Tuberculous meningitis (TBM) is a frequent cause of meningitis in South Africa (SA) and has a dismal prognosis. In a study from a Cape Town hospital, TBM accounted for more than half of adult meningitis cases over a 6-month period; at 6-month follow-up mortality was 48%. HIV co-infection, particularly in patients with severe immunosuppression, increases the risk of disseminated forms of tuberculosis (TB), such as meningitis, and contributes significantly to the TBM burden in high HIV/TB settings. The diagnosis of TBM is often complicated and optimal management strategies are uncertain; such challenges are likely to contribute to poor outcome in affected patients.

**Diagnosis**

Early diagnosis and treatment initiation are crucial to improve outcome in TBM, as advanced disease, prolonged symptom duration and delayed treatment initiation are associated with increased mortality during hospitalisation, when the majority of deaths occur. As discussed below, definitive microbiological tests for TBM are insensitive; therefore diagnosis and TB treatment initiation are usually based on a combination of suggestive clinical and cerebrospinal fluid (CSF) findings, evidence of TB outside the central nervous system (CNS), supportive features on brain imaging (if available) and exclusion of other common causes for meningitis.

**Clinical findings**

TBM typically presents sub-acutely after an average of 5 - 30 days of neurological symptoms (e.g. headache, vomiting, neck pain/ stiffness, seizures, focal neurological signs and confusion) – unlike bacterial meningitis, which usually presents more acutely, but similar to cryptococcal meningitis (CM). However, shorter (a few days) or longer (>1 month) duration of neurological symptoms is well described and does not exclude the diagnosis of TBM. Systemic symptoms of *Mycobacterium tuberculosis* infection, such as cough, night sweats and loss of weight, may be indicative of TB, but may also be present with other causes of meningitis. Untreated HIV infection frequently results in loss of weight.

**Routine CSF features**

The usual CSF findings in TBM include the combination of a clear appearance, lymphocyte-predominant pleocytosis (50 - 1 000 x 10⁶/L), increased protein concentrations (0.5 - >2.5 g/L) and decreased glucose (CSF/blood ratio <0.5 or absolute value <2.2 mmol/L). However, atypical routine CSF findings that may cause diagnostic uncertainty are well described, including a mildly elevated or normal white cell count, normal protein or glucose concentrations, neutrophil predominance, or completely normal CSF. Atypical findings occur more frequently in the context of HIV infection, and a normal CSF white cell count is particularly common with severe immune suppression (CD4⁺ count <50 cells/μL).

**Features of TB elsewhere**

A search for evidence of TB outside the CNS is crucial in the diagnostic work-up of suspected TBM. Chest radiography should be performed in all cases, as abnormalities suggestive of TB are seen in a large proportion (33 - 85%) of TBM patients. Further investigations such as sputum examination (smear, culture and/or Xpert), lymph node fine-needle aspiration biopsy and abdominal ultrasound should be considered, depending on the clinical presentation.

**Brain imaging**

The most common reason for brain imaging (usually computed tomography (CT)) in suspected TBM in SA is to rule out a contraindication to lumbar puncture (LP). Contrast-enhanced
brain imaging may additionally be useful in suspected TBM where diagnostic uncertainty exists. Typical imaging features, including hydrocephalus, basal meningeal enhancement, tuberculoma(s) and/or infarcts, may provide supportive evidence for a diagnosis of TBM in such cases (Fig. 1). However, brain imaging may be completely normal, especially early during the course of the disease. Furthermore, several factors may complicate the interpretation of brain imaging results in HIV-infected patients. In particular, generalised cerebral atrophy is common in the context of HIV and could be confused with communicating hydrocephalus, and a tuberculoma has a similar radiological appearance to other causes of intracranial space-occupying lesions, such as toxoplasmosis, commonly seen in HIV-infected patients.

Exclusion of other causes of meningitis

The most common differential diagnosis for TBM in SA, which predominantly affects HIV-infected patients, is CM. CM cannot be distinguished from TBM by clinical or routine CSF findings and should be investigated by CSF India ink and/or cryptococcal antigen testing with or without fungal culture. CSF Gram staining and bacterial culture should be performed to exclude pyogenic bacterial meningitis. However, negative stain and culture results do not always exclude a diagnosis of bacterial meningitis, especially in patients partially treated with antibiotics before presentation, and a high index of suspicion should be maintained in such cases, as well as in those with a CSF neutrophil predominance. Meningitis due to non-opportunistic viruses (e.g. Enterovirus) that does not require specific treatment may mimic TBM. These viruses can be investigated in selected patients by CSF viral polymerase chain reaction (PCR). HIV itself is often associated with chronic CSF inflammation, including mildly increased lymphocyte counts (5 - 25 cells ×10⁶/L) and protein concentrations (0.46 - 1 g/L). This emphasises the importance of considering CSF results in the context of clinical and other investigative findings. Patients in whom considerable doubt regarding the diagnosis exists, such as those with atypical presentations and mild CSF abnormalities, a watch-and-wait approach could be employed with an LP repeated, if necessary, a few days after the initial LP. A limited list of other infectious differential diagnoses of HIV-associated TBM and their investigation is presented in Table 1.

Definitive diagnostic methods

Detection of acid-fast bacilli in CSF by smear examination is a rapid, inexpensive method of confirming the diagnosis of TBM. However, studies from SA report extremely low diagnostic yields by this method. Culture of M. tuberculosis from CSF is similarly an insensitive diagnostic test and as time to positivity is at least 2 weeks, it is too slow to be clinically relevant in guiding treatment initiation in TBM. Measures shown to improve the sensitivity of these microbiological tests, which can easily be implemented in our setting, include analysing large volumes of CSF (>6 mL is advised), and performing repeated LPs.

The Xpert MTB/RIF test (Xpert, Cepheid, Sunnyvale, CA, USA), a real-time PCR assay for M. tuberculosis that simultaneously detects rifampicin (RIF) resistance, is of potential value in the rapid diagnosis of TBM. In a study of TBM patients from Vietnam, the overall sensitivity of Xpert on CSF was 59.3% using clinical diagnosis as the reference standard, and the specificity was 99.5%. In this study, the sensitivity of Xpert was significantly higher in HIV-infected compared with HIV-uninfected patients (sensitivity 78.8% v. 47.9%). In a predominantly HIV-infected SA TBM cohort study (87% of the 204 participants were HIV-infected), the sensitivity and specificity of Xpert were 67% and 94%, respectively; this analysis included patients with definite TBM (CSF M. tuberculosis culture and/or Amplicor PCR positive), compared with patients with other causes of meningitis as controls. Although the overall sensitivity decreased to 36% when probable TBM was included in the reference standard, using a larger volume (3 mL) of centrifuged CSF compared with 1 mL of neat CSF increased the sensitivity markedly from 26% to 65% in this analysis.

Management

TB treatment

Similar to guidelines globally, current SA Department of Health (SA DoH) guidelines suggest RIF, isoniazid, ethambutol and pyrazinamide for 2 months, followed by RIF and isoniazid for a further 7 months as first-line treatment in adults with CNS TB. However, the principles of treating TBM are based on those developed for pulmonary TB and not informed by randomised controlled trials (RCTs) in TBM. RIF is one of the backbone drugs in TBM treatment, but the evidence for the current recommended dose (10 mg/kg/day) is scant and may be too low. RIF has poor CSF penetration and TBM patients often present critically ill, vomit and receive drugs through a nasogastric tube. All these factors may further contribute to suboptimal CNS TB drug concentrations. Isoniazid and pyrazinamide have good CSF penetration and are therefore considered critical drugs in TBM treatment. However, the choice of the fourth drug during the initiation phase of TBM treatment is contentious. Ethambutol crosses the meninges poorly at the recommended dose. Alternatives such as streptomycin and ethionamide are of limited use in TBM owing to poor CNS penetration, dose-limiting toxicity and intolerable
gastrointestinal side-effects in adults. Fluoroquinolones such as levofloxacin and moxifloxacin have high bactericidal activity, are safe and well tolerated and have good CSF penetration; therefore they are attractive treatment options for TB.

There is increasing interest in exploring alternative evidence-based treatment regimens for TB. RCT findings suggest a mortality benefit from an ‘intensified’ treatment regimen early during TB treatment.[10] This study investigated the safety and pharmacokinetic profiles of higher-than-normal dose, intravenous (IV) RIF and oral moxifloxacin in HIV-infected and -uninfected TBM patients. Although not powered to detect a mortality benefit, an improved outcome was observed in patients receiving IV RIF (~13 mg/kg/d) than in those on the oral standard dose during the initial 2 weeks of TB treatment. Patients who received IV RIF had a reduced mortality at 6-month follow-up (34%) compared with those who received oral TB treatment. Patients who received IV RIF had a reduced mortality compared with placebo, which was significant (p=0.04).

Corticosteroids
Corticosteroid treatment is associated with improved survival in HIV-uninfected patients with TB and is recommended in all affected patients, regardless of HIV status.[11] In an RCT of adjunctive dexamethasone in TB, this medication was associated with a reduced risk of death compared with placebo, which was significant in all patients at 9-month follow-up (relative risk: 0.69; p=0.01),[12] but only a trend for mortality benefit with dexamethasone was observed in subgroup analysis of HIV-infected patients (p=0.08). Of note, corticosteroid treatment was associated with a decrease in severe adverse events, in particular hepatitis (0/274 v. 8/271 cases in the placebo group; p=0.004).

Table 1. Infective causes and their investigation in the differential diagnosis of patients with suspected HIV-associated tuberculous meningitis and/or intracerebral tuberculosis

<table>
<thead>
<tr>
<th>Differential diagnosis</th>
<th>Investigation(s)*</th>
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<tbody>
<tr>
<td>Cryptococcal meningitis</td>
<td>India ink, cryptococcal antigen testing, fungal culture</td>
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<tr>
<td>Bacterial meningitis</td>
<td>Gram stain, bacterial culture</td>
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<tr>
<td>Non-opportunistic viral meningitis (e.g. Enterovirus)</td>
<td>Viral PCR</td>
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<tr>
<td>Neurosyphilis</td>
<td>VDRL and TPHA or FTA tests</td>
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<tr>
<td>Herpesvirus meningencephalitis (e.g. HSV, HZV, CMV, HHV-6)</td>
<td>Viral PCR</td>
</tr>
<tr>
<td>Cryptococcomas</td>
<td>Serum p24 antigen and conversion of antibody tests</td>
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<tr>
<td>Immunocompromised meningitis</td>
<td>Exclusion of other causes</td>
</tr>
<tr>
<td>HIV seroconversion</td>
<td>Mycobacterial culture</td>
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<tr>
<td>Chronic HIV infection</td>
<td></td>
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<tr>
<td>Non-tuberculous mycobacteria (e.g. MAC)</td>
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<tr>
<td>Intracerebral space-occupying lesion(s)*</td>
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<tr>
<td>Toxoplasmosis</td>
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<tr>
<td>Primary CNS lymphoma</td>
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<td>Bacterial brain abscess</td>
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<tr>
<td>Cryptococcus</td>
<td></td>
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<tr>
<td>Neurosyphilis (gamma)</td>
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<tr>
<td>PML-IRIS</td>
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</tbody>
</table>

Treatment of HIV infection in TBM patients
A large proportion of HIV-infected patients are antiretroviral therapy (ART)-naive or have defaulted ART at TB presentation. Starting ART during TB treatment improves outcome in HIV/TB co-infected patients, and one large RCT from Vietnam has provided guidance on the timing of ART in such patients.[12] In this study of patients with HIV-associated TB, there was no difference in 9-month mortality between severely immunosuppressed TB patients (median CD4 count = 41 cells/μL) who started ART immediately (within 7 days of TB treatment) and those who started later (2 months after TB treatment initiation). Grade 4 adverse events were significantly more frequent in the ART group who started treatment immediately (80 v. 69%; p=0.04), suggesting that delayed treatment may be preferable. In view of these findings and the risk of CNS TB-IRIS, current SA DoH ART guidelines recommend starting ART 4 - 6 weeks after TB treatment in TB patients, regardless of CD4 count.

Paradoxical TBM-IRIS
TB-IRIS occurs owing to an exaggerated immune response against TB antigens in HIV-infected patients after ART initiation. Paradoxical TB-IRIS occurs in patients who typically show clinical improvement after starting appropriate TB treatment, and subsequently present with new, recurrent or worsening TB symptoms after ART initiation in the context of a recovering immune system. Neurological TB-IRIS is the most life-threatening form of TB-IRIS, with an associated mortality of 13 - 75%. Neurological IRIS may present as meningitis, intracerebral tuberculosis(s), tuberculous brain abscess, radiculomyelitis or spinal epidural abscess. Patients frequently present with atypical inflammatory features such as focal meningeal enhancement on brain imaging (Fig. 2). In an observational study from Cape Town, 47% of TB patients developed TBM-IRIS at a median of 14 days after ART initiation, while mortality due to TBM-IRIS was 12.5% (2/16).
orally (or IV dexamethasone) for at least 2 weeks, after which the patients with neurological TB-IRIS with prednisone 1.5 mg/kg/d corticosteroids in neurological TB-IRIS, our practice is to treat all on these findings and anecdotal evidence of the benefit of symptomatic improvement associated with prednisone.\[15\] Based therapeutic procedures. Additionally, there was also significant benefit of non-life-threatening paradoxical TB-IRIS, significant benefit available for TB-IRIS. In an RCT of prednisone for the treatment of \(M.\) tuberculosis (reflected by culture positivity). Factors at TBM presentation associated with subsequent TBM-IRIS included high CSF neutrophil count and high CSF bacillary load of \(M.\) tuberculosis meningitis in adolescents and adults. N Engl J Med 2004;351:1741-1751. Corticosteroids are the only evidence-based treatment currently available for TB-IRIS. In an RCT of prednisone for the treatment of non-life-threatening paradoxical TB-IRIS, significant benefit was demonstrated with prednisone compared with placebo. The combined endpoint was days hospitalised and outpatient therapeutic procedures. Additionally, there was also significant symptomatic improvement associated with prednisone.\[13\] Based on these findings and anecdotal evidence of the benefit of corticosteroids in neurological TB-IRIS, our practice is to treat all patients with neurological TB-IRIS with prednisone 1.5 mg/kg/d orally (or IV dexamethasone) for at least 2 weeks, after which the dose is reduced gradually according to clinical response. Temporary interruption of ART should only be considered in patients with a severe or persistently depressed level of consciousness and in those with severe neurological disability unresponsive to corticosteroid therapy.\[16\] A vital component of the management of HIV-associated TBM patients who will start ART is a comprehensive discussion with the patient, and preferably also with a family member, about the risk of developing neurological TB-IRIS, the typical symptoms that could be expected and the need to return to hospital should any of these develop.

**Conclusion**

Owing to a lack of rapid, sensitive diagnostic methods, the diagnosis of TB relies strongly on suggestive clinical, laboratory and imaging features and the exclusion of common differential diagnoses. The optimal TB treatment regimen remains to be defined and results of ongoing RCTs exploring different treatment options are eagerly awaited. Neurological TB-IRIS is a life-threatening complication in HIV-associated TBM that should be anticipated in patients who start ART during TB treatment.

**References**