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Brain under Parasitic Siege — A Comprehensive Descriptive Review of Neuroparasitic Diseases

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Abstract: *Parasitic infections of the central nervous system (CNS) represent a significant yet frequently under-recognised cause of neurological morbidity and mortality worldwide. These infections are caused by a diverse range of protozoa, helminths, and free-living amoebae and may lead to acute or chronic neurological manifestations through mechanisms including direct neural invasion, immune-mediated inflammation, vascular compromise, and blood–brain barrier disruption. Clinically, neuroparasitic diseases present with a broad spectrum of symptoms, ranging from seizures and focal neurological deficits to encephalopathy, cognitive impairment, and coma. This narrative review synthesises current evidence published between 2000 and 2025 regarding the pathophysiology, clinicopathological features, diagnostic approaches, and management strategies of major neuroparasitic diseases, including cerebral malaria, neurocysticercosis, neurotoxoplasmosis, human African trypanosomiasis, and amoebic encephalitis. Emphasis is placed on integrating clinical presentation with histopathological and neuroimaging findings to support diagnostic reasoning and therapeutic decision-making. Advances in diagnostic methodologies, including molecular techniques, magnetic resonance imaging, and computed tomography are discussed, alongside emerging perspectives on the potential role of artificial intelligence (AI) in diagnostic support and epidemiological modelling. By consolidating dispersed evidence into a unified framework, this review aims to serve as an educational and interdisciplinary reference for clinicians and researchers encountering neuroparasitic diseases in neurological practice.*

Keywords: *cerebral malaria; neurocysticercosis; neurotoxoplasmosis; human African trypanosomiasis; primary amoebic meningoencephalitis.*

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1. Introduction

Parasitic infections remain a significant but often neglected cause of neurological disease worldwide, particularly in tropical and resource-limited regions. These infections can affect the central nervous system (CNS) through a variety of mechanisms, including direct invasion of neural tissue, immune-mediated inflammation, vascular occlusion, and space-occupying lesions, leading to a wide spectrum of clinical manifestations ranging from headaches and seizures to coma and long-term cognitive impairment (Garcia, Nath, & Del Brutto, 2019; Mallewa & Wilmshurst, 2014). Although many parasitic infections are asymptomatic or subclinical, those that involve the CNS can be associated with severe morbidity and mortality, especially when diagnosis is delayed or treatment access is limited (Garcia, Nath, & Del Brutto, 2019).

Protozoan parasites such as *Plasmodium falciparum (P. falciparum)* and *Toxoplasma gondii* (T. gondii) are notable examples: *P. falciparum* can cause cerebral malaria, a life-threatening encephalopathy characterised by coma and seizures, mainly affecting young children in sub-Saharan Africa, while T. gondii may cause encephalitis in immunocompromised patients and has been linked with behavioural and neuropsychiatric effects in a proportion of infected individuals (Elshafey et al., 2023). Helminths such as *Taenia solium (T. solium)* and *Schistosoma spp.* contribute substantially to acquired epilepsy and focal neurological deficits in endemic areas through mechanisms related to cyst formation and granulomatous inflammation within the nervous system (Carpio & Romo, 2014). *T. solium* larvae form cysticerci in the central nervous system (neurocysticercosis), which is one of the most common preventable causes of epilepsy and is estimated to account for approximately 30 % of epilepsy cases in endemic regions; cysts and their subsequent host inflammatory response disrupt neural tissue, leading to seizures and focal deficits detectable on neuroimaging (World Health Organization [WHO], 2021). Neuroschistosomiasis arises when *Schistosoma* eggs or, rarely, adult worms reach the brain or spinal cord and induce a granulomatous inflammatory response, producing mass-effect lesions or localised damage; clinical reports and reviews document that this granulomatous inflammation is associated with seizures, encephalopathy, and focal neurological signs in affected individuals (Nascimento-Carvalho & Moreno-Carvalho, 2005).

Moreover, other parasitic pathogens including African trypanosomes and free-living amoebae such as *Naegleria fowleri (N. fowleri)* highlight the diverse etiologies of parasitic CNS disease. African trypanosomiasis manifests with progressive neuropsychiatric and sleep-wake disturbances upon CNS invasion, while infections by free-living amoebae typically lead to rapidly fatal meningoencephalitis. These infections impose a considerable burden of disability-adjusted life years (DALYs) and socioeconomic impact in affected populations, yet they often receive limited attention in research, policy, and clinical practice relative to their morbidity (Garcia, Nath, & Del Brutto, 2019).

Given this landscape, clinicians and researchers must maintain a high index of suspicion for neuroparasitic disease in patients with relevant epidemiological exposures and neurological symptoms, as early recognition and appropriate management can mitigate long-term complications. The complexity of host–parasite interactions, variable clinical presentations, and diagnostic challenges underscore the need for comprehensive review and synthesis of current evidence on these important CNS infections.

Although this review does not aim to introduce novel experimental data, its significance lies in the interdisciplinary integration of parasitology, neuropathology, neuroimaging, clinical neuroscience, and artificial intelligence (AI). Neuroparasitic diseases are frequently underrepresented in mainstream neurological literature despite their substantial global burden. By consolidating dispersed clinical, pathological, and diagnostic evidence into a unified framework, this review provides a clinically relevant reference for neurologists, neurosurgeons, radiologists, and researchers who may encounter these entities infrequently but with potentially severe consequences.

2. Material and Methods

The primary objective of this narrative review was to address the following research question: *How do major parasitic infections affect the central nervous system with respect to pathophysiological mechanisms, clinical manifestations, diagnostic approaches, and management strategies?* A narrative descriptive review methodology was selected due to the heterogeneity of neuroparasitic diseases and the variability in study design, diagnostic criteria, and epidemiological context. This approach allows qualitative synthesis and interpretive integration of diverse clinical and experimental evidence, which would be unsuitable for quantitative meta-analysis.

A comprehensive literature search was performed to identify studies on parasitic infections with neurological manifestations. Databases searched included PubMed, Scopus, Web of Science, and Google Scholar, covering publications from 2000 up to 2025. Search terms were selected to capture both specific parasites and neurological involvement and were combined using Boolean operators to ensure precision and completeness. The main search strategy combined parasite-specific terms such as "Neurocysticercosis" OR "*Taenia solium*"; "Cerebral malaria" OR "*Plasmodium falciparum*"; "Neurotoxoplasmosis" OR "*Toxoplasma gondii*"; "Human African trypanosomiasis" OR "*Trypanosoma brucei*"; and "*Naegleria fowleri*" OR "*Acanthamoeba* spp." with neurological keywords including "neurological manifestations" OR "central nervous system" OR "encephalitis".

Additionally, data from the *Centres for Disease Control and Prevention (CDC*) website were consulted to provide current and historical epidemiological information; multiple years of *CDC* reports were reviewed to ensure a comprehensive overview of trends and guidelines. Other relevant guidelines from the *World Health Organization (WHO*) were also selected to provide standardised definitions, diagnostic criteria, and management recommendations for these parasitic diseases.

Articles were included if they: reported clinical manifestations, diagnostic methods, or treatment of parasitic infections involving the CNS, were original research, systematic reviews, or narrative reviews published in peer-reviewed journals, focused on human subjects. Exclusion criteria were: animal-only studies, unless providing mechanistic insight relevant to human CNS disease, case reports with insufficient clinical data, non-English publications.

To improve conceptual balance, repetitive clinical descriptions were condensed, while sections addressing pathogenic mechanisms and diagnostic challenges were expanded to enhance interpretative depth. This structuring was undertaken to improve coherence without compromising educational clarity.

3. Results and Discussion

As this study is a narrative review, it does not present original datasets, statistical analyses, or quantitative results. Instead, the results consist of a structured qualitative synthesis of published clinical, pathological, and diagnostic findings. To reduce redundancy, repeated clinical descriptions were consolidated, and emphasis was placed on interpretative relevance and clinicopathological correlation rather than repetition of symptom lists.

3.1. Pathophysiological Mechanisms

3.1.1. Direct parasitic invasion

Many parasites can cross the blood–brain barrier (BBB) through various mechanisms, including exploiting existing anatomical routes or disrupting barrier integrity. For example, *N. fowleri* trophozoites invade the central nervous system via the olfactory neuroepithelium: after contaminated water enters the nasal cavity, the amoebae travel along the olfactory nerves, traverse the cribriform plate, and reach the olfactory bulbs, leading to fulminant primary amoebic meningoencephalitis (PAM). Once in the brain parenchyma, *N. fowleri* induces intense inflammation, tissue necrosis, and rapid clinical deterioration. Similarly, *Toxoplasma gondii* tachyzoites can traverse the BBB, causing encephalitis, particularly in immunocompromised

individuals (Alloo et al., 2022). Organisms physically invade brain parenchyma or meninges (e.g., *T. gondii* tissue cysts, *Taenia solium* cysts, *Naegleria* trophozoites), causing local necrosis, oedema, and focal deficits (Alloo et al., 2022; Chao-Pellicer et al., 2024).

3.1.2. Vascular and metabolic effects

Microvascular sequestration and endothelial dysfunction are central to cerebral malaria pathogenesis, leading to blood–brain barrier (BBB) disruption, ischaemia, and cerebral oedema (Garcia, Nath, & Del Brutto, 2019). Space-occupying lesions and mass effect: Helminthic cysts (neurocysticercosis) or granulomas can cause mass effect, focal deficits, hydrocephalus, and provoke seizures (Butala et al., 2021).

3.1.3. Immune-mediated Inflammation

The host's immune response to parasitic infections often leads to inflammation within the CNS, contributing to tissue damage and neurological dysfunction. In cerebral malaria, for example, Plasmodium falciparum-infected erythrocytes adhere to endothelial cells, causing microvascular obstruction and subsequent inflammatory responses (Garcia, Nath, & Del Brutto, 2019). This inflammation can result in cerebral oedema, increased intracranial pressure, and neuronal injury.

3.1.4. Vascular Disruption and Ischaemia

Parasites can induce vascular changes that compromise cerebral blood flow. In Schistosoma infections, for instance, eggs deposited in the CNS can elicit granulomatous inflammation, leading to vascular occlusion and ischaemic damage (Stelzle et al., 2023). These vascular disruptions can exacerbate neurological deficits and complicate disease management.

3.1.5. Metabolic and Toxin-mediated Effects

Some parasites produce metabolites or toxins that directly affect neuronal function. Trypanosoma brucei, the causative agent of human African trypanosomiasis, secretes factors that can alter neurotransmitter levels and disrupt neuronal signaling (Kennedy, 2006). Additionally, the metabolic demands of rapidly proliferating parasites can lead to hypoglycaemia and other metabolic disturbances, further impairing CNS function.

While individual neuroparasitic diseases differ in transmission and biological behaviour, several convergent pathogenic pathways emerge, including blood–brain barrier disruption, immune-mediated neurotoxicity, microvascular compromise, and chronic neuroinflammation. Recognising these shared mechanisms allows for a more unified understanding of neurological injury across parasitic infections and supports the rationale for adjunctive anti-inflammatory and neuroprotective strategies alongside antiparasitic therapy (Aloo et al., 2022).

3.2. Major Parasitic Infections with Neurological Manifestations

3.2.1. Cerebral malaria

Cerebral malaria (CM) is driven by the sequestration of *Plasmodium falciparum*–infected erythrocytes (iRBCs) in the cerebral microvasculature (Figure 1). Infected red blood cells express variant surface antigens, especially *Plasmodium falciparum* erythrocyte membrane protein-1 (PfEMP1), which binds to endothelial receptors such as intercellular adhesion molecule-1 (ICAM-1) and endothelial protein C receptor (EPCR) on brain endothelial cells. This cytoadherence leads to microvascular obstruction, reduced cerebral perfusion, and localised hypoxia. Specific PfEMP1 variants that bind both ICAM-1 and EPCR are strongly linked to severe cerebral involvement and brain swelling in paediatric CM cases (Adams et al., 2021).

Sequestration activates endothelial cells and promotes a pro-inflammatory response. Endothelial activation increases expression of adhesion molecules, recruits leukocytes, and amplifies cytokine release (e.g., TNF-α, IFN-γ), which further disrupts the blood–brain barrier

(BBB). BBB breakdown permits plasma leakage and vasogenic oedema, contributing to raised intracranial pressure and neuronal dysfunction. Procoagulant changes, including thrombin generation and fibrin deposition from PfEMP1–EPCR interactions, also contribute to microcirculatory damage and BBB impairment. Astrocytes and microglia become activated, exacerbating neuroinflammation and cytotoxic injury (Bernabeu & Smith, 2017; Shabani et al., 2017).

Thus, a combination of microvascular obstruction, endothelial dysfunction, inflammatory responses, and BBB disruption underlies the neurological manifestations of CM, including coma, seizures, and long-term sequelae (Shabani et al., 2017).

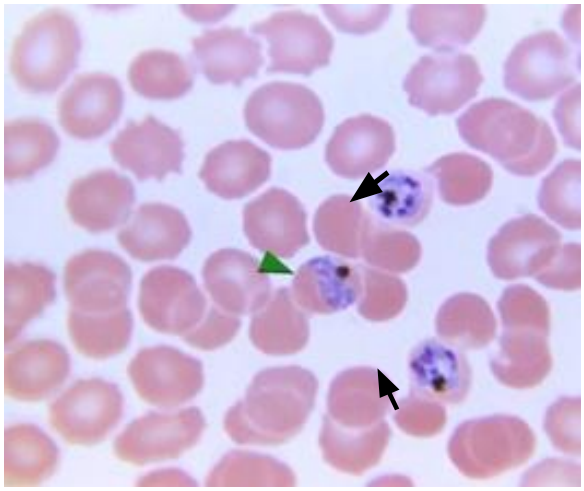

Figure 1. Microscopic imaging of three Plasmodium malariae trophozoites inside the red blood cells. One of the parasites had assumed a band form morphology (arrow) (Wright-stained blood smear) (public domain, Centres for Disease Control and Prevention).

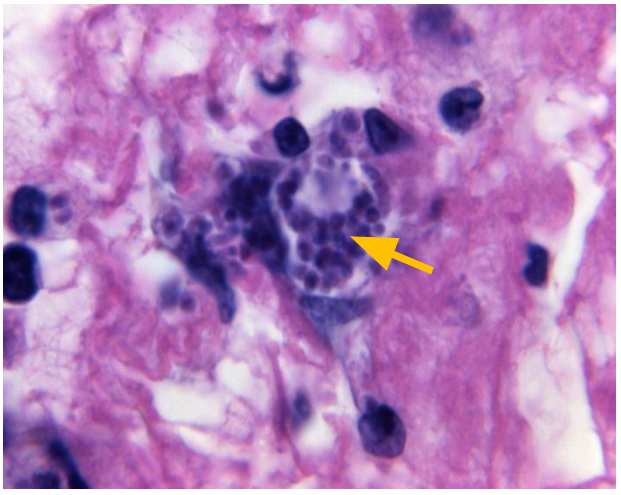

Figure 2. Microphotography of a tissue sample revealing a close view of a darkly stained Toxoplasma gondii tissue cyst (yellow arrow), which contained numbers of spherical-shaped bradyzoites (HE, x1000) (public domain, Centres for Disease Control and Prevention).

Cerebral malaria (CM) is the most severe neurological complication of *Plasmodium falciparum* infection and a major cause of mortality in endemic regions. It is defined by unconsciousness or coma that cannot be attributed to other causes, such as hypoglycaemia or meningitis, in a patient with confirmed parasitemia (Albrecht-Schgoer et al., 2022). CM occurs in both adults and children, but children under five years in sub-Saharan Africa are most frequently affected. Common manifestations include impaired consciousness, seizures, and focal neurological deficits. Paediatric patients may additionally present with brainstem dysfunction, including abnormal pupillary responses and irregular respiration (Chairunnisa, Putri, & Arwati, 2023). Long-term sequelae in survivors may include cognitive impairment, hemiplegia, epilepsy, and behavioural changes (Albrecht-Schgoer et al., 2022). Mortality remains high, often due to raised intracranial pressure and systemic complications (CDC, 2024).

Diagnosis of CM is primarily clinical, supported by parasitological confirmation. CM should be suspected in any patient presenting with fever and impaired consciousness in an endemic area or following recent travel to such regions (Albrecht-Schgoer et al., 2022). Laboratory confirmation involves detecting *P. falciparum* on peripheral blood smear microscopy or by rapid diagnostic tests. A high parasite burden is frequently observed in CM patients. Unlike bacterial or viral meningitis, meningeal signs (neck stiffness, photophobia) are usually absent, making careful clinical evaluation essential. In settings where feasible, lumbar puncture may be performed to exclude other causes of coma (Chairunnisa, Putri, & Arwati, 2023).

Cerebral malaria is a medical emergency, requiring immediate intervention. The *World Health Organization (WHO*) recommends intravenous artesunate as first-line therapy for severe *P.*

falciparum infections, including CM, due to superior mortality reduction compared to quinine (*WHO*, 2021). Once the patient can tolerate oral medication, treatment should transition to a full course of artemisinin-based combination therapy (ACT), such as artemether-lumefantrine. If artesunate is unavailable, parenteral artemether or quinine should be administered immediately (CDC, 2024). Supportive care is essential, including management of seizures, hypoglycaemia, and raised intracranial pressure, as well as careful monitoring of vital signs and organ function (*CDC,* 2024; Albrecht-Schgoer et al., 2022). Routine prophylactic anticonvulsants are not recommended unless respiratory support is available, due to potential adverse effects (Chairunnisa, Putri, & Arwati, 2023).

3.2.2. Neurotoxoplasmosis

Toxoplasma gondii is an intracellular protozoan (Figure 2) that invades the host via ingestion of cysts or oocysts. After systemic dissemination, tachyzoites (Figure 2) penetrate the blood–brain barrier through infected leukocytes and direct endothelial adhesion. Within the CNS, tachyzoites replicate in neurons and glial cells, forming parasitophorous vacuoles; immunological pressure induces conversion into bradyzoites with chronic cyst formation. In immunocompromised patients, latent bradyzoites reactivate, leading to focal necrotising encephalitis with marked microglial activation, perivascular lymphocytic infiltration, and cytokine-mediated neuroinflammation that disrupts neural circuits and contributes to cerebral oedema (Elsheikha, Marra, & Zhu, 2020; Dubey & Jones, 2008).

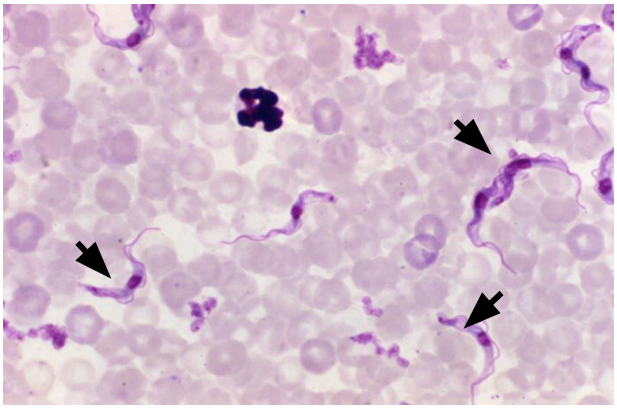

Figure 3. Microphotograph of a Giemsa-stained blood smear specimen showing the presence of a number of parasitic Trypanosoma brucei protozoa (black arrows) (x1000) (public domain, Centres for Disease Control and Prevention)

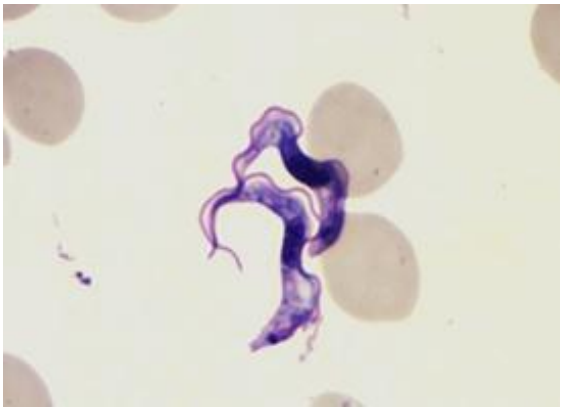

Figure 4. Microphotograph of a Giemsa-stained blood smear specimen showing the presence of two Trypanosoma brucei protozoa - detail (public domain, Centres for Disease Control and Prevention)

Neurotoxoplasmosis manifests with subacute to acute onset of focal neurological signs including hemiparesis, aphasia, and ataxia, accompanied by headaches, confusion, and seizures. Immunocompetent individuals may remain asymptomatic or have mild symptoms, whereas immunosuppressed patients — particularly those with HIV/AIDS — are at high risk for severe encephalitis, altered mental status, and coma (Elsheikha, Marra, & Zhu, 2020).

Diagnosis is established through characteristic neuroimaging findings on MRI or CT, typically showing multiple ring-enhancing lesions with surrounding oedema in basal ganglia or cortical regions. Serological testing for *T. gondii* IgG and IgM antibodies supports the diagnosis, with PCR detection of parasitic DNA in cerebrospinal fluid increasing specificity. Elevated CSF protein and mild lymphocytic pleocytosis are common but non-specific (Elsheikha, Marra, & Zhu, 2020).

First-line therapy consists of pyrimethamine, sulfadiazine, and folinic acid to mitigate bone marrow toxicity. In patients intolerant to sulphonamides, clindamycin may be substituted. After clinical improvement, maintenance therapy is recommended in immunocompromised individuals to

prevent relapse. Adjunctive corticosteroids are used in patients with significant mass effect or cerebral oedema (Elsheikha, Marra, & Zhu, 2020).

3.2.3. Human African Trypanosomiasis

Human African trypanosomiasis (HAT), caused by *Trypanosoma brucei* subspecies (Figures 3 and 4), begins with cutaneous and systemic infection following a tsetse fly bite. Parasites replicate extracellularly in blood and lymph, using antigenic variation of variant surface glycoproteins to evade host immunity. CNS invasion occurs via disrupted blood–brain barrier and immune modulation, resulting in widespread neuroinflammation, astroglial activation, and disruption of neuroendocrine sleep–wake regulation, which contribute to hallmark neurological symptoms (Kennedy, 2006; Sternberg, 2004).

The early haemolymphatic stage is characterised by fever, malaise, lymphadenopathy, and pruritus. Once the CNS is invaded, patients develop neuropsychiatric symptoms including mood disturbances, sleep fragmentation, cognitive decline, ataxia, and progressive somnolence. If untreated, meningoencephalitis advances to stupor and coma (World Health Organization [WHO], 2023); Kennedy, 2006).

Diagnosis relies on parasite demonstration in blood, lymph node aspirates, or CSF. Trypanosomes may be identified microscopically, and CSF typically shows elevated protein and lymphocytic pleocytosis in late-stage disease. Serological tools (e.g., CATT for T. b. gambiense) improve screening sensitivity (WHO, 2023).

Stage-specific therapy is critical: early disease due to T. b. gambiense is treated with pentamidine, whereas suramin is used for T. b. rhodesiense. CNS involvement requires drugs that cross the blood–brain barrier — eflornithine, often combined with nifurtimox for T. b. gambiense, or melarsoprol if eflornithine is unavailable. Supportive care and management of complications are essential (WHO, 2023).

3.2.4. Primary Amoebic Meningoencephalitis

Naegleria fowleri is a thermophilic free-living amoeba found in warm fresh water. Trophozoites adhere to the olfactory epithelium and migrate along olfactory nerve fibres through the cribriform plate into the anterior cranial fossa, where they proliferate rapidly, releasing cytolytic enzymes that cause extensive neuronal necrosis (Figure 5), haemorrhage, and fulminant cerebral oedema (CDC, 2025).

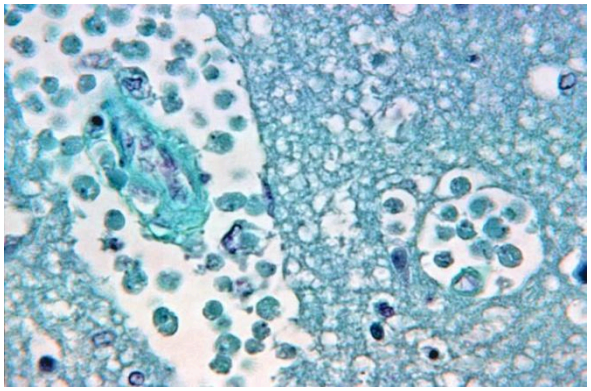

Figure 5. Microphotograph of a brain tissue specimen depicting the cytoarchitectural changes associated with a free-living Naegleria fowleri amoebic infection (x500) (public domain, Centres for Disease Control and Prevention).

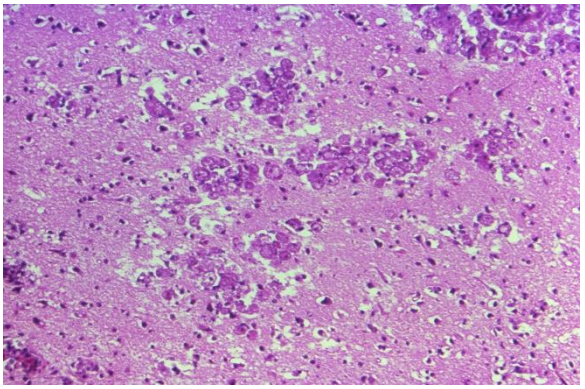

Figure 6. Microphotograph of histopathological changes associated with an infection found in a brain tissue specimen, due to the presence of free-living amoebae of the genus Acanthamoeba (HE, x125) (public domain, Centres for Disease Control and Prevention).

After a short incubation period of 1–12 days, patients develop abrupt high-grade fever, severe headache, photophobia, nausea, neck stiffness, altered mental status, seizures, and rapidly worsening coma. The disease course is typically fulminant, with mortality exceeding 95% even with aggressive treatment (CDC, 2025).

Cerebrospinal fluid (CSF) analysis reveals elevated opening pressure, neutrophilic pleocytosis, low glucose, and high protein. Motile trophozoites may be observed on wet mount preparations, and PCR assays improve specificity. Neuroimaging often demonstrates cerebral oedema and meningeal enhancement (CDC, 2025).

Treatment includes high-dose intravenous amphotericin B with adjunctive agents such as miltefosine and aggressive supportive care. Despite combination therapy, outcomes remain poor due to rapid CNS destruction (CDC, 2024).

3.2.5. Granulomatous Amoebic Encephalitis

Acanthamoeba spp. are ubiquitous free-living amoebae that cause granulomatous amoebic encephalitis (GAE), predominantly in immunocompromised individuals. Haematogenous dissemination from respiratory or skin entry points leads to CNS seeding. Within the brain, trophozoites and cysts induce granulomatous inflammation, microvascular damage, vasculitis, and progressive parenchymal necrosis (Figure 6) (Visvesvara, 2013; Schuster & Visvesvara, 2004).

GAE presents subacutely over weeks to months with headaches, altered mental status, focal neurologic deficits, personality changes, and seizures. Cognitive decline and progressive deterioration are common, reflecting widespread parenchymal involvement (Marciano-Cabral & Cabral, 2003).

Definitive diagnosis requires identification of trophozoites or cysts in brain biopsy or CSF, supported by PCR and culture. MRI typically shows multifocal lesions with surrounding oedema and ring enhancement. Elevated CSF protein and lymphocytic pleocytosis are frequent but non-specific (Schuster & Visvesvara, 2004).

No standardised therapy exists; combination antimicrobial regimens incorporating pentamidine, azoles (e.g., fluconazole), flucytosine, and miltefosine have been reported with variable success. Early diagnosis and aggressive treatment offer the best chance for survival (Visvesvara, 2013; Marciano-Cabral & Cabral, 2003).

3.2.6. Neurocysticercosis

Neurocysticercosis occurs when humans ingest eggs of *T. solium* (Figures 7 and 8), which release oncospheres in the intestinal lumen, penetrate the mucosa, and disseminate haematogenously to the CNS. Once lodged in brain parenchyma or ventricles, oncospheres develop into cysticerci (Figure 9 and 10). The host immune system initially tolerates viable cysts; however, cyst degeneration triggers a robust inflammatory response with oedema, gliosis, and blood–brain barrier disruption that underlies most clinical manifestations (Nash & Garcia, 2011).

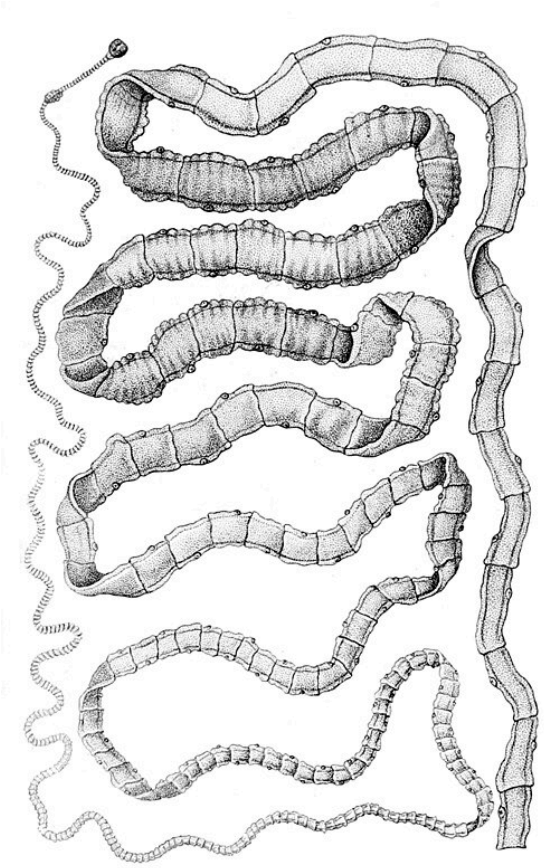

Figure 7. Morphology of Taenia solium (the pork tapeworm): a small, hooked scolex (head) with four suckers, a narrow neck, and a long, ribbon-like body (strobila) of segments (proglottids), 2-3 metres long (public domain)

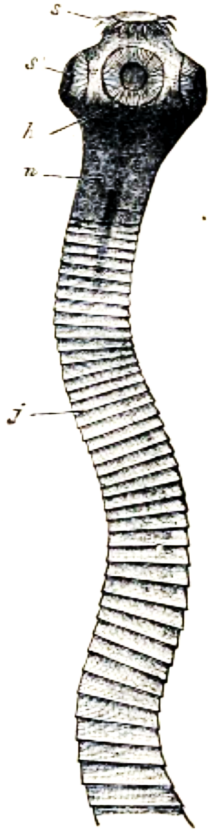

Figure 8. Details: Taenia solium has a head (h) with its suckers (s') and crown of hooks (s), the unjointed neck (n) and a few of the succeeding joints (j). (public domain)

The clinical spectrum is broad, ranging from seizures — the most common presentation — to chronic headaches, focal neurological deficits, hydrocephalus, and signs of raised intracranial pressure. Parenchymal cysts are more often associated with seizures and headaches, whereas ventricular or subarachnoid cysts can cause obstructive hydrocephalus and more severe neurological compromise (Hurła et al., 2024). Parenchymal forms pose diagnostic dilemmas in differentiating from primary or secondary cerebral tumours due to their clinical spectrum (Sava et al., 2021).

Cranial CT or MRI is the cornerstone of diagnosis, revealing cystic lesions, some with a visible scolex (“dot sign”), and surrounding oedema (Figure 9A). Serological assays such as the enzyme-linked immunoelectrotransfer blot (EITB) provide supportive evidence in endemic settings, and CSF analysis may show lymphocytic pleocytosis and elevated protein (Del Brutto, 2012). Epidemiological context is essential for interpretation.

Antiparasitic therapy with albendazole, often combined with praziquantel, is indicated for viable parenchymal cysts, with concomitant corticosteroids to reduce inflammatory reactions during cyst degeneration. Neurosurgical intervention, including ventricular shunting or endoscopic removal, is considered in cases of obstructive hydrocephalus or large extraparenchymal cysts (Nash & Garcia, 2011; Del Brutto et al., 2001).

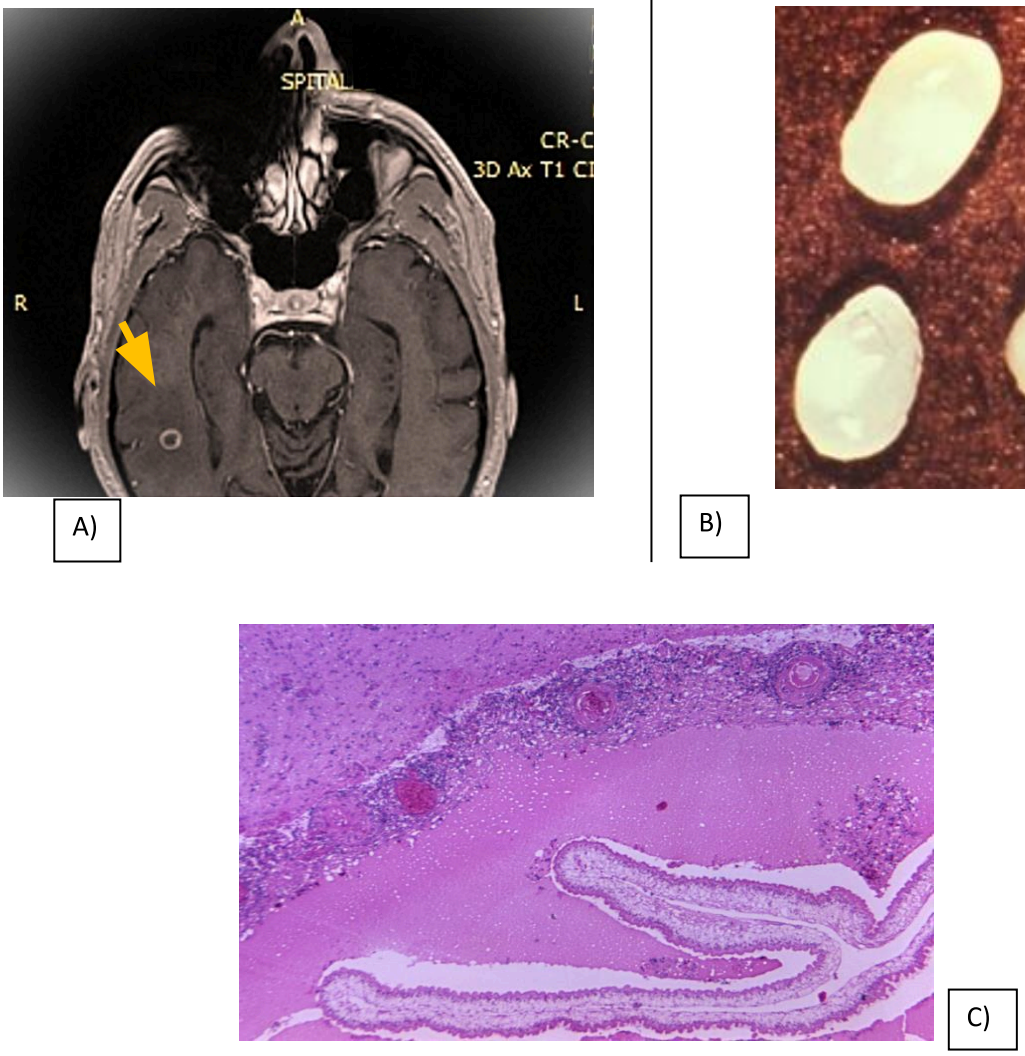

Figure 9. A). Cranio-cerebral MRI with contrast of a neurocysticercosis case showing a rounded parenchymal cystic lesion (yellow arrow) with peripheral enhancement and perilesional oedema (personal collection). B). Gross features of multiple cysticerci produced by the parasitic tape worm, Taenia solium. They are small whitish vesicles (public domain, Centres for Disease Control and Prevention). C). Microphotograph of a brain tissue specimen shows histopathological features in a case of neurocysticercosis, revealing the cysticercus (HE stain, x125) (public domain, Centres for Disease Control and Prevention)

3. Neuroparasitology in the Artificial Intelligence Era

As there is a low prevalence of neuroparasitic diseases in high-income countries, doctors may have a reduced clinical suspicion. Also, neuroparasitic infections generate a spectrum of brain injury phenotypes—parenchymal cysts, granulomas, ring-enhancing lesions, microhaemorrhages, vasculitic infarcts, meningeal/basal cistern disease, ventriculitis, and secondary epileptogenic scars—whose imaging overlaps substantially with neoplasia and non-parasitic infections. In this context, artificial intelligence (AI) using deep learning (DL) and convolutional neural networks (CNNs) has quickly become a valuable clinical tool in medicine, playing a significant role in the control of parasitic diseases, rapid and improved diagnosis, and the application of personalised treatments.

In the field of epidemiology, AI predictive algorithms have proven useful in predictive disease modelling because they create models of parasite transmission and outbreaks by analysing vast amounts of epidemiological data, environmental factors, and population demographics (Parija & Poddar, 2024).

In parallel, AI in neuroradiology has progressed rapidly since 2020, with systematic reviews documenting growth in deep learning tasks such as detection, classification, segmentation, and workflow triage across MRI and CT.

This progress is directly relevant to neuroparasitology because using AI in neuroradiology can enable automated detection of brain anomalies and recognise MRI/CT patterns of parasitic infection. Especially for neurocysticercosis, deep learning models (CNN-based architectures such as VGGNet, ResNet, and DenseNet) (Minaee et al., 2022) are now trained to support triage, which can reduce missed lesions, as lesion appearance changes with parasite degeneration and host immune response (viable cyst → colloidal → granular-nodular → calcified), and clinical presentation (seizures, headaches) is non-specific (Ozturk et al., 2025).

Also, using AI in neuroradiology can distinguish neurocysticercosis from metastases or glioma, identify stage-specific cyst evolution, detect subtle oedema, ventricular involvement, or basal cistern disease. AI neuroradiology is especially relevant for parenchymal versus extraparenchymal neurocysticercosis, distinguishing toxoplasmosis versus primary CNS lymphoma or parasitic abscess vs pyogenic abscess (Troiani et al., 2011).

A new field in parasitology is digital microscopy, where deep learning algorithms are already processing microscopy images to detect and count parasites via egg identification in parasitological stool examinations with 87% global accuracy (Caetano, Santana, & Ataíde de Lima, 2023).

AI can also provide an approach for parasite detection in cases of intracellular parasites such as *Plasmodium falciparum* using red blood cell smears (Mujahid et al., 2024).

Some authors used spatial features of Plasmodium falciparum extracted from microscopic images, then employed image processing and machine learning-based techniques to diagnose malaria. The obtained results had an accuracy of 93.1% in identification of the disease in infected individuals (Vijayalakshmi & Kanna, 2020).

Thus, AI can be used for clinical decision support as it can integrate imaging, serology, and cerebrospinal fluid data in order to predict seizure risk (Ratcliffe et al., 2023), and estimate response to antiparasitic therapy (Parija & Poddar, 2024).

4. Limitations of the Review

This review has several limitations inherent to its narrative design. Although a broad literature search was conducted, the absence of formal quality assessment and meta-analytical synthesis introduces the possibility of selection bias. Heterogeneity among included studies, particularly regarding diagnostic criteria, imaging protocols, and regional epidemiology, limits direct comparison across disease entities. Furthermore, conclusions are based on secondary analysis of published data rather than primary data generation. These limitations should be considered when interpreting the findings.

5. Further Recommendations and Conclusion

Neuroparasitic diseases continue to pose a significant global health burden, particularly in low-resource and endemic regions, necessitating a multifaceted approach to reduce morbidity and mortality. First, strengthening public health infrastructure is essential, including improving access to clean water, sanitation, and vector-control programmes to prevent parasite transmission (WHO, 2023; Garcia, Nash, & Del Brutto, 2014). Second, early detection strategies should be prioritised, with investment in rapid point-of-care diagnostics, molecular tools, and neuroimaging availability in endemic areas to allow timely clinical intervention (Garcia, Nash, & Del Brutto, 2014).

Third, integrated clinical management protocols combining antiparasitic therapy, corticosteroid use when indicated, and supportive care should be standardised and widely disseminated among health care providers in endemic regions (Elsheikha, Marra, & Zhu, 2020; Nash & Garcia, 2011). For parasites with high treatment complexity, such as *Trypanosoma brucei*

and free-living amoebae, ongoing research into novel therapeutics, immunomodulatory agents, and combination regimens is crucial to improve survival outcomes (Garcia, Nash, & Del Brutto, 2014).

Furthermore, community education and awareness programmes can empower populations at risk to adopt preventive behaviours, recognise early symptoms, and seek care promptly (WHO, 2023). Finally, fostering international collaboration and data-sharing among researchers and public health authorities is key to monitoring emerging drug resistance, identifying novel pathogens, and facilitating the development of vaccines and innovative therapies. Collectively, these strategies offer a sustainable path toward reducing the neurological burden of parasitic infections globally and improving long-term patient outcomes (Visvesvara, 2013).

Neuroparasitic diseases remain a significant global health challenge, particularly in resource-limited and endemic regions. Despite substantial advances in diagnostic imaging, serology, and molecular techniques, effective management is often hampered by late diagnosis, limited health care infrastructure, and emerging drug resistance. Conditions such as cerebral malaria, neurocysticercosis, and amoebic encephalitis demonstrate that parasitic infections can rapidly progress to severe neurological compromise, highlighting the importance of early recognition and timely intervention.

Effective management requires multidisciplinary strategies combining antiparasitic therapy, adjunctive corticosteroids when indicated, supportive care for neurological complications, and, in selected cases, surgical interventions. Public health measures, including sanitation, vector control, vaccination programmes, and community education, play a pivotal role in reducing transmission and disease burden. Furthermore, ongoing research into novel therapeutics, vaccines, and rapid diagnostic tools is essential to address the limitations of current interventions and improve long-term neurological outcomes.

Early recognition, accurate diagnosis, and appropriate treatment, coupled with public health initiatives and innovative research, are crucial to mitigate the morbidity and mortality associated with neuroparasitic infections. Strengthening health care infrastructure and promoting global collaboration in research and education are key to reducing the burden of these diseases and improving patient outcomes worldwide.

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