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Ocular Cysticercosis: Epidemiology, Diagnosis, and Management in the Era of Multimodal Imaging

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ABSTRACT

Background: Ocular cysticercosis, caused by the larval stage of *Taenia solium*, is a significant but preventable cause of blindness in endemic regions. Prognosis is heavily dictated by the cyst's anatomical location, the host's inflammatory response, and the speed of clinical intervention. Despite its public health impact, diagnostic delays and varied clinical presentations persist. This narrative review synthesizes current evidence regarding the epidemiology, pathogenesis, and management of the disease.

Methods: A comprehensive review was performed using peer-reviewed literature and clinical guidelines from the past 20 years. The study analyzed data across various manifestations, including intraocular, orbital, adnexal, and neuro-ophthalmic involvements, focusing on the interplay between immunopathogenesis and therapeutic outcomes.

Results: Prevalence is highest in areas with poor sanitation and traditional pig husbandry. Intraocular cysts, particularly subretinal and intravitreal types, present the highest risk for irreversible vision loss due to secondary retinal detachment and severe vitreous inflammation. Diagnostic precision has significantly improved with high-resolution optical coherence tomography (OCT) and B-scan ultrasonography, which can visualize scolex morphology. However, neuroimaging remains a mandatory adjunct to rule out concurrent neurocysticercosis. Treatment must be highly individualized: surgical excision is preferred for intraocular cysts to prevent inflammatory toxic reactions, while medical therapy (anthelmintics) requires careful corticosteroid cover to mitigate inflammatory damage. Integrated "One Health" strategies, including porcine vaccination and mass drug administration, are effective but require broader implementation.

Conclusion: Addressing ocular cysticercosis requires a multidisciplinary approach. Early detection via advanced imaging and coordinated public health interventions are vital for improving visual recovery and achieving long-term disease control.

Keywords: Ocular cysticercosis, *Taenia solium,* Intraocular parasites, Orbital cysticercosis, Neurocysticercosis, Albendazole, Corticosteroids

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INTRODUCTION

Neurocysticercosis (NCC), resulting from infection of the central nervous system by the larval form of *Taenia solium*, remains a significant parasitic neurologic disease in many low- and middle-income countries. [1,2]

In endemic regions, NCC is among the leading causes of seizures, with most patients presenting with seizures or features of raised intracranial pressure.[3] Transmission of *T. solium* continues in endemic regions where inadequate sanitation and suboptimal pig-husbandry practices facilitate the parasite life cycle, Sustainable community-based interventions are urgently needed to control transmission of the causative parasite, *Taenia solium*, in endemic regions.[4] Advances in CT, MRI, and immunodiagnostic techniques have substantially improved understanding of its clinical spectrum and disease course.[5] Recent evidence shows that vision loss in NCC most commonly arises from intravitreal and retinal involvement, underscoring the importance of early ophthalmic assessment in affected patients.[6]

Ocular and orbital cysticercosis, a preventable cause of visual loss in endemic regions, presents with a wide spectrum of clinical features depending on lesion location and host response, often making early diagnosis challenging.[7]

Clinical and epidemiologic series illustrate that ocular involvement may occur in diverse anatomical locations including the orbit, extraocular muscles, subconjunctival space, eyelid/adnexa, vitreous cavity, and subretinal (including submacular) space with presentations ranging from subconjunctival or periocular masses and proptosis to decreased vision, diplopia, or ocular motility disturbances.[8,9] Submacular and subretinal cysts, although uncommon, pose particular challenges as they often necessitate advanced vitreoretinal surgical techniques for definitive management; reports describe successful removal using bimanual, three-dimensional, heads-up-assisted pars plana vitrectomy.[10]

Recent ophthalmic literature has underscored the role of multimodal ocular imaging particularly ultrasound B-scan and optical coherence tomography (OCT) in identifying and localizing intraocular or extraocular cysticerci, thereby assisting diagnosis and informing surgical planning in appropriate cases.[11-13]

Given the anatomical and clinical heterogeneity of OCC, and the potential for serious vision loss, it is vital for clinicians especially in endemic regions to maintain a high index of suspicion. Early diagnosis and prompt multidisciplinary management, combining imaging, medical therapy, and when indicated, vitreoretinal surgery, can optimize outcomes and preserve vision.

ETIOPATHOGENESIS

Human infection with *Taenia solium* results from fecal-oral ingestion of parasite eggs shed by human tapeworm carriers; subsequent oncosphere dissemination may result in cysticercosis in multiple tissues, including the eye and orbit. Following ingestion, T. solium eggs hatch and disseminate hematogenously to the CNS, eye, and orbit, where they develop into cysts that evolve from vesicular to colloidal and finally calcified stages. [7,14]

Cysticercosis predominantly affects regions with poor sanitation across South Asia, Southeast Asia, Latin America, and sub-Saharan Africa. Ocular involvement shows geographic variation: while posterior segment disease is most common in Western reports, Indian series more often document adnexal involvement. [15-19]

Ocular cysticercosis can involve any intraocular or extraocular structure, with anterior chamber, vitreous, and subretinal sites forming the main intraocular loci. [9,19,20] Subretinal and intravitreal cysts typically present with diminished vision due to retinal detachment or vitreous haze, and appear as dome-shaped lesions with an invaginated scolex showing undulating movements on indirect ophthalmoscopy.[21,22] These posterior segment cysts may also cause chorioretinal scarring, macular holes, retinal detachment, vitreous hemorrhage, or even phthisis bulbi, reflecting the broad clinical spectrum.[23-26] Because of these potential complications, timely diagnosis and surgical intervention are critical, although visual recovery may remain limited when the macula is involved or longstanding inflammation is present.[27,28]

Under recognition remains a major challenge in understanding the true burden of ocular cysticercosis. Routine clinical and epidemiologic evaluations often prioritise neurologic involvement, and dedicated ocular assessment is frequently lacking. As a result, ocular and orbital disease may remain undetected, particularly in settings where advanced ophthalmic imaging is not consistently available. Strengthening clinical vigilance, improving access to diagnostic tools, and integrating human and animal health strategies can help in earlier detection and more effective management in endemic regions.

CLINICAL FEATURES

Ocular cysticercosis (OCC) presents with a wide clinical spectrum depending on cyst location, parasite stage, and host inflammatory response; presentations range from asymptomatic adnexal nodules to vision-threatening intraocular or orbital disease requiring urgent intervention.

Extraocular (adnexal and orbital) disease:

Extraocular cysticercosis commonly involves the extraocular muscles, subconjunctival space, orbital tissues, and optic nerve, and unlike intraocular disease, these lesions are not directly visible, making diagnosis dependent on a high index of suspicion and appropriate imaging. [7,29]

Subconjunctival cysticercosis accounts for a significant proportion of adnexal cases and typically presents as

single or multiple, soft, non-tender cystic nodules with variable congestion or chemosis; in some patients particularly children spontaneous extrusion through the conjunctiva has been reported. [30-32]

Extraocular muscle involvement is the most frequent orbital manifestation, attributed to hematogenous spread, and often presents with painful ocular motility restriction, diplopia, eyelid edema, or focal tenderness with the superior and medial rectus muscles among the most commonly affected. [9,29,33]

Clinical severity may increase when cyst rupture triggers a dense inflammatory response, leading to ophthalmoplegia, misalignment, proptosis, or ptosis. [9,34]

Superior oblique involvement can occasionally mimic acquired Brown syndrome, highlighting the wide clinical variability and potential for diagnostic confusion. [35,36]

Anterior chamber cysts, though uncommon (≈1.5% of ocular cases), can present with pain, redness, and decreased vision, and may appear free-floating or attached to the iris, corneal endothelium, or anterior lens capsule; in some cases, they induce marked inflammation including iridocyclitis, hypopyon, or fibrinous reaction with elevated intraocular pressure, necessitating careful slit-lamp examination for accurate localization. [7,37-43]

Intraocular disease

Subretinal and intravitreal cysticerci represent the principal intraocular forms of ocular cysticercosis. The parasite is believed to access the subretinal space through the high-flow choroidal circulation and may subsequently migrate into the vitreous cavity, where it can appear as a freely mobile cyst. [21,22] Patients commonly present with diminished visual acuity secondary to retinal detachment or vitreous haze. [44-47] On dilated fundus examination, lesions typically appear as dome-shaped subretinal cysts containing an invaginated scolex with characteristic undulating movements; calcified foci may demonstrate hyperechogenicity on ultrasonography.[28] Inflammatory manifestations including anterior uveitis, hypopyon, or neovascular glaucoma may occur when cysts degenerate, and posterior segment complications such as retinal holes, macular holes, hemorrhage, or exudative/tractional retinal detachment have also been reported.[9,25,40]

Anterior segment involvement anterior chamber cysts, iris cysts, cyst-induced uveitis, and secondary glaucoma is less common but significant, as it may mimic neoplastic or inflammatory ocular conditions. [41,42]

Orbit and optic nerve

Optic nerve cysticercosis is uncommon but clinically important, with the retrobulbar segment reported as the most frequent site of involvement. [48,49] Patients may present with visual loss, ocular pain, proptosis, RAPD, visual field defects, or disc edema.[50-53] In some cases, optic neuropathy results from direct nerve involvement, while in others it is secondary to adjacent extraocular muscle cysts or orbital apex lesions.[54-56] Because of its potential for severe, irreversible visual damage, prompt neuroimaging and multidisciplinary management are essential.

Severe inflammatory manifestations

Posterior-segment cysticerci may trigger a broad inflammatory spectrum, ranging from anterior uveitis and vitritis to hypopyon, neovascular glaucoma, and panuveitis.[57,58] Chronic or intense inflammation can lead to complications such as retinal detachment, macular hole, chorioretinal scarring, vitreous hemorrhage, or even phthisis bulbi.[7,9,25,40] Across reported cases, the severity and duration of inflammation, rather than cyst size, correlate most strongly with visual prognosis

Pediatric presentations

Pediatric patients may show higher rates of extraocular muscle and subconjunctival involvement, often presenting with painful motility restriction, lid edema, or recurrent ocular inflammation.[9,59,60] Spontaneous extrusion of subconjunctival cysts has also been described in children.[31,61] Compared with adults, children may present earlier and sometimes exhibit a heightened inflammatory response.

DIAGNOSIS

Accurate diagnosis of ocular and orbital cysticercosis requires a combination of careful clinical assessment, high-resolution imaging, and supportive laboratory investigations; imaging remains central to determine cyst location, viability, and associated inflammation to guide management.

Clinical examination: A thorough ophthalmic examination (slit-lamp, dilated fundus) may reveal translucent subconjunctival cysts, mobile intravitreal cysticerci, vitritis, or optic nerve changes; however, clinical signs alone are often insufficient to determine cyst stage or deep orbital involvement, underscoring the need for imaging.

Ultrasonography (B-scan): B-scan ultrasonography serves as a rapid, cost-effective first-line modality, especially when media are opaque. Typical features include a well-defined cystic lesion with an eccentric, highly reflective focus (scolex) and a smooth cyst wall; degenerating cysts may show internal echoes and inflammatory membranes.[11,62]

Optical coherence tomography (OCT) and fundus imaging: OCT is useful for subretinal, intraretinal, or submacular cyst detection showing dome-shaped retinal elevation, outer retinal layer disruption in degenerating cysts, or a hyper-reflective scolex-like focus. Wide-field fundus photography and ultra-widefield imaging enhance documentation of peripheral lesions, migration, and inflammatory sequelae.[12,13]

CT and MRI: Computed tomography (CT) helps detect calcified cysticerci and assess muscle enlargement or chronic bony changes. Magnetic resonance imaging (MRI), especially with high-resolution orbital sequences

like 3D-CISS or FIESTA, provides optimal visualization of orbital apex lesions, optic nerve involvement, and small cysts not obvious on CT. [51,52,63]

Serology and molecular diagnostics: Serologic assays (EITB, antigen ELISA) and PCR-based molecular tests provide supportive evidence especially in cases with systemic or neurocysticercosis though their sensitivity may be limited in isolated ocular disease.[64,65]

Diagnostic strategy: An integrated diagnostic algorithm begins with clinical examination and B-scan/OCT for posterior segment disease, followed as needed by CT or MRI for orbital or optic nerve involvement. Serology, antigen detection, and molecular assays serve as adjunctive tools; management planning should involve a multidisciplinary team including ophthalmology, neurology, and infectious disease specialists.

TREATMENT

Management of ocular and orbital cysticercosis is determined primarily by cyst location, inflammatory status, and threat to vision. Broadly, intraocular cysts require surgical removal, whereas extraocular and orbital cysts generally respond well to medical therapy. [66-69]

Medical Therapy: Extraocular cysticercosis including extraocular muscle and subconjunctival cysts typically responds to a combination of oral albendazole and systemic corticosteroids, which help reduce the inflammatory response associated with cyst degeneration. [9,50] Albendazole (15 mg/kg/day in divided doses) is commonly administered for 4-6 weeks, with steroids tapered gradually thereafter. Clinical improvement is often seen within 2-3 weeks as the scolex collapses and the cyst regresses on serial ultrasonography.[9]

While most extraocular lesions respond favourably, occasional cases may show migration or spontaneous subconjunctival extrusion, and rare non-responding cysts may require surgical excision. [30,70-71]

Surgical Management: Because cyst lysis inside the eye can trigger vision-threatening inflammation, antihelminthic therapy is avoided in intraocular cysticercosis, which is managed primarily with surgery.

Anterior chamber cysts have been successfully removed using Visco expression, capsule-forceps extraction, or aspiration techniques with minimal manipulation to avoid rupture. [72-75]

Posterior segment cysts (intravitreal and subretinal) are treated with pars plana vitrectomy (PPV), often employing high cut/suction rates to prevent spillage of cyst contents. Subretinal cysts may require a localized retinotomy or an external approach depending on location. [7,23,76]

Optic nerve or orbital apex cysts may warrant orbitotomy or neurosurgical intervention when compressive symptoms are present. [77,78]

FOLLOW-UP AND OUTCOMES

Extraocular cysts typically show excellent resolution with medical therapy, with most cases achieving complete regression and only occasional residual motility deficits.[9,79] In contrast, visual prognosis in intraocular disease depends heavily on cyst location: intravitreal or non-macular subretinal cysts generally have better outcomes, while submacular cysticercosis often results in poor vision due to photoreceptor and retinal pigment epithelium damage despite timely surgery. [80]

Regular follow-up with serial B-scan ultrasonography and fundus evaluation is essential to monitor regression, detect recurrence, and manage inflammatory sequelae.

PREVENTION AND ONE HEALTH APPROACHES

Effective control of *Taenia solium* requires a comprehensive One Health strategy addressing human health, animal health, food systems, sanitation, and community behavior. Ocular cysticercosis (OCC) and neurocysticercosis (NCC) are preventable, and long-term reduction in disease burden depends on disrupting transmission at multiple points in the parasite's life cycle. [81]

Transmission Cycle and Prevention Targets: Human cysticercosis results from fecal-oral ingestion of *T. solium* eggs, often due to poor sanitation and environmental contamination. Prevention strategies must target multiple points: a) Human tapeworm carriers to prevent egg shedding, b) Pigs, which act as intermediate hosts, c) Environmental sanitation to reduce contamination, d) Food hygiene and cooking practices, and e) Meat inspection and safe pork handling

Human-Focused Interventions: It comprise of Pharmacologic Treatment of Human Taeniasis. Eliminating human tapeworm carriers is central to interrupting transmission. Recommended therapies include: a) Praziquantel 10 mg/kg, single dose, and b) Niclosamide 2 g, single dose in adults. Mass drug administration (MDA) programs in endemic regions have shown substantial reductions (40-60%) in community-level cysticercosis following taeniasis treatment campaigns. [82]

Health Education and Behavioral Change: Health education efforts reduce reinfection by promoting proper hand hygiene, safe pork handling and cooking, avoidance of open defecation, and early identification and treatment of carriers. Community-based education has demonstrated robust reductions in environmental contamination and transmission risk.

Pig-Focused Interventions

Vaccination: TSOL18: The recombinant TSOL18 vaccine confers >95% protection against porcine cysticercosis. When combined with antiparasitic therapy, TSOL18 achieves near-elimination of infection in controlled field trials.[83]

Oxfendazole Treatment: A single dose of Oxfendazole 30 mg/kg clears viable cysticerci in pigs with nearly 100% efficacy. Combined with TSOL18 vaccination, it provides synergistic protection and significantly reduces transmission. [84]

Environmental and Sanitation Interventions

Sanitation and Latrine Use: Open defecation is a major determinant of ongoing transmission. Construction and proper utilization of latrines reduce soil contamination by 50-80% and lower risk to humans and pigs.

Meat Inspection and Food Safety: Rigorous meat inspection prevents infected pork from entering the human food chain. Countries with structured inspection systems report markedly lower porcine cysticercosis prevalence.

Control of Free-Roaming Pigs: Restricting pig access to contaminated environments and encouraging penned rearing significantly reduces infection rates.

Global Policy Priorities: The WHO NTD Roadmap (2021-2030) identifies *T. solium* as a priority zoonotic parasite requiring coordinated national and international strategies.[85]

Recommendations include a) Adoption of national One Health control frameworks, b) Community-based surveillance and early detection, c) Standardized diagnostic tools for humans and pigs, d) Strengthening veterinary and public health systems, and e) Monitoring sanitation, environmental contamination, and pig husbandry practices

RESEARCH GAPS AND FUTURE DIRECTIONS

Despite advances in multimodal imaging, surgical techniques, AI-assisted diagnostics, and One Health interventions, significant knowledge gaps limit high-quality, evidence-based management of ocular cysticercosis (OCC). Addressing these gaps is essential for improving visual outcomes, developing standardized diagnostic frameworks, and guiding public health strategies.

Lack of High-Quality Prospective Clinical Trials: Most data on orbital and intraocular cysticercosis derive from retrospective case series or individual case reports, particularly for submacular cysts. Major unresolved clinical questions include a) Optimal treatment for extraocular muscle cysticercosis (albendazole alone vs. albendazole + corticosteroids), b) Timing and safety of antihelminthic therapy in relation to intraocular surgery, and c) Comparative outcomes of early vs. delayed surgery in submacular and posterior segment cysts.

No randomized controlled trials exist, resulting in variability in treatment practices across regions.

Absence of Standardized Imaging-Based Diagnostic Criteria: Although OCT, B-scan, CT, and MRI are widely used, universally accepted diagnostic criteria for ocular cysticercosis are lacking. Key deficiencies include a) No standardized classification for cyst stage (viable vs. degenerating), b) Lack of consensus on scolex visibility, cyst wall integrity, and inflammation severity, and c) No validated imaging scoring system to predict surgical difficulty or visual prognosis.

Insufficient Research on Artificial Intelligence and Automated Diagnostics: AI has shown promise in ophthalmology and neuroimaging; however, dedicated models for ocular cysticercosis do not yet exist.[86] Gaps include a) Lack of annotated datasets for AI-based scolex recognition on OCT/B-scan/MRI, b) No automated cyst segmentation or inflammation quantification tools, and c) Absence of AI-enabled triage systems for clinicians in endemic regions.

Major Limitations in Molecular Diagnostics for Ocular Disease: Current serological and antigen detection assays have poor sensitivity for isolated ocular involvement. Research priorities include a) Development of PCR-based assays for aqueous or vitreous samples, b) Molecular markers to distinguish viable vs. degenerating cysts, and c) Standardization of laboratory protocols across centers.

Lack of Long-Term Outcome Data and Recurrence Analysis: Existing studies rarely include follow-up beyond 6-12 months. Research needs a) Defined recurrence rates after medical therapy in extraocular or orbital disease, b) Long-term visual recovery after submacular cyst removal, c) Registries capturing late complications (fibrosis, epiretinal membrane, optic atrophy), and d) Patient-reported outcomes and vision-related quality of life.

Public Health and Economic Evaluation Gaps: While One Health programs reduce T. solium transmission, their impact on ocular disease specifically is unclear [89]. Research priorities are a) Cost-effectiveness analyses of integrated human-animal interventions, b) Tracking changes in OCC incidence after community sanitation, vaccination, and meat inspection programs, and c) Feasibility assessment for regional elimination strategies in endemic areas.

Need for International, Multicentric Collaborative Networks: Due to localized endemicity, datasets remain small and fragmented. Key priorities are a) International Ocular Cysticercosis Consortium, b) Shared imaging and molecular biobanks, c) Harmonized diagnostic and treatment guidelines, and d) Multicenter clinical trials across endemic regions.

CONCLUSION

Ocular cysticercosis remains an important yet underrecognized cause of preventable vision loss, particularly in endemic regions. Clinical outcomes are strongly influenced by cyst location, inflammatory response, and timeliness of intervention. Advances in multimodal imaging have improved diagnostic precision and facilitated

tailored management, with surgical intervention remaining central for intraocular disease and medical therapy effective for most extraocular manifestations.

Long-term disease control, however, requires coordinated public health strategies integrating human, animal, and environmental health. Strengthening early diagnosis, standardizing management approaches, and expanding One Health-based interventions are essential to improve visual outcomes and reduce disease burden.

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