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An Evaluation of Clinical and Radiological Profile of Tuberculous Meningitis and Prediction of Prognostic Factors Cross-Sectional Study in a Tertiary Care Centre of West Bengal .

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ABSTRACT

Background: Tuberculous Meningitis (TBM) remains one of the most devastating forms of extra-pulmonary tuberculosis, accounting for considerable morbidity and mortality in developing nations, particularly in India. West Bengal, owing to its high population density, poverty, and nutritional deficiencies, continues to bear a disproportionate burden of the disease. Despite advances in anti-tubercular chemotherapy and neuroimaging, early diagnosis and prediction of prognosis remain formidable challenges in clinical practice.**Objectives**: To evaluate the clinical and radiological profile of patients presenting with Tuberculous Meningitis, to determine the sociodemographic characteristics of the study population, and to identify independent prognostic factors associated with adverse outcomes.**Methods:** A hospital-based cross-sectional study was conducted at a tertiary care centre of West Bengal over a period of 18 months (January 2023 to June 2024). A total of 74 patients diagnosed with TBM, based on clinical, cerebrospinal fluid (CSF), and radiological criteria, were enrolled using purposive (consecutive) sampling. Sociodemographic data, clinical features, CSF analysis, MRI brain findings, treatment details, and outcomes were systematically recorded. Statistical analysis was performed using SPSS version 25.0.**Results**: The study population had a mean age of 36.4 ± 12.3 years, with male predominance (62.2%). The majority of patients were from rural areas (66.2%), belonged to low socioeconomic strata (40.5%), and were underweight (51.4%). Fever (91.9%), headache (87.8%), and neck stiffness (82.4%) were the most common presenting features. MRC Stage II disease was most prevalent at admission (48.6%). Basal meningeal

enhancement on MRI was observed in 62.2% of cases. HIV co-infection (OR 4.21, p = 0.002), late MRC Stage III presentation (OR 4.05, p = 0.001), and delayed diagnosis beyond 14 days (OR 3.33, p = 0.009) emerged as significant prognostic factors. The in-hospital mortality was 18.9%.**Conclusion**: Tuberculous Meningitis disproportionately affects the young, poor, and malnourished population of West Bengal. HIV co-infection, advanced MRC stage at presentation, and delayed diagnosis are the most critical independent predictors of poor prognosis. Early recognition, prompt initiation of anti-tubercular therapy (ATT) with corticosteroids, and multi-disciplinary management are imperative to improve outcomes.

Keywords: *Tuberculous Meningitis, Clinical Profile, Radiological Profile, Prognostic Factors, West Bengal, Anti-Tubercular Therapy, CSF Analysis, MRC Staging*

1. INTRODUCTION

Tuberculosis (TB) continues to be a major public health concern in India, which carries the highest burden of the disease globally, accounting for nearly 28% of the world's TB cases as per the Global Tuberculosis Report 2023. Among the various manifestations of TB, Tuberculous Meningitis (TBM) is considered the most severe and lethal form. It accounts for approximately 1–5% of all tuberculosis cases but is responsible for a disproportionately high share of mortality and permanent neurological disability[1].

TBM results from haematogenous dissemination of Mycobacterium tuberculosis to the meninges, most often arising from a primary focus in the lungs or lymph nodes. The pathological hallmark of TBM is a thick, gelatinous, basal exudate that envelops the cranial nerves, obstructs cerebrospinal fluid (CSF) pathways, and causes endarteritis of small cerebral vessels, ultimately leading to hydrocephalus, cranial nerve palsies, and cerebral infarctions[2].

The clinical presentation of TBM is often insidious and non-specific in its early stages, which leads to substantial delays in diagnosis and initiation of treatment. This diagnostic delay, compounded by limited access to advanced microbiological and neuroimaging facilities in resource-limited settings, contributes significantly to the high case fatality rate observed in developing countries. The overall mortality of TBM ranges from 20–50% in various published studies from India, with survivors often left with considerable neurological sequelae[3-8].

West Bengal, being one of the most densely populated states in India, has a significant burden of TB. Urbanisation, migration, poverty, malnutrition, and the HIV epidemic have created an epidemiological milieu that is particularly conducive to the spread and progression of TBM. Tertiary care centres in this region serve as the final referral point for the most seriously ill patients, and thus provide a unique and valuable window into the natural history and clinical spectrum of this disease.

Despite its importance, there is a relative paucity of published data from this region specifically addressing the clinical and radiological profile of TBM along with a systematic evaluation of prognostic factors. Most published Indian studies on TBM have been conducted in northern or southern India. The present study was, therefore, undertaken to fill this regional knowledge gap, with the specific objective of characterising TBM patients attending a tertiary care centre in West Bengal, and identifying factors that predict poor prognosis[9].

The findings of this study are expected to provide actionable evidence for clinicians, public health administrators, and policymakers in tailoring early-warning systems, improving diagnostic algorithms, and allocating resources towards the highest-risk population groups. The study also aims to build upon the existing national and international evidence base on TBM management and to generate region-specific recommendations for improved clinical outcomes[10].

2. OBJECTIVES

2.1 Primary Objective

- To evaluate the clinical profile (presenting symptoms, neurological staging, and CSF characteristics) of patients with Tuberculous Meningitis admitted to a tertiary care centre of West Bengal.
- To assess the radiological profile (MRI brain findings) in patients diagnosed with TBM.
- To identify independent prognostic factors associated with in-hospital mortality and adverse neurological outcomes.

2.2 Secondary Objectives

- To describe the sociodemographic characteristics of the study population.
- To determine the risk factors for TBM in the study cohort.
- To evaluate the clinical management strategies employed and their outcomes.
- To recommend evidence-based interventions for early diagnosis and prevention of TBM.

3. METHODOLOGY

3.1 Study Design

The study was designed as a hospital-based, observational, cross-sectional study. The cross-sectional design was chosen as it allows evaluation of multiple variables simultaneously in a defined study population at a single point in time, making it particularly suitable for assessing disease profiles and identifying associated risk factors in a clinical setting.

3.2 Study Setting

The study was conducted at a tertiary care teaching hospital in West Bengal, India, which serves as a major referral centre for neurological, infectious, and general medicine cases from the state and neighbouring districts. The institution is affiliated with a medical university and is equipped with facilities for advanced neuroimaging (MRI), microbiological investigations, and neurological care.

3.3 Study Duration

The study was conducted over a period of 18 months, from January 2023 to June 2024, encompassing both winter and monsoon seasons, which are epidemiologically significant periods for infectious diseases in the region.

3.4 Study Population

All patients aged 15 years and above, admitted to the medical and neurology wards with a diagnosis of Tuberculous Meningitis, were considered for inclusion in the study.

Inclusion Criteria

- Patients aged ≥ 15 years presenting with clinical features of meningitis (fever, headache, neck stiffness, altered sensorium).
- CSF analysis showing lymphocytic pleocytosis, elevated protein, and low glucose consistent with TBM.
- MRI brain findings suggestive of TBM (basal meningeal enhancement, hydrocephalus, or tuberculoma).
- Positive CBNAAT / GeneXpert MTB/RIF on CSF or AFB smear positive.
- Clinical diagnosis of TBM with response to ATT in the absence of another confirmed aetiology.

Exclusion Criteria

- Patients aged < 15 years.
- Patients with bacterial meningitis, viral meningitis, fungal meningitis, or carcinomatous meningitis confirmed on investigations.
- Incomplete clinical records or refusal to provide informed consent.
- Patients who were already on anti-tubercular therapy for > 2 weeks prior to admission.

3.5 Sample Size Calculation

The sample size for the present study was calculated using the standard formula for cross-sectional studies for proportion estimation:

$$n = Z^2 \times p \times (1 - p) / d^2$$

Where:

- n = required sample size
- Z = 1.96 (value of standard normal deviate at 95% confidence interval)
- p = expected proportion of TBM cases with poor outcome = 0.40 (40%), based on published Indian literature (Misra et al., 2010; Kalita et al., 2017)
- d = allowable margin of error = 0.11 (11%)

$$n = (1.96)^2 \times 0.40 \times 0.60 / (0.11)^2$$

$$n = 3.8416 \times 0.24 / 0.0121$$

$$n = 0.9220 / 0.0121$$

$$n \approx 76.2 \rightarrow \text{Rounded to } n = 76$$

Accounting for an anticipated attrition or dropout rate of approximately 3%, the adjusted sample size required was approximately 76. During the study period, 74 patients fulfilled the eligibility criteria and provided valid consent, giving a final study sample of n = 74. This sample size was considered statistically adequate for the objectives of the present study.

3.6 Sampling Method

The present study employed a Non-Probability Purposive Sampling (Consecutive Sampling) technique. All eligible patients who were admitted with a diagnosis of TBM during the study period and who satisfied the inclusion and exclusion criteria were enrolled consecutively until the required sample size was achieved. This method is widely employed in clinical research where the study population is restricted to patients attending a particular institution, as it ensures minimal selection bias while being practical and feasible within the given time frame.

Consecutive sampling is particularly appropriate in this context because TBM is a relatively uncommon but serious condition, and random sampling from the general population would not be feasible for such a targeted clinical study. Every patient meeting the diagnostic criteria was systematically included, ensuring representativeness within the institutional context.

3.7 Diagnostic Criteria for TBM

Tuberculous Meningitis was diagnosed based on the Marais Criteria for definite, probable, and possible TBM (Marais et al., 2010). The following parameters were used in assessment:

- Clinical criteria: Fever, headache, meningismus, altered sensorium, and focal neurological deficits.
- CSF criteria: Lymphocytic pleocytosis (> 10 cells/mm³), elevated protein (> 45 mg/dL), low glucose (< 45 mg/dL or CSF:serum glucose ratio < 0.5).
- Microbiological criteria: AFB smear positivity on CSF, CBNAAT (GeneXpert MTB/RIF) positivity on CSF.
- Neuroimaging criteria: MRI brain showing basal meningeal enhancement, hydrocephalus, tuberculoma, or cerebral infarction.
- Clinical criteria: Improvement on empirical ATT in probable/possible TBM cases.

3.8 Data Collection

Informed written consent was obtained from all participants or their legal guardians prior to enrolment. A pre-designed, pretested, structured data collection form was used to record the following information: sociodemographic details, presenting symptoms, duration of illness, clinical staging (British MRC criteria), vital parameters, neurological examination findings, CSF analysis reports, MRI brain reports, HIV serostatus, blood glucose, haematological and biochemical parameters, treatment details (ATT regimen, corticosteroids, surgical interventions), and final outcomes.

3.9 Statistical Analysis

Data were entered and analysed using the Statistical Package for the Social Sciences (SPSS), Version 25.0 (IBM Corp., Armonk, NY). Descriptive statistics were used to summarise continuous variables as mean ± standard deviation (SD) and categorical variables as frequency and percentage. The Chi-Square test was employed to assess associations between categorical variables. Binary logistic regression was used to identify independent predictors of adverse outcomes. Odds Ratios (OR) with 95% Confidence Intervals (CI) were computed for each risk factor. A p-value of < 0.05 was considered statistically significant.

3.10 Ethical Considerations

The study was conducted in compliance with the Declaration of Helsinki and the Indian Council of Medical Research (ICMR) ethical guidelines for biomedical research. Ethical clearance was obtained from the Institutional Ethics Committee (IEC) prior to commencement of the study (IEC Ref. No.: [XXX/2022]). Participation was entirely voluntary, and patients were assured of the confidentiality of their data. Patient identifiers were anonymised for the purposes of analysis and publication.

4. RESULTS

4.1 Sociodemographic Characteristics

A total of 74 patients diagnosed with Tuberculous Meningitis were enrolled in the study. The sociodemographic profile of the study population is presented in Table 1 below. The findings provide a comprehensive picture of the population at risk for TBM in this tertiary care setting.

The mean age of the study participants was 36.4 ± 12.3 years. The largest age group was 26–35 years (28.4%), followed by 36–45 years (24.3%), confirming that TBM predominantly affects the productive age group in this region. Male patients constituted 62.2% of the study population, consistent with the well-documented male preponderance in TB cases attributed to greater social exposure, tobacco, and alcohol use.

A substantial majority of patients (66.2%) were from rural areas, reflecting the lower healthcare accessibility, delayed health-seeking behaviour, and limited awareness prevalent in rural communities. Low socioeconomic status was highly prevalent, with 40.5% of participants earning less than ₹5,000 per month. Illiteracy and primary-level education together accounted for 67.5% of the study population, further underscoring the socioeconomic vulnerability of the TBM cohort.

Nutritional assessment by Body Mass Index (BMI) revealed that 51.4% of participants were underweight, highlighting the important role of malnutrition in the pathogenesis and susceptibility to TBM.

Table 1: Sociodemographic Profile of Study Population (n = 74)

Variable	Frequency (n)	Percentage (%)
15 – 25 years	12	16.2%
26 – 35 years	21	28.4%
36 – 45 years	18	24.3%
46 – 55 years	13	17.6%
> 55 years	10	13.5%
Total	**74**	**100%**
Gender		
Male	46	62.2%
Female	28	37.8%

Variable	Frequency (n)	Percentage (%)
Total	**74**	**100%**
Religion		
Hindu	52	70.3%
Muslim	18	24.3%
Christian/Others	4	5.4%
Total	**74**	**100%**
Residence		
Rural	49	66.2%
Urban	25	33.8%
Total	**74**	**100%**
Education Status		
Illiterate	22	29.7%
Primary educated	28	37.8%
Secondary / Higher	24	32.5%
Total	**74**	**100%**
Occupation		
Labourer / Farmer	31	41.9%
Self-employed / Business	14	18.9%
Homemaker	16	21.6%
Student	8	10.8%
Others / Unemployed	5	6.8%
Total	**74**	**100%**
Monthly Family Income		
< ₹5,000	30	40.5%
₹5,000 – ₹10,000	28	37.8%
> ₹10,000	16	21.7%
Total	**74**	**100%**
Nutritional Status (BMI)		
Underweight (< 18.5)	38	51.4%
Normal (18.5 – 24.9)	29	39.2%
Overweight / Obese	7	9.4%

Variable	Frequency (n)	Percentage (%)
Total	**74**	**100%**

Values are expressed as frequency and percentage. BMI = Body Mass Index.

4.2 Clinical Profile of TBM Patients

The clinical features, CSF analysis findings, and neuroimaging characteristics of the 74 TBM patients are summarised in Table 2. Fever was the most prevalent presenting symptom, present in 91.9% of patients, followed by headache (87.8%), neck stiffness (82.4%), and vomiting (78.4%). Altered sensorium was documented in 59.5% of patients, emphasising the advanced neurological involvement at the time of presentation in a significant subset.

Seizures were recorded in 41.9% of patients. Focal neurological deficits were present in 28.4% of cases, and cranial nerve palsy was documented in 22.9%, most commonly involving the sixth and third cranial nerves. These findings are consistent with the predilection of the basal exudate to involve the cranial nerves at the base of the brain.

Regarding the duration of illness prior to admission, 41.9% of patients presented between 7 and 14 days of symptom onset, while 28.4% had an illness duration exceeding 14 days, indicating considerable diagnostic delay in a substantial proportion of the cohort.

Clinical staging according to the British Medical Research Council (MRC) criteria revealed that the majority of patients presented with Stage II disease (48.6%). MRC Stage III, indicative of the most severe neurological impairment with Glasgow Coma Scale (GCS) ≤ 10, was present in 27.1% of patients at admission.

CSF analysis demonstrated lymphocytic pleocytosis in 90.5% of patients and elevated protein in 86.5%. CSF glucose was low in 75.7% of cases. CBNAAT / GeneXpert MTB/RIF was positive on CSF in 36.5% of patients, while AFB smear was positive in only 12.2%, reflecting the expected low sensitivity of direct smear microscopy in TBM. Cobweb formation was noted in 32.4% of CSF samples, a classical but non-specific finding.

MRI brain was the most valuable neuroimaging modality. Basal meningeal enhancement was documented in 62.2% of patients — the most specific radiological finding of TBM. Communicating hydrocephalus was detected in 45.9% of cases, necessitating active management. Cerebral infarctions, predominantly in the territory of perforating vessels of the middle cerebral artery, were noted in 29.7% of patients. Tuberculomas were identified in 24.3% of cases.

Table 2: Clinical and Radiological Profile of TBM Patients (n = 74)

Clinical Feature	n = 74	Percentage (%)
Presenting Symptoms		
Fever	68	91.9%
Headache	65	87.8%
Vomiting	58	78.4%
Neck stiffness / meningismus	61	82.4%

Clinical Feature	n = 74	Percentage (%)
Altered sensorium / Confusion	44	59.5%
Seizures	31	41.9%
Focal neurological deficit	21	28.4%
Cranial nerve palsy	17	22.9%
Photophobia	29	39.2%
Duration of illness (median days)		
< 7 days	22	29.7%
7 – 14 days	31	41.9%
> 14 days	21	28.4%
British Medical Research Council (MRC) Stage at Admission		
Stage I (GCS 15, no deficit)	18	24.3%
Stage II (GCS 11–14 or deficit)	36	48.6%
Stage III (GCS ≤ 10)	20	27.1%
CSF Analysis Findings		
Elevated opening pressure (>200 mmH2O)	52	70.3%
Lymphocytic pleocytosis (>10 cells)	67	90.5%
Elevated proteins (>45 mg/dL)	64	86.5%
Low glucose (<45 mg/dL)	56	75.7%
Cobweb formation	24	32.4%
AFB smear positive (CSF)	9	12.2%
CBNAAT / GeneXpert positive (CSF)	27	36.5%
MRI Brain Findings		
Normal MRI	10	13.5%
Basal meningeal enhancement	46	62.2%
Hydrocephalus	34	45.9%
Cerebral infarction	22	29.7%
Tuberculoma	18	24.3%
Cerebral oedema	14	18.9%

GCS = Glasgow Coma Scale; CSF = Cerebrospinal Fluid; AFB = Acid-Fast Bacilli; CBNAAT = Cartridge-Based Nucleic Acid Amplification Test; MRC = Medical Research Council.

4.3 Risk Factors and Prognostic Analysis

Table 3 presents a detailed analysis of the risk factors associated with adverse outcomes in TBM patients. Univariate logistic regression was used to compute Odds Ratios (OR) and corresponding p-values for each risk factor. Factors achieving statistical significance ($p < 0.05$) are highlighted.

HIV co-infection emerged as the strongest individual risk factor for poor outcome, with an Odds Ratio of 4.21 ($p = 0.002$). Among the 18 HIV-positive patients (24.3%), the severity of immunosuppression, atypical clinical presentation, and frequent co-existence of other opportunistic infections contributed to significantly worse outcomes.

Immunosuppressive therapy or long-term steroid use was the second most significant risk factor (OR 3.76, $p = 0.005$), highlighting the role of immune compromise in TBM pathogenesis. Late MRC Stage III presentation carried an OR of 4.05 ($p = 0.001$), confirming that the severity of disease at admission is one of the strongest predictors of in-hospital mortality.

Malnutrition (OR 3.15, $p = 0.008$) and delayed diagnosis beyond 14 days (OR 3.33, $p = 0.009$) were both highly significant risk factors. Low socioeconomic status (OR 2.72, $p = 0.018$), rural residence (OR 2.45, $p = 0.028$), and previous contact with TB (OR 2.87, $p = 0.015$) were also statistically significant. Alcohol use (OR 2.54, $p = 0.021$) and diabetes mellitus (OR 2.10, $p = 0.043$) were additional modifiable risk factors of significance.

Tobacco use and illiteracy, though showing elevated Odds Ratios (1.89 and 1.96 respectively), did not reach statistical significance ($p > 0.05$) in this study, possibly due to the relatively small sample size. They remain clinically important risk contributors.

Table 3: Risk Factors and Prognostic Analysis in TBM Patients (n = 74)

Risk Factor	Present n (%)	Absent n (%)	OR	p-value
HIV co-infection	18 (24.3%)	56 (75.7%)	4.21	**0.002***
Malnutrition / Underweight	38 (51.4%)	36 (48.6%)	3.15	**0.008***
Previous TB contact history	32 (43.2%)	42 (56.8%)	2.87	**0.015***
Alcohol use (regular)	26 (35.1%)	48 (64.9%)	2.54	**0.021***
Diabetes mellitus	14 (18.9%)	60 (81.1%)	2.10	**0.043***
Tobacco use	22 (29.7%)	52 (70.3%)	1.89	0.062
Immunosuppressive therapy / steroids	9 (12.2%)	65 (87.8%)	3.76	**0.005***
Rural residence	49 (66.2%)	25 (33.8%)	2.45	**0.028***
Illiteracy	22 (29.7%)	52 (70.3%)	1.96	0.057
Low socioeconomic status (< ₹5000/month)	30 (40.5%)	44 (59.5%)	2.72	**0.018***
Delayed diagnosis (> 14 days)	21 (28.4%)	53 (71.6%)	3.33	**0.009***
Late presentation (MRC Stage III)	20 (27.1%)	54 (72.9%)	4.05	**0.001***

**Statistically significant ($p < 0.05$). OR = Odds Ratio; p-value obtained from univariate binary logistic regression analysis. Highlighted cells (yellow) indicate statistically significant risk factors.*

4.4 Clinical Management

4.4.1 Anti-Tubercular Therapy (ATT)

All 74 patients (100%) received a standard four-drug intensive phase regimen comprising Isoniazid (H), Rifampicin (R), Pyrazinamide (Z), and Ethambutol (E) — the HRZE regimen — as per the Revised National Tuberculosis Control Programme (RNTCP) / National TB Elimination Programme (NTEP) guidelines and WHO recommendations. The intensive phase was maintained for a minimum of 2 months, following which the continuation phase consisted of Isoniazid and Rifampicin for an extended period of 10 months, giving a total treatment duration of at least 12 months for TBM, in accordance with national guidelines.

Pyridoxine (Vitamin B6) supplementation at 10–25 mg/day was administered concurrently to all patients receiving Isoniazid, in order to prevent peripheral neuropathy. Drug dosages were weight-based. Drug sensitivity testing (DST) was undertaken in all CBNAAT-positive cases; no rifampicin resistance was detected in the present cohort.

4.4.2 Corticosteroid Therapy

Adjunctive corticosteroid therapy was administered to 72 out of 74 patients (97.3%), consistent with established evidence and WHO guidelines recommending routine steroid use in TBM to reduce inflammation, cerebral oedema, and vasculitis. Dexamethasone was the preferred corticosteroid, initiated at a dose of 0.4 mg/kg/day in the first week, with gradual tapering over 6–8 weeks. In patients with severe oedema or elevated intracranial pressure, higher initial doses were employed with close monitoring.

The rationale for corticosteroid use is well-established: it suppresses the inflammatory cascade triggered by mycobacterial antigens, reduces basal exudate formation, decreases vascular complications, and has been shown to reduce mortality in MRC Stage I and II TBM in landmark randomised controlled trials (Thwaites et al., 2004).

4.4.3 Management of Raised Intracranial Pressure (ICP)

Elevated intracranial pressure was a common and potentially life-threatening complication encountered in the study cohort. Hydrocephalus was present in 34 patients (45.9%), and active ICP management was required in 34 patients (45.9%). Initial conservative measures included 30-degree head elevation, fluid restriction, osmotic agents (intravenous Mannitol 20%, 0.5–1 g/kg body weight every 6–8 hours), and optimisation of ventilation in patients requiring respiratory support.

For patients with communicating hydrocephalus not responding to medical management, repeated lumbar punctures for CSF drainage were performed where feasible. Ventriculo-Peritoneal (VP) shunt surgery was performed in 12 patients (16.2%) with progressive communicating or obstructive hydrocephalus, demonstrating clinically significant improvement in neurological status post-procedure in 9 of these 12 patients.

4.4.4 Anticonvulsant Therapy

Seizures were reported in 31 patients (41.9%). All patients with seizures were initiated on antiepileptic drugs (AEDs). Levetiracetam was the preferred agent in the majority of cases due to its minimal interaction with the cytochrome P450 enzyme system and consequently fewer pharmacokinetic interactions with Rifampicin, which is a potent enzyme inducer. Sodium valproate

was used in selected cases. Antiepileptic therapy was continued for a minimum of 12 months or until clinical and electroencephalographic resolution of seizure activity.

4.4.5 Management of Specific Complications

Cranial nerve palsy was managed conservatively with corticosteroids and close neurological monitoring. Eye patching was provided for patients with sixth nerve palsy causing diplopia. Patients with focal neurological deficits were referred to physiotherapy and rehabilitation services. Nutritional rehabilitation with high-protein, high-calorie diet and micronutrient supplementation was initiated in all malnourished patients.

HIV co-infected patients (n = 18) were managed in consultation with the ART Centre. Antiretroviral therapy (ART) was initiated or continued in all HIV-positive patients; however, initiation was deferred by 2–8 weeks after ATT commencement (depending on CD4 count) to reduce the risk of Immune Reconstitution Inflammatory Syndrome (IRIS).

4.4.6 Outcome Summary

The outcomes of the study cohort are summarised in Table 4. Of the 74 patients enrolled, 44 (59.5%) showed clinical improvement and were discharged on ATT with follow-up plans. Sixteen patients (21.6%) were discharged with residual neurological deficits including cognitive impairment, hemiparesis, or cranial nerve palsy. The in-hospital mortality was 14 patients (18.9%), with the majority of deaths occurring in patients presenting with MRC Stage III disease and those with HIV co-infection.

Table 4: Treatment and Outcome Summary (n = 74)

Outcome Measure	Value	Percentage (%)
Improved and discharged	44	59.5%
Residual neurological deficit at discharge	16	21.6%
In-hospital mortality	14	18.9%
Duration of hospital stay (mean)	18.4 days	—
Corticosteroid therapy given	72	97.3%
Intracranial pressure management required	34	45.9%
VP shunt inserted for hydrocephalus	12	16.2%
ATT regimen completed (4 drugs)	74	100%

VP = Ventriculo-Peritoneal; ATT = Anti-Tubercular Therapy; ICP = Intracranial Pressure.

5. DISCUSSION

The present cross-sectional study provides a comprehensive evaluation of the clinical, radiological, and sociodemographic profile of TBM patients attending a tertiary care centre in West Bengal, along with a systematic identification of prognostic factors. The findings are consistent with and contribute

to the existing body of literature on TBM in the Indian subcontinent, while adding important region-specific insights[11].

5.1 Sociodemographic Observations

The predominance of TBM in the 26–45-year age group (combined 52.7%) is consistent with reports from Misra et al. (2010) and Kalita et al. (2009), and reflects the active TB disease burden in the productive working-age population. The male predominance (62.2%) is a well-recognised epidemiological pattern, attributed to higher exposure risk, social habits such as alcohol and tobacco use, and delayed health-seeking behaviour in males[12].

The strikingly high proportion of rural (66.2%), illiterate or semi-literate (67.5%), and low-income (40.5%) patients reinforces the deep nexus between poverty and tuberculosis. These findings align with the Social Determinants of Health model, wherein socioeconomic disadvantage creates vulnerability through nutritional deficiency, overcrowding, limited access to healthcare, and reduced health literacy. Singh et al. (2019), in a multicentre study from northern India, reported similar socioeconomic clustering among TBM patients, corroborating the present findings[13].

The alarming prevalence of undernutrition (BMI < 18.5 in 51.4% of patients) is particularly noteworthy. Malnutrition impairs both innate and adaptive immunity, reducing the capacity to contain Mycobacterium tuberculosis and facilitating meningeal dissemination. Addressing nutritional deficiency through targeted supplementation programmes and food security interventions must therefore be considered a public health priority for TB control in West Bengal.

5.2 Clinical Profile

Fever, headache, and neck stiffness — the classical triad of meningitis — were present in over 80% of patients in this study. The high prevalence of altered sensorium (59.5%) and seizures (41.9%) at presentation indicates that a significant proportion of patients sought medical attention only after the disease had progressed to an advanced neurological stage. This delay is multifactorial, involving patient-related factors (limited health literacy, financial constraints, reliance on local healers) and system-related factors (delayed referral from peripheral facilities, lack of diagnostic capability at primary level).

Cranial nerve palsies were documented in 22.9% of patients, with the sixth cranial nerve most commonly affected — a finding consistent with the pathological predilection of the gelatinous basal exudate to compress the cranial nerves traversing the basal cisterns. Focal neurological deficits in 28.4% of patients are attributable to cerebral infarctions occurring as a result of the endarteritis of the perforating arteries of the circle of Willis[14].

The MRC staging distribution — Stage I (24.3%), Stage II (48.6%), Stage III (27.1%) — reflects a pattern of late presentation, with over 75% of patients presenting with moderate to severe neurological compromise. This has major implications for prognosis, as MRC Stage III at admission is the single most powerful predictor of mortality in most published series (Kalita et al., 2009; Thwaites et al., 2005). The present study confirmed this, with MRC Stage III carrying an OR of 4.05 ($p = 0.001$) for poor outcome.

5.3 CSF and Radiological Findings

The CSF profile in this cohort — lymphocytic pleocytosis (90.5%), elevated protein (86.5%), low glucose (75.7%) — is consistent with the typical biochemical footprint of TBM described in the literature. The low AFB smear positivity (12.2%) confirms the well-known limitation of smear microscopy for TBM, necessitating reliance on more sensitive diagnostic modalities. The CBNAAT (GeneXpert MTB/RIF) positivity of 36.5% in CSF is consistent with published data reporting sensitivities of 30–50% for this assay in TBM (Pandie et al., 2014). While superior to smear microscopy, CBNAAT still misses a substantial proportion of TBM cases, underscoring the continued importance of clinical and radiological diagnosis in resource-limited settings[15].

Basal meningeal enhancement was the most common MRI finding (62.2%), followed by hydrocephalus (45.9%) and cerebral infarction (29.7%). These findings closely mirror those reported by Gupta et al. (2015) and Kumar et al. (2020) from comparable Indian settings. MRI brain, where available, should be considered an indispensable tool in the diagnostic workup of suspected TBM, as it provides critical information on disease extent, complications, and prognosis that directly influences management decisions.

5.4 Prognostic Factors

The identification of significant prognostic factors in this study has important clinical and public health implications. HIV co-infection (OR 4.21) was the most powerful predictor of adverse outcome in this cohort. The immunosuppressive state in HIV-positive patients impairs granuloma formation, facilitates unchecked mycobacterial proliferation in the meninges, and predisposes to opportunistic co-infections that compound morbidity and mortality. These findings emphasise the critical need for routine HIV testing in all patients presenting with TBM, as well as early and optimised ART initiation.

Malnutrition (OR 3.15) and delayed diagnosis (OR 3.33) were both strongly and independently associated with poor outcomes. The impact of delayed diagnosis cannot be overstated — each day of untreated TBM is associated with incremental neuronal damage, progression of hydrocephalus, and cerebral infarction. Public health interventions aimed at shortening the diagnostic interval — through improved referral networks, point-of-care diagnostics at the district level, and community health worker training — are urgently needed[16].

Low socioeconomic status (OR 2.72) and rural residence (OR 2.45) are structural determinants of health that create barriers to timely access to care. Addressing these through universal health coverage, Jan Aushadhi programmes, and telemedicine-based neurological consultation services would significantly reduce the inequity in TBM outcomes.

The in-hospital mortality of 18.9% in this study is consistent with rates reported from other Indian tertiary centres (range 15–30%), and is markedly lower than rates reported from sub-Saharan Africa (40–60%), likely reflecting the relatively better clinical infrastructure and availability of comprehensive management at the study institution.

5.5 Clinical Management Perspectives

The near-universal use of corticosteroids (97.3%) in the present cohort reflects the adoption of evidence-based management. The landmark VIBAT trial by Thwaites et al. (2004) demonstrated a significant mortality benefit with dexamethasone in TBM, and this finding has since been incorporated into national and international guidelines. The extended 12-month ATT duration

employed in this study, as opposed to the 6-month regimen used in pulmonary TB, is supported by evidence demonstrating higher relapse rates with shorter durations in TBM[17].

The VP shunt insertion rate of 16.2% in the present study is clinically significant. Hydrocephalus is a major preventable cause of neurological deterioration in TBM, and timely neurosurgical intervention can be life-saving and function-preserving. Seamless collaboration between the neurology and neurosurgery teams is, therefore, essential in the management of complicated TBM[18].

The management of seizures with Levetiracetam rather than Phenytoin or Carbamazepine deserves special mention. Rifampicin, a potent inducer of hepatic cytochrome P450 enzymes, significantly reduces plasma levels of Phenytoin and Carbamazepine, potentially compromising seizure control. Levetiracetam, being renally excreted and not metabolised through the P450 system, avoids this pharmacokinetic interaction and should be the preferred antiepileptic agent in TBM patients on ATT, a practice that is increasingly supported by clinical pharmacology literature[19-20].

6. CONCLUSION

The present study confirms that Tuberculous Meningitis continues to be a disease of the socially marginalised — predominantly affecting young males from rural, low-income, and malnourished backgrounds in West Bengal. The clinical burden at presentation is severe, with a majority of patients presenting with MRC Stage II or III disease, underscoring the critical problem of delayed diagnosis and late health-seeking behaviour in this region.

The most significant prognostic determinants identified in this study are HIV co-infection, advanced MRC stage at admission, delayed diagnosis (> 14 days), malnutrition, and immunosuppressive status. These factors, when present in combination, portend a particularly grim prognosis. Early clinical recognition, prompt lumbar puncture, urgent neuroimaging, and rapid initiation of ATT with corticosteroids constitute the therapeutic cornerstones that must be expedited to achieve better outcomes.

The radiological findings, particularly basal meningeal enhancement on contrast-enhanced MRI brain, remain the most reliable and specific markers for TBM diagnosis in the absence of microbiological confirmation. The limitations of CSF AFB smear highlight the necessity of CBNAAT as the preferred first-line microbiological test, supplemented by clinical and radiological judgment in ambiguous cases.

At the health systems level, the findings of this study make a strong case for integrating TBM-specific protocols into the national TB elimination programme, with an emphasis on neuro-TB management training at district hospitals, fast-track referral pathways for suspected TBM, and expansion of HIV-TB co-management services.

7. RECOMMENDATIONS

Clinical Level

- All patients presenting with sub-acute meningitis should be evaluated for TBM as a priority differential diagnosis, particularly in HIV-positive individuals and the immunocompromised.
- Lumbar puncture should be performed without undue delay in the absence of contraindications. CBNAAT on CSF should be the preferred first microbiological test over AFB smear.
- Contrast-enhanced MRI brain should be performed in all suspected TBM cases to assess disease extent, complications, and guide prognosis.
- Adjunctive dexamethasone should be administered to all TBM patients regardless of MRC stage, as per current WHO and NTEP guidelines.
- Antiepileptic therapy in TBM patients on ATT should preferably employ Levetiracetam to avoid cytochrome P450-mediated drug interactions.
- VP shunting should be considered early for patients with progressive hydrocephalus unresponsive to medical management.

Public Health Level

- TB contact tracing and community-based screening should be intensified in rural areas of West Bengal, targeting high-risk socioeconomic groups.
- Nutrition rehabilitation programmes and supplementary feeding schemes should be expanded for TB-affected households.
- Routine HIV testing must be offered to all TBM patients as part of the NACP-NTEP convergence framework.
- Telemedicine-based neurology consultation services should be developed to reduce the diagnostic gap at district and sub-district levels.
- Health literacy campaigns targeting TB symptoms, early health-seeking, and treatment adherence should be reinforced through ASHA workers and community health platforms.

Research Level

- A multicentre prospective cohort study across West Bengal is recommended to generate more robust, region-representative data on TBM epidemiology and outcomes.
- Future studies should incorporate advanced molecular diagnostics (metagenomic NGS, MTB-LAMP) and novel biomarkers for early TBM diagnosis.
- Longitudinal follow-up studies are needed to characterise long-term neurological and neuropsychological sequelae of TBM survivors.

8. LIMITATIONS OF THE STUDY

The authors acknowledge the following limitations of the present study:

- The cross-sectional design precludes causal inference; only associations between risk factors and outcomes have been established.
- The study was conducted at a single tertiary centre, which may limit the generalisability of findings to the broader population of West Bengal.
- The relatively small sample size (n = 74) may have reduced the statistical power to detect significant associations for less prevalent risk factors such as tobacco use and illiteracy.

- Mycobacterial culture from CSF, which is the gold standard for TBM diagnosis, was not performed in all patients due to resource limitations and the time-intensive nature of the test.
- Long-term neurological outcomes beyond the period of hospitalisation were not assessed, limiting the conclusions that can be drawn about residual disability.

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10.Funding: This study received no external funding. It was conducted as part of routine institutional academic research.

11.Submission Declaration: This submission has not been published anywhere previously and that it is not simultaneously being considered for any other journal**.**

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