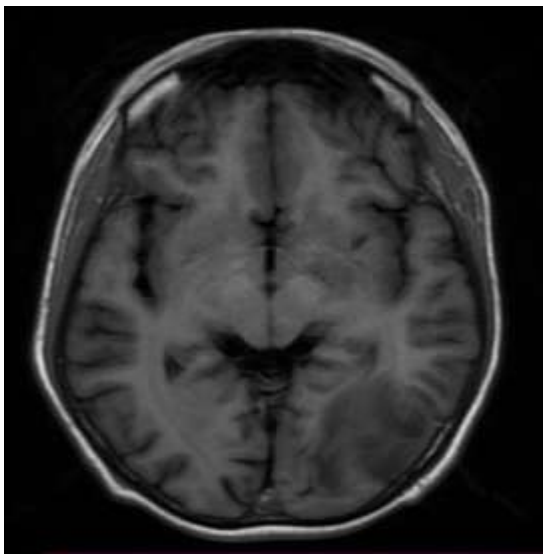

Figure 6a: Axial T1

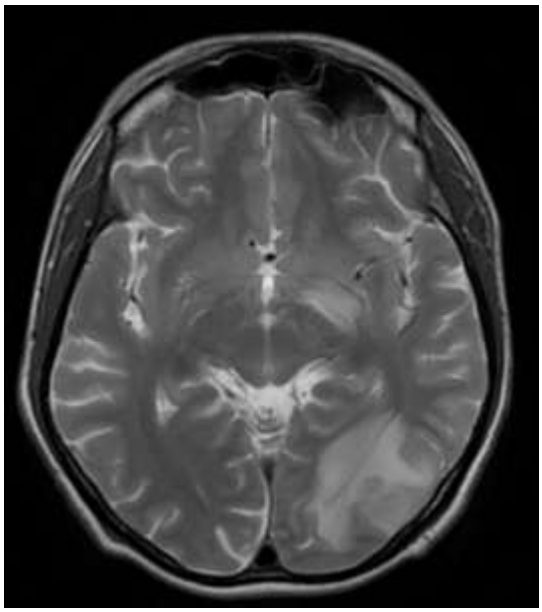

Figure 6b: Axial T2

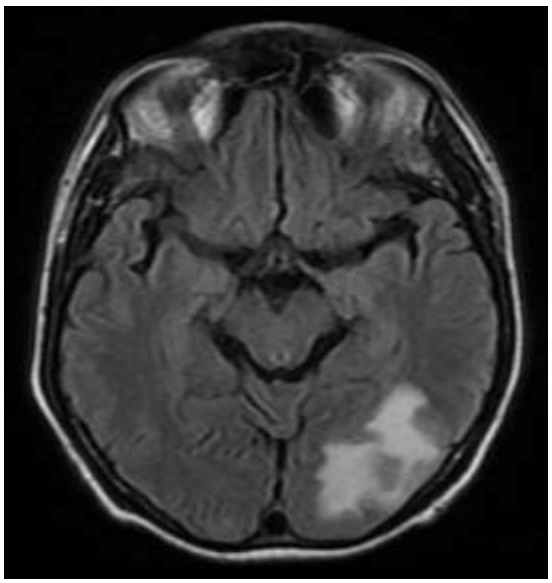

Figure 6c: Axial FLAIR

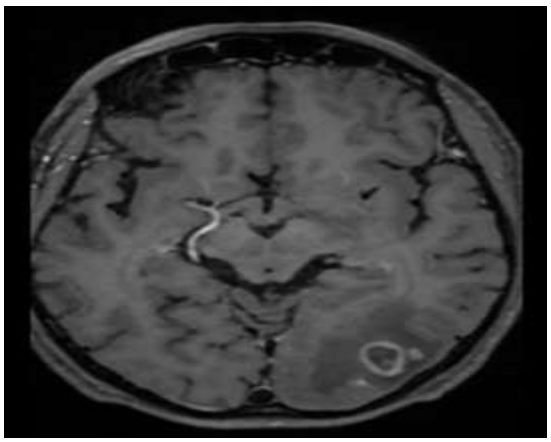

Figure 6d: Axial Post Contrast T1

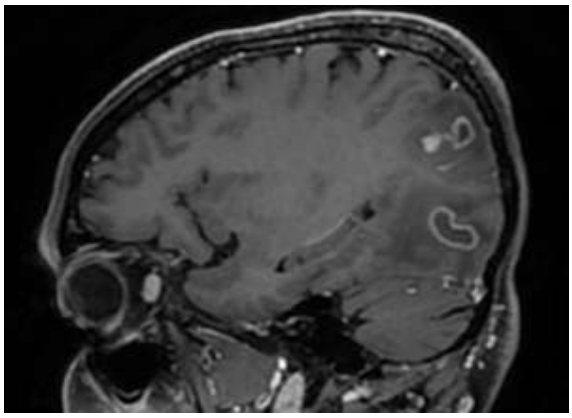

Figure 6e: Sagittal Post Contrast T1

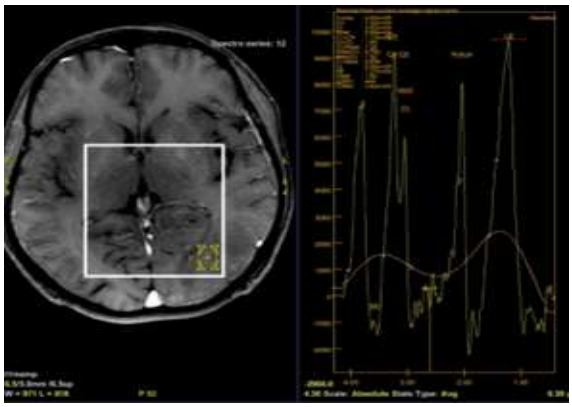

Figure 6f: MRS

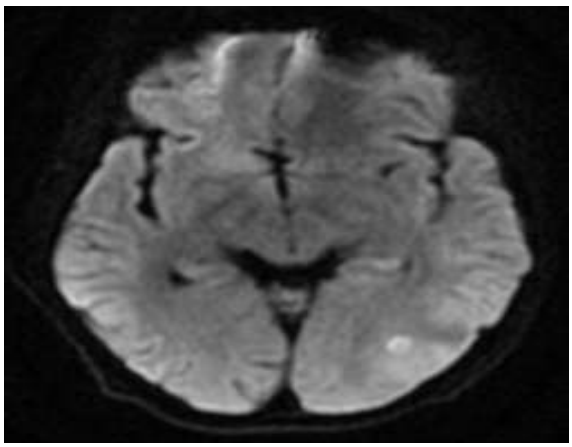

Figure 6g: Axial DWI

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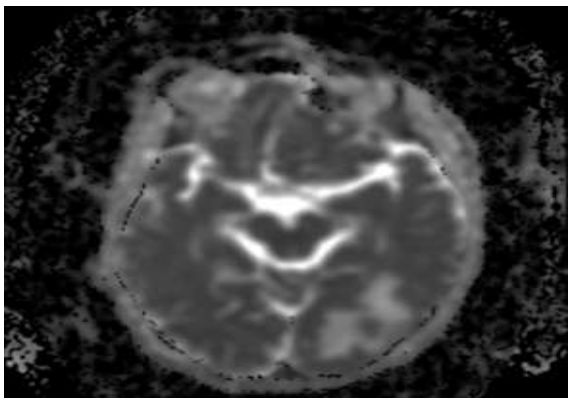

Figure 6h: Axial ADC

Figures 6 (a-h): A 50-year-old female presented with new-onset generalized tonic-clonic seizures. Contrast-enhanced MRI brain was performed and the MR images of the patient (Figure 6 (a-h), Origin-Department of Radiodiagnosis, Jorhat Medical College and Hospital)

demonstrated few well-defined ring-enhancing lesions in the left occipital and parietal lobe with surrounding vasogenic edema. The lesions were T1- and T2-hypointense, showed patchy diffusion restriction and were associated with adjacent leptomeningeal enhancement. On MRS it showed characteristic lipid-lactate peak, consistent with caseating tuberculomas.

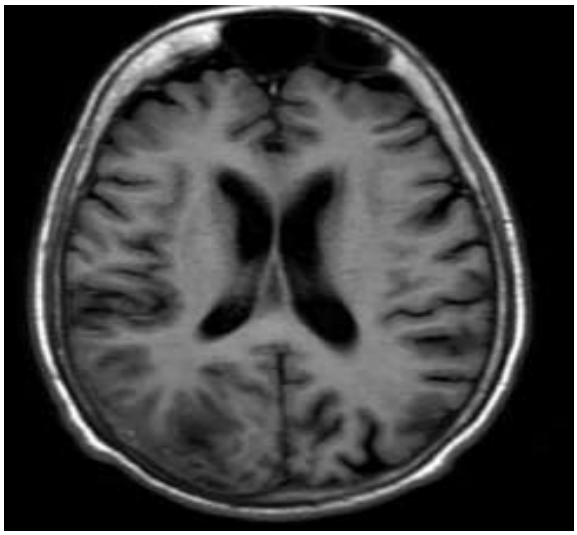

Figure 7a: Axial T1

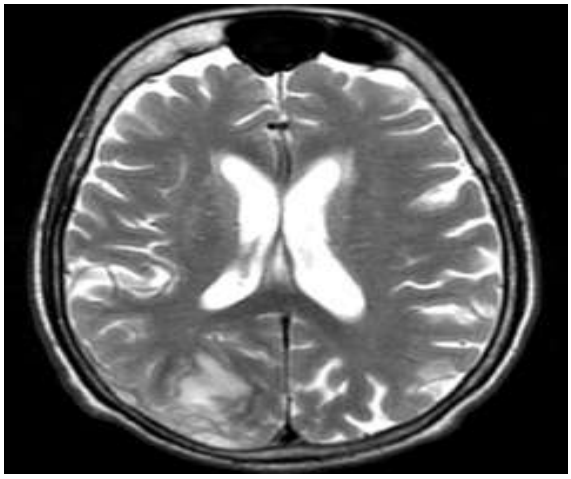

Figure 7b: Axial T2

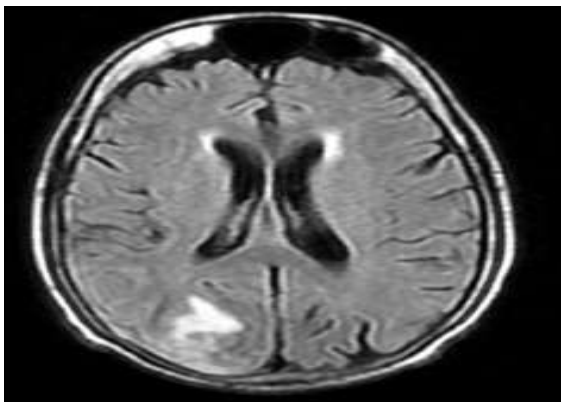

Figure 7c: Axial FLAIR

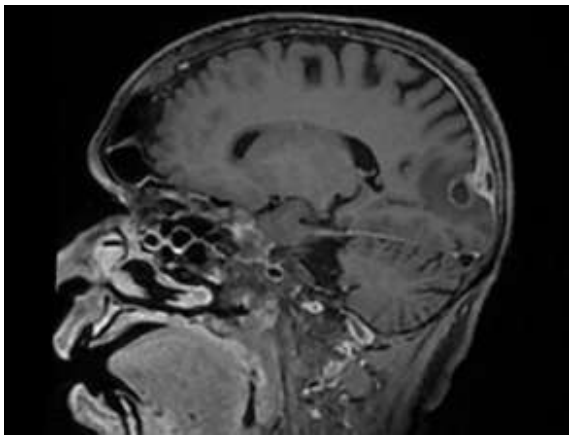

Figure 7d: Sagittal Post Contrast T1

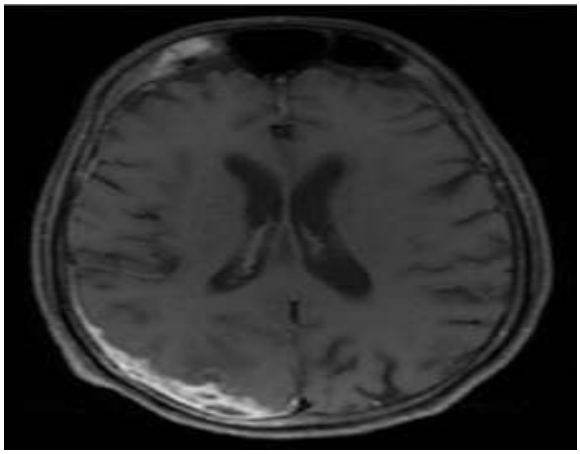

Figure 7e: Axial Post Contrast T1

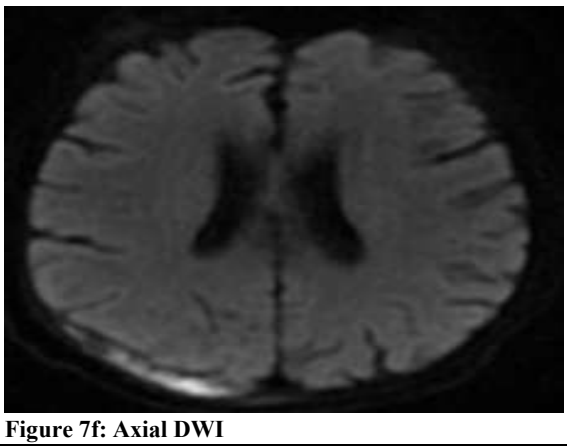

Figure 7f: Axial DWI

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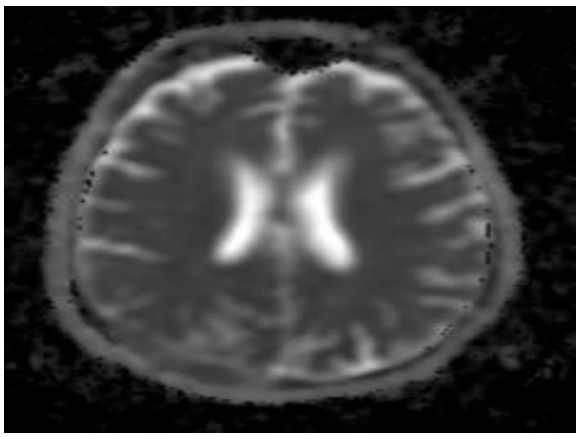

Figure 7g: Axial ADC

Figures 7 (a-g): A 62-year-old male presented with seizures. MRI brain was performed and the MR images of the patient (Figures 7 (a-g), Origin-Department of Radiodiagnosis, Jorhat Medical College and Hospital) revealed a small peripherally enhancing cystic lesion in the right occipital lobe with surrounding edema and adjacent focal pachymeningeal enhancement over the right occipital and parietal convexities. The lesion showed diffusion restriction, suggesting tuberculous pachymeningitis associated with a tuberculous granulomatous lesion.

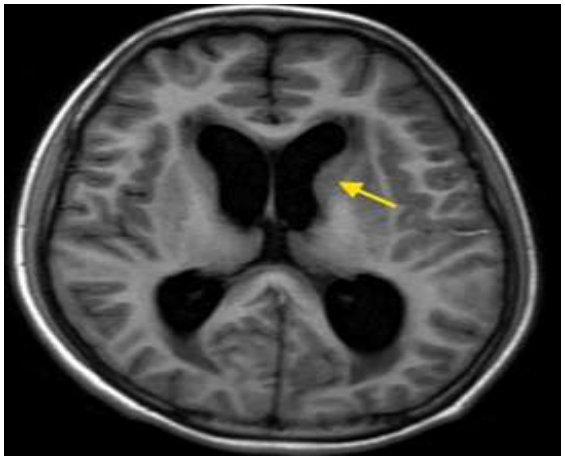

Figure 8a: Axial T1

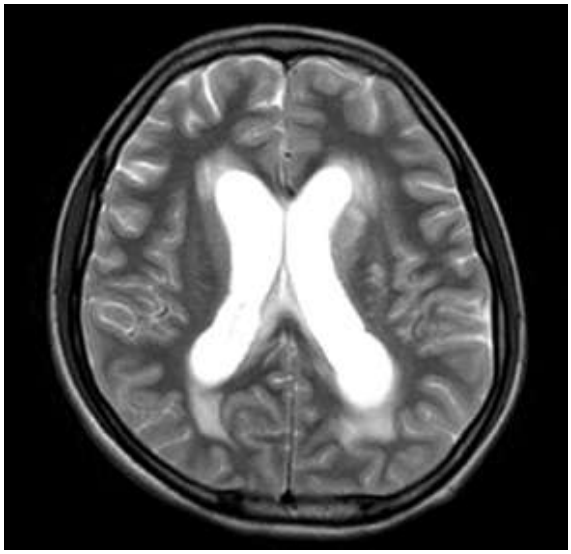

Figure 8b: Axial T2

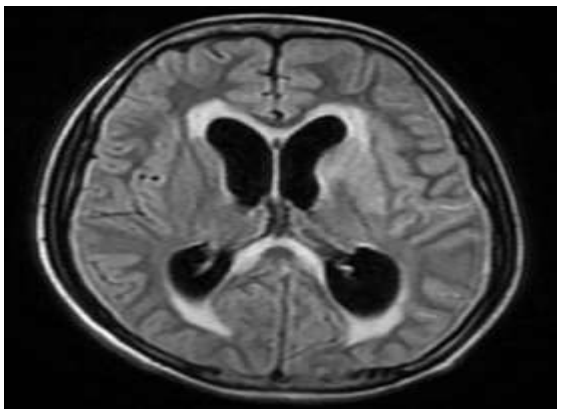

Figure 8c: Axial FLAIR

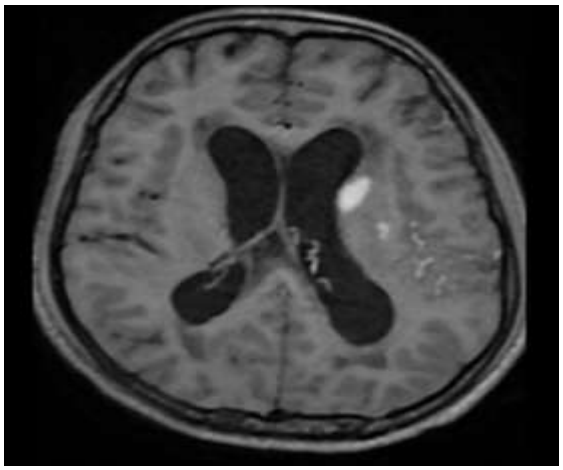

Figure 8e: Axial Post Contrast T1

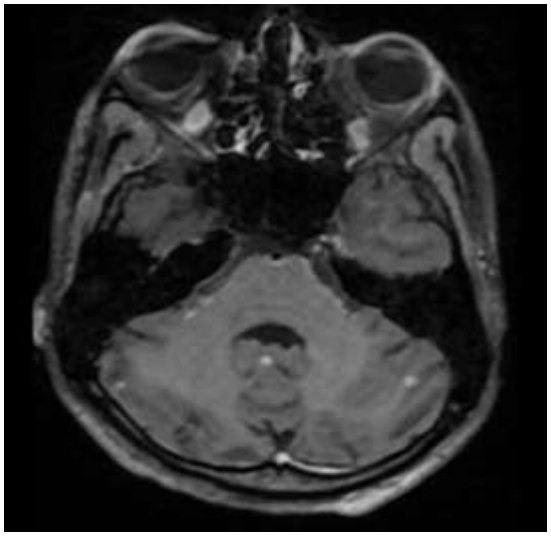

Figure 8e: Axial Post Contrast T1

Figures 8 (a-e): A 36-year-old male with history of pulmonary tuberculosis presented with focal seizures. Contrast enhanced MRI brain was performed and the MR images of the patient (Figures 8 (a-e), Origin-Department of Radiodiagnosis, Jorhat Medical College and Hospital) revealed T1 isointense, T2, FLAIR intermediate to hyperintense lesion showing homogenous post contrast enhancement was noted in left caudate nucleus. Few nodular homogenously enhancing lesions were also noted in bilateral cerebellar hemisphere with no significant perilesional edema, consistent with noncaseating tuberculoma.

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The age and sex distribution of the study population is depicted in [Figure 1]. The various distribution of MRI findings of neurotuberculosis are depicted in [Figure 2].

DISCUSSION

Neurotuberculosis remains the most severe manifestation of extrapulmonary tuberculosis and is associated with considerable neurological morbidity, particularly in tuberculosis endemic countries such as India. MRI has become the imaging modality of choice because of its high sensitivity for detecting both parenchymal and meningeal abnormalities. In the present study, MRI demonstrated a broad spectrum of neurotuberculosis, including tuberculomas, tuberculous abscesses, tuberculous meningitis, hydrocephalus, and vasculitic cerebral infarctions, highlighting the heterogeneous nature of the disease and the importance of comprehensive imaging evaluation.[5,8]

The study population had a mean age of 38 years with a marked male predominance (75%), findings comparable to previous studies from tuberculosis-endemic regions. Rock et al. reported that central nervous system tuberculosis predominantly affects young and middle-aged adults, while Wilkinson et al. observed a similar demographic distribution with a higher incidence among males.[2,4] These findings reflect the epidemiological characteristics of tuberculosis in developing countries.[1]

Tuberculous meningitis was the most common manifestation in our series, accounting for half of all patients. Basal meningitis was the predominant pattern, followed by leptomeningitis and pachymeningitis. These findings are consistent with previous neuroradiological studies describing basal cisternal enhancement as the characteristic imaging hallmark of tuberculous meningitis.[5,8] Early recognition of meningeal disease is crucial because delayed diagnosis may result in hydrocephalus, cerebral infarction, and irreversible neurological deficits.[4,9]

Among the meningeal manifestations, one patient demonstrated pachymeningitis, an uncommon presentation of neurotuberculosis. Tuberculous pachymeningitis is considerably less frequent than leptomeningitis and results from inflammatory involvement of the dura mater, either secondary to chronic leptomeningeal infection or, less commonly, through hematogenous dissemination of Mycobacterium tuberculosis. MRI typically demonstrates focal or diffuse dural thickening with intense homogeneous post-contrast enhancement, while FLAIR imaging improves visualization of dural involvement.[5,11] The imaging findings in our patient were consistent with these characteristic features. Recognition of this rare manifestation is important because it may mimic en plaque meningioma, idiopathic hypertrophic pachymeningitis, neurosarcoidosis and other inflammatory or neoplastic dural disorders.[11,13]

Parenchymal involvement was observed in half of our patients, with tuberculomas representing the predominant lesion. Caseating tuberculomas were more common than non-caseating lesions, reflecting the natural progression of granulomatous inflammation. The MRI appearances observed in our study closely correspond with previously described imaging features, where caseating tuberculomas typically demonstrate T2 hypointensity with ring or nodular enhancement, whereas non-caseating lesions usually exhibit T2 hyperintensity with homogeneous enhancement.[5,10] Recognition of these imaging characteristics is clinically important because tuberculomas frequently mimic metastatic lesions, high-grade gliomas, fungal granulomas and neurocysticercosis.[5,7]

Tuberculous abscesses accounted for 14.3% of our study population. Although less common than tuberculomas, they represent an important differential diagnosis because they often resemble pyogenic abscesses on conventional MRI. In our study, diffusion-weighted imaging and MR spectroscopy provided valuable complementary information by demonstrating diffusion restriction and characteristic lipid-lactate peaks. Gupta et al. demonstrated that MR spectroscopy improves diagnostic confidence in differentiating tuberculous abscesses from pyogenic abscesses and other ring-enhancing intracranial lesions.[6] Similar observations have been reported by Shukla et al. and Raut et al., emphasizing the complementary role of advanced MRI techniques in lesion characterization.[15,16]

Hydrocephalus and vasculitic cerebral infarctions were identified as important complications of tuberculous meningitis. Hydrocephalus results from obstruction of cerebrospinal fluid pathways by dense inflammatory exudates, whereas cerebral infarctions occur secondary to inflammatory vasculitis involving perforating cerebral vessels. These complications are associated with adverse neurological outcomes and require prompt recognition and management.4,9 Previous studies have similarly identified hydrocephalus and cerebral infarction as important predictors of poor prognosis in patients with tuberculous meningitis.[12,14]

The coexistence of diverse parenchymal, meningeal, and vascular manifestations within a single cohort highlights the broad imaging spectrum of neurotuberculosis. A systematic MRI-based approach incorporating conventional and advanced imaging techniques improves diagnostic confidence, facilitates differentiation from common intracranial mimics and supports the timely initiation of appropriate antitubercular therapy. Recent MRI-based studies continue to emphasize the value of comprehensive imaging protocols in improving diagnostic accuracy and patient outcomes.[13,17]

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The principal strength of the present study lies in its comprehensive evaluation of the MRI spectrum of neurotuberculosis using both conventional and advanced imaging sequences, including diffusion-weighted imaging, susceptibility-weighted imaging and MR spectroscopy. Unlike studies focusing on isolated manifestations, our series illustrates the coexistence of multiple intracranial disease patterns encountered in routine clinical practice. However, the study has certain limitations. It was a retrospective single-centre study with a relatively small sample size. Nevertheless, the findings provide valuable insight into the varied MRI manifestations of neurotuberculosis and reinforce the importance of clinico-radiological correlation in establishing an early diagnosis.

CONCLUSION

Neurotuberculosis encompasses a diverse spectrum of intracranial manifestations that may involve the brain parenchyma, meninges and cerebral vasculature, often coexisting within the same patient. MRI remains the cornerstone of diagnosis by accurately depicting disease extent, characterizing lesion morphology and identifying associated complications. The integration of conventional MRI with advanced techniques, including diffusion-weighted imaging, susceptibility-weighted imaging and magnetic resonance spectroscopy, improves diagnostic accuracy. Awareness of these imaging patterns and a systematic clinico-radiological approach can facilitate early diagnosis, guide appropriate management and potentially improve neurological outcomes in patients with neurotuberculosis.

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