MULTIMODAL IMAGING IN THE DIAGNOSIS OF NEUROCYSTICERCOSIS: CORRELATION BETWEEN EVOLUTIONARY STAGES ACROSS RADIOLOGICAL MODALITIES AND THERAPEUTIC STRATEGIES

Mendonça, GR[1]; Santos, JVM[2]; Silva, JP[1]; Sacramento, LMF[1]; Santos, MEAN[1]; Santos, GMG[2]; Ferreira, RKC[3]; Aires, AL[4].

[1]Biosciences Center, UFPE, Recife - PE.

[2]Departament of Nutrition, UFPE, Recife - PE.

[3]Departament of Nuclear Energy, UFPE, Recife - PE

[4]Academic area of Tropical Medicine, UFPE, Recife - PE

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ABSTRACT

Neurocysticercosis (NCC) is a parasitic infection of the central nervous system caused by the larvae of *Taenia solium*, and is one of the main causes of acquired epilepsy in endemic regions. Diagnosis depends on identifying the different developmental stages of the cysts, Vesicular, Colloidal, Granular-Nodular, Calcified and Racemose, using imaging techniques such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). This study aimed to investigate how different imaging modalities contribute to the characterization of the developmental stages of NCC, correlating radiological findings with clinical manifestations and therapeutic decisions. A narrative review of the scientific literature between 2020 and 2025 was conducted, selecting articles from SCIELO, PubMed, PLOS and Google Scholar databases. The results demonstrated that MRI is superior in detecting vesicular and racemose lesions, while CT is more effective in identifying calcified lesions. The colloidal form showed a strong association with perilesional edema and an intense inflammatory response, requiring combined treatment with antiparasitic agents and corticosteroids. The more aggressive racemose form is associated with hydrocephalus and vasculitis and is best visualized by MRI. It is concluded that a multimodal approach is essential for accurate diagnosis, treatment planning, and improved clinical outcomes.

Keywords: Neurocysticercosis; Computed Tomography; Magnetic Resonance Imaging; Diagnostic Imaging; Evolutionary Stages.

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INTRODUCTION

Neurocysticercosis (NCC) is a zoonosis caused by infection of the central nervous system by the larvae of *Taenia solium*. Infection occurs through accidental ingestion of *T. solium* eggs, usually through food or water contaminated with human feces containing the parasite's eggs. After ingestion, the oncosphere hatches from the egg, and the larva crosses the intestinal wall, reaches mesenteric capillaries, and subsequently enters the systemic circulation. From there, it can settle in various tissues, including skeletal muscles, eyes and, predominantly, the brain, where it develops into cysticercus (Prodjinotho et al., 2020).

The disease progresses through different stages: vesicular, colloidal, granular-nodular, and calcified, which correspond to the developmental phases of the cysticercus during the course of infection and the inflammatory response of the accidental host, humans (Costa et al., 2020; Sharma et al., 2024). In the brain, the cysticercus stimulates a discreet acute inflammatory response during the vesicular phase. Subsequently, progressive degeneration of the parasite and intense granulomatous inflammatory reaction occur during the colloidal and granular-nodular phases, characterized by infiltration of lymphocytes, macrophages and eosinophils. After this, the inflammatory response regresses, resulting in healing of the inflammation through calcification (Prodjinotho et al., 2020). NCC is considered the main cause of acquired epilepsy in developing countries, with a high prevalence in areas with poor sanitation (Takayanagui & Haes, 2022).

Accurate diagnosis depends on characterizing the inflammatory developmental phases using imaging techniques, especially computed tomography (CT) and magnetic resonance imaging (MRI). CT uses X-rays and measures the attenuation of these beams as they pass through tissue. It is especially effective in detecting calcified and dense structures, such as mineralized cysts in NCC (Bustos et al., 2023). MRI uses magnetic fields and radio waves to generate images with high tissue contrast, making it superior in the evaluation of soft tissues, fluids, and deep intracranial structures (COSTA et al., 2020). The integration of these modalities allows the differentiation of active from scarred lesions, the assessment of complications, and the guidance of pharmacological and/or surgical therapeutic decisions, contributing to a more accurate and effective diagnostic approach. The multimodal approach allows the differentiation of active from scarred lesions, the assessment of complications, and the guidance of therapeutic decisions. Difficulties in the radiological diagnosis of NCC include the variability of the cysticercus developmental stages, the deep or discreet location of the lesions, and the presence of perilesional edema that can mask the structures. Furthermore, in non-endemic areas, the lack of experience and qualifications of radiology professionals, as well as the lack of adequate equipment, compromise accurate interpretation for a reliable diagnosis (Monk et al., 2021). Therefore, the present study aimed to investigate different imaging modalities and the clinical, inflammatory, and radiological characteristics of neurocysticercosis, correlating the cysticercus developmental stages with CT and MRI findings, in order to improve diagnostic accuracy and inform therapeutic strategies.

MATERIALS AND METHODS

This is a narrative review conducted between September and October 2025. The research was conducted on the Scientific Electronic Library Online (SCIELO), National Library of Medicine (PubMed), Public Library of Science (PLOS), and Google Scholar platforms, using the descriptors "neurocysticercosis," "magnetic resonance imaging," "computed tomography," "calcified cysticercosis," and "racemose neurocysticercosis."

Inclusion criteria included original articles, case studies, and systematic reviews addressing the developmental stages of NCC, the use of CT and MRI, and clinical correlation. Initially,

selection was based on a critical and reflective evaluation of the literature by reading the titles and abstracts, and studies deemed potentially relevant were subsequently examined in full to confirm their eligibility. Studies with non-human samples, duplicates, or without access to the full text were excluded. Because this was a literature review, approval by an Ethics Committee was not required.

RESULTS AND DISCUSSIONS

In endemic areas, an integrated approach is recommended, including transmission control measures, early diagnosis and adequate treatment to prevent neurological complications. NCC is characterized by the presence of viable or degenerate cysticercus in the brain parenchyma, triggering various inflammatory and neurological manifestations. Lesions can be single or multiple, located in different brain regions, with structural changes and perilesional edema. Clinically, it is manifested by epileptic crises, headache, focal neurological deficits and signs of intracranial hypertension (Prodjinotho et al., 2020). The NCC evolves in different stages, each with different morphological and pathophysiological characteristics. Imaging evaluation is essential for diagnosis, clinical follow-up and therapeutic definition. Computed tomography (CT) and magnetic resonance imaging (MRI) are the main tools used, each with specific advantages according to the stage of the disease (Takayanagui & Haes, 2022).

Vesicular Stage

This stage represents the initial phase of the infection, with viable tissue cyst, clear liquid and thin wall. MRI is particularly effective, revealing well-defined lesions with a signal similar to the cerebrospinal fluid and visible as a hyperdense point. CT shows hypodense lesions, usually without edema. Clinically, it can be asymptomatic or cause mild epileptic seizures. As reported by Takayanagui and Haes (2022), it is the ideal stage for intervention with antiparasitics. The guidelines of the World Health Organization (WHO) and the Brazilian Ministry of Health recommend the use of albendazole and praziquantel for the treatment of NCC. The WHO indicates albendazole at a dose of 15 mg/kg/day, divided into two or three daily doses, and praziquantel at a dose of 50 mg/kg/day, divided into three daily doses, both for 10 to 14 days, always under medical supervision. In addition, the Brazilian Ministry of Health reinforces the association of these antiparasitics with corticosteroids to control inflammation and reduce neurological symptoms, highlighting that the choice of medication and the duration of treatment should be individualized, considering the location of the lesions, the clinical severity and the patient's response (Monk et al., 2021).

Colloidal Stage

At this stage, the cyst begins to degenerate, releasing antigens that cause intense inflammatory response around the parasite. MRI shows peripheral enhancement after contrast with perilesional edema and hypersignal cyst. While CT shows hyperdense lesions with inflammatory halo often accompanied by edema and the cyst has slightly increased density and peripheral enhancement; it can simulate abscesses or tumors. Brazilian studies indicate that this stage is strongly associated with seizures, headache and signs of intracranial hypertension. This pattern indicates active injury with granulomatous inflammatory response. Treatment requires association of antiparasitics with corticosteroids to control inflammation. Treatment should be supervised by qualified health professionals, who can assess the need for additional interventions, such as the use of anticonvulsants in patients with epileptic seizures or, in severe cases, surgical removal of lesions (Prodjinotho et al., 2020). The introduction of anti-inflammatory and anticonvulsants is due to the mechanism of action of praziquantel, which increases the permeability of the tegumentary membrane to calcium ions, causing disintegration of cysticercus, and albendazole, which inhibits the polymerization of

tubulin, compromising intracellular transport and leading to the degeneration and death of the parasite (Prodjinotho et al., 2020; Monk et al., 2021; Takayanagui and Haes 2022). Clinical and radiological monitoring is essential to evaluate the response to treatment.

Granular-Nodular Stage

The cyst is in the process of reabsorption and retraction, with fibrosis capsule formation and reduction of the inflammatory process and edema; polarization of a Th1 response to a Th2 response. MRI the cyst shows heterogeneous signs, usually hypotense, nodular lesions with discreet peripheral enhancement and moderate to minimal perilesional edema, without visible scolex. While CT has intermediate density and absence of edema, characteristic of injury as a hypodense or discreetly hyperdense nodule, with irregular contours; often accompanied by minor edema compared to the colloidal phase. These findings indicate a partially degenerate lesion, in transition to the calcified phase. Symptoms tend to regress, but epileptic seizures can still occur. According to Costa et al. (2020), this stage may present intermittent signs of inflammatory reactivation, requiring continuous monitoring.

Calcified Stage

The calcification of cysticercus in the NCC occurs as a result of the complete degeneration of the parasite and the resolution of the host's inflammatory response. As inflammation regresses, calcium salts are deposed in the remains of the cysticercus and extracellular matrix, forming permanent calcified lesions (Prodjinotho et al., 2020; Monk et al., 2021). CT, the most sensitive method to identify calcified cysticercus, is considered the gold standard, showing small well-delimited hyperdense areas, without post-contrast enhancement or minimal or absent perilesional edema (Prodjinotho et al., 2020). MRI has a hypointense signal; do not identify these lesions accurately. Although the parasite is inactive, there is a risk of late epileptic seizures, as evidenced by Bustos et al. (2020). In the calcified stage, the X-ray of the skull may show small rounded radiopaque areas corresponding to cysticercus, but has low sensitivity, especially for deep or multiple lesions, with computed tomography being the test of choice (Prodjinotho et al., 2020; Monk et al., 2021; Takayanagui and Haes 2022). The use of antiparasitics is not indicated, but symptomatic control with anticonvulsants may be necessary. The study of each case is important to determine if there is a need for surgical intervention to remove the calcified cyst, taking into account the patient's quality of life.

Racemose Form

According to Sharma et al. (2024) it is an atypical variant associated with intense inflammation, hydrocephalus and higher risk of neurological complications. Clinically, it is associated with hydrocephalus, arachnoiditis and vasculitis, requiring specialized neurological approach. MRI is the most sensitive technique for detection, the images show irregular multilocular cysts, without scolex, located in ventricles or subarachnoid space or basal cisterns, often associated with hydrocephalus and perilesional edema. While CT has limitations in deep structures. Sharma et al. (2024) point out that this form can evolve with liquor obstruction and the need for ventricular derivation.

The literature reinforces that MRI is superior in the evaluation of liquid lesions, escolex and intracranial complications, while CT stands out in the identification of calcifications. The combination of both techniques, multimodal imaging allows a comprehensive evaluation, increasing diagnostic accuracy and contributing to better clinical outcomes. In addition, the combination of albendazole and praziquantel proved to be more effective in eliminating viable cysts, especially in patients with multiple parenchymal lesions.

Studies also highlight that MRI is able to detect inflammatory changes in lesions previously considered inactive, such as in the intermittent calcified nodular phase, which can modify the therapeutic conduct and justify the use of anti-inflammatory drugs even in advanced stages. CT, in turn, remains the most accessible and fastest tool, especially useful in emergency contexts and in regions with lower availability of MRI.

It is important to note that the treatment of neurocysticercosis should be supervised by qualified health professionals, who can assess the need for additional interventions, such as the use of anticonvulsants or, in severe cases, the surgical removal of injuries.

CONCLUSION

NCC is a complex disease, with variable clinical and radiological presentation according to the evolutionary stages of cysticercus. Imaging diagnosis, using CT and MRI, is essential to identify lesions, differentiate active phases from scars and guide pharmacological or surgical intervention. Treatment with albendazole and praziquantel, associated with corticosteroids and, when necessary, anticonvulsants, should be individualized according to the location and severity of the lesions. The integration of clinical, laboratory and radiological findings, combined with the supervision of qualified professionals, is essential to optimize management, prevent neurological complications and improve outcomes in patients affected by NCC.

REFERENCES

BUSTOS, Javier A.; ARROYO, Gianfranco; DEL BRUTTO, Oscar H.; GONZALES, Isidro; SAAVEDRA, Herbert; GUZMAN, Carolina; SANCHEZ-BOLUARTE, Sofia S.; THAKUR, Kiran T.; COYLE, Christina; O'NEAL, Seth E.; GARCIA, Hector H. **Calcified Neurocysticercosis: Demographic, Clinical, and Radiological Characteristics of a Large Hospital-Based Patient Cohort.** 2023. Disponível em: <https://pubmed.ncbi.nlm.nih.gov/38251334/>. Acesso em: 01 out. 2025.

COSTA, Anaídia Lopes; SILVA FILHO, Wilson Seraine; FRAZÃO, Denys Wanderson Pereira. **A importância da Ressonância Magnética na fase nodular calcificada intermitente da Neurocisticercose: Um estudo de prospecção da Literatura científica.** 2020. Disponível em: <https://scholar.google.com/scholar_lookup?doi=10.34117/bjdv6n10-356>. Acesso em: 02 out. 2025

MONK, E. J. M.; ABBA, K.; RANGANATHAN, L. N. **Anthelmintics for people with neurocysticercosis.** *The Cochrane Database of Systematic Reviews*, v. 6, n. 6, CD000215, 2021. Disponível em: https://doi.org/10.1002/14651858.CD000215.pub5. . Acesso em: 29 set. 2025.

PRODJINOTHO, U. F.; LEMA, J.; LACORCIA, M.; SCHMIDT, V.; VEJZAGIC, N.; SIKASUNGE, C.; et al. **Host immune responses during *Taenia solium* neurocysticercosis infection and treatment.** *PLoS Neglected Tropical Diseases*, v. 14, n. 4, e0008005, 2020. Disponível em: https://doi.org/10.1371/journal.pntd.0008005. . Acesso em: 06 out. 2025.

SHARMA, Srishti; SINGH, Anuradha; MANI, Vinita Elizabeth; MISHRA, Sarvesh Chandra; CHATURVEDI, Pragya; JAIN, Shweta; KUMAR, Sunil; JAIN, Neeraj. **Racemose neurocysticercosis: a case series.** 2024 Disponível em: <https://pubmed.ncbi.nlm.nih.gov/38352260/>. Acesso em: 01 out. 2025.

TAKAYANAGUI, Osvaldo Massaiti; HAES, Tissiana Marques. **Update on the diagnosis and management of neurocysticercosis.** 2022. Disponível em: <https://www.scielo.br/j/anp/a/WrGM7gYRhpkqK6mGMmZ8WWw/>. Acesso em: 01 out. 2025.