Chapter

The Pandemonium of Cysticercosis in Human

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Abstract

The pandemonium of cysticercosis in human has pulled the focus of WHO to develop a guideline and promote actions to prevent the causes of epilepsy by taenia worms affecting human health, leading to stigmatization and discrimination and increases public health interventions. In most developing countries such as Sub-Saharan Africa and Asia, cysticercosis mainly affects the health and livelihoods of agrarian farmers, resulting in devastating effects on their health through the ingestion of the parasite's larval cysts in undercooked infected pork or contaminated water. Though, as one of the neglected zoonotic diseases, potentially eradicable yet it is now becoming an emerging disease with approximately 50 million people globally infected.

Keywords: pandemonium, cysticercosis, stigmatization, discrimination, public health interventions, epidemiology

1. Introduction

The World Health Organization foodborne disease burden epidemiology reference group (WHO-FERG) in 2016, estimated and identified the global burden of 31 microorganisms as a leading cause of deaths from foodborne diseases amounting to 2.8 million disability-adjusted life-years (DALY). Because of this, they must be given due consideration as a possible differential diagnosis in areas of high prevalence of cysticercosis, which is termed to be acquired only from the fecal-oral route (ingestion of infected eggs) and ingestion of the cysticerci in undercooked pork that may lead to intestinal taeniasis. The *Taenia solium* tapeworm infections can lead to cysticercosis, which is a disease that can cause seizures, so it is important to seek treatment. In recent times, researchers reported that cysticercosis is prevalent in most West African countries where favorable conditions for parasitic transmission in both humans and pigs occur widely within the region and as such, defecation in the open field, illicit slaughtering of pigs, and unhygienic way of handling meat with unqualified meat inspectors involved in the process [1–3]. The aim of this is to provide updated knowledge as regards cysticercosis diagnostic tools challenges outlined by WHO report in endemic resource-limiting settings and specify needs for adoption to local context considering practical implementation to advance the desire goal for test determinants.

2. Epidemiology of cysticercosis

The genus Taenia are human parasite consisting of three species (*T. solium*, *T. saginata*, and *T. asiatica*). These parasites live as an adult tapeworms in human intestines causing taeniasis, and the cause leads to cysticercosis in human after ingesting eggs with water, contaminated food, or *via* dirty hands. The World Health Organization (WHO) lists neurocysticercosis as a neglected tropical disease and infection accounted for 50 million people worldwide with 50,000 deaths each year. The clinical manifestations of cysticercosis are highly variable both in kind and in severity with the period of initial infection expressed and the onset of symptoms is generally dependent on the concentration, size, and location of the cysts as well as the host immune response to the parasite's infectivity. However, the preferred locations are the muscles, subcutaneous tissues, central nervous system (CNS), and eyes. Subcutaneous and muscular forms are often asymptomatic. Severe cysticercosis is due to larvae located in human CNS—neurocysticercosis. Most frequently clinical manifestations are seizures, intracranial hypertension, neurological deficits, and sometimes psychiatric manifestations, and over 50% of cases of late-onset epilepsy in developing countries. Usually, cysticercosis is characterized by mild and nonspecific symptoms with abdominal pain, nausea, diarrhea, or constipation may arise when the tapeworms become fully developed in the intestine, approximately 8 weeks after ingestion of meat containing cysticerci. These symptoms may however continue until the tapeworm dies following treatment, otherwise, it may live for several years. In the case of cysticercosis due to *T. solium*, the incubation period prior to the appearance of clinical symptoms is variable, and infected people may remain asymptomatic for many years.

3. The danger of cysticercosis in human

Human cysticercosis can result in devastating effects on human health. The larvae (cysticerci) may develop in the muscles, skin, eyes, and the central nervous system. When cysts develop in the brain, the condition is referred to as neurocysticercosis (NCC). Symptoms include severe headache, blindness, convulsions, and epileptic seizures can be fatal. In developing countries, cysticercosis affects mainly the health and livelihoods of subsistence farmers and reduces the market value of pigs by making the pork unsafe to eat [4, 5].

In developing countries, the endemic human cysticercosis associated with epilepsy is relatively common but rarely reported due to fear of stigmatization. The risk factors for human cysticercosis are closely associated with the characteristics of smallholder or backyard pig farming systems prevalent in this region, which tends to affect poor control and are hampered by infrastructural and financial resources coupled with inadequate information about the eradication and distribution of the disease. The human populations considered to be at the highest risk of infection are those who earn their livelihood wholly or partially through livestock rearing, including pigs, and have limited access to good sanitation [2, 3].

4. Causative agent of cysticercosis in human

The tapeworm Taenia solium invades the human central nervous system and causes neurocysticercosis. The adult tapeworm finds its dwellings in the human

small intestine after consumption of varied cysticerci in undercooked pork or contaminated fruits, vegetables, and water, resulting in traceable taeniasis. This zoonotic tapeworm constitutes a serious public health concern as the disease emerged as a continuous problem in most resource-limited settings where pig rearing and pork are served in abundance with little hygienic processes [6]. However, neglected surrounding issues for the presence, magnitude, and parasitic impacts of cysticercosis have led to the disease scarcity of information for the common man [3].

5. Signs and symptoms of cysticercosis in human

Cysticercosis symptoms occurred depending on the site of infection in the human body such that seizures or brain tumor, decreased vision or blindness, abnormal heart rhythms or heart failure and weakness or changes in walking due to damage to the nerves, appearance of lumps under the skin, sometimes vomiting, nausea, headache, dizziness or confusion, and lack of attention resulting in death [7]. Moreso, the antemortem findings present fever in acute stage with muscular stiffness, and the postmortem findings identify cyst in the heart, skeletal muscles, liver, brain, and meninges [8].

6. Complications of cysticercosis in human

The possible complication of cysticercosis may include:

a. Seizures may occur as a result of uncontrolled electrical signals discharged to malfunction the brain cells. This kind of electrical activity overloads the brain functionality causing abnormal sensations and uncontrolled muscle movements [9].

b. Blindness and decreased vision occurred as a result of injuries, inflammation of infections affecting one or two eyes, leading to serious health conditions known as uveitis [9].

7. Diagnostic accuracy of cysticercosis

Diagnostic and management tools for cysticercosis in human resource-limiting settings are challenging in healthcare settings are small, inadequate number of trained personnel, and limited laboratory [10].

It is well documented that the detection of human cysticercosis is key to the management of the disease and identification of proglottids or eggs of *T. solium* have both low sensitivity and specificity, though, a confirmatory of the infection by the adult stage of parasite is made possible macroscopically [11, 12]. However, deoxyribonucleic acid (DNA) based techniques are sensitive and specific [13]. On the other hand, achievable diagnosis of human cysticercosis can be through ELISA, Cysticercus IgG Western Blot Assay, computed tomography (CT) scan, and Magnetic Resonance Imaging (MRI).

8. Sample/specimens appropriate for the diagnosis of cysticercosis

8.1 Noninvasive sampling involving noncritical equipment, materials, and techniques

8.1.1 Fecal specimen

The classic, standard diagnostic tool in most settings is the microscopic examination of stools after concentration with formol-ether aims to demonstrate *Taenia solium* eggs [14]. Moreso, diagnosing taenia tapeworm infection is made by microscopic examination of stool specimen collected on three different days [15].

8.1.2 Urine specimen

Concentration of urine, preparation of *Cysticercus cellulosae* complete homogenate antigen, and hyperimmune cysticercus antiserum were performed by methods described earlier [16, 17].

8.2 Invasive sampling involving critical equipment, materials, and techniques

8.2.1 Cerebrospinal fluid (CSF)

The CSF examination constitutes an important diagnostic and clinical tool in diagnosis of suspected neurocysticercosis [10, 18]. CSF has the advantage of being in more direct contact with the central nervous system (CNS) and its collection requires an aseptic lumber puncture procedure. However, CSF examination may complement serological and biochemical diagnosis. Though, antibody detection by enzyme-linked immunoelectrotransfer blot (EITB) is similarly higher in CSF as compared to other methods [19, 20].

8.2.2 Blood (serum)

Serum samples are preferred for antibody-antigen diagnosis of cysticercosis serologically. Serodiagnostic assay recognized by the World Health Organization and the Pan American Health Organization for cysticercosis and neurocysticercosis outline in Lee et al. [21] in comparison to CSF uses both lentil lectin-purified glycoproteins (LLGP) in an enzyme-linked immunoelectrotransfer blot (EITB) format.

8.2.3 Tissue sampling

Once eggs or proglottids are ingested, oncospheres hatch in the intestine invade the intestinal wall, enter the bloodstream, and migrate to multiple tissues and organs where they mature into cysticerci over several months. Definitive diagnosis consists of the demonstration of the cysticercus in human tissue affected by the larval *Taenia solium* cysts in tissue sections [22].

9. Laboratory diagnosis of human cysticercosis

Diagnosis involves a careful history and physical examination of clinical features, neuroimaging studies [non-computed tomography (CT) scan or Magnetic Resonance

Imaging (MRI)], epidemiological and laboratory-based serological testing in patients strongly suspected of having cysticercosis or neurocysticercosis [22]. In 2015, the WHO report of stakeholder meeting outlined below as diagnostic tools for Taeniasis/Cysticercosis with priorities that this method is time-consuming and requires sophisticated facilities yet in resource-limiting settings, microscopy is necessary at a moment using the formol-ether concentration techniques to demonstrate the visibility of *T. solium* eggs [23].

i. Ag-ELISA, Ab-ELISA, and Corpo-Ag-ELISA: The assay is to perform antigen-antibody glycoprotein embedded enzyme-linked immunosorbent assay (Ag-ELISA) detection in the diagnosis of viable *T. solium* cysticercosis in naturally infected slaughter-age pigs in an endemic area. The Ag-ELISA test characteristics report may indicate that the test is more reliable in ruling out *T. solium* cysticercosis in pigs, than in confirming it [24, 25]. The Ag-ELISA reported a sensitivity range from 86 to 90% and the specificity is estimated at 94–98% the Ab-ELISA reported a specificity of 97.4% and a sensitivity of 96.3% to detect circulating antigens and antibodies in human serum. However, studies indicated that the estimated prevalence rates of human cysticercosis range from 4.6 to 29.7% for Ag-ELISA, and that of Ab-ELISA is reported to be between 1.3 and 51.6% [26] in endemic zones around the world. The estimated prevalence of human cysticercosis antigen around the world is 5.12% and that of the antibodies was estimated to be 15.36%. Nevertheless, these vary from country and region.

ii. LLGP-EITB and EITB: One of the most well-characterized tests for diagnosing neurocysticercosis (NCC) is the enzyme-linked immunoelectrotransfer blot (EITB) assay developed and recommended by CDC uses lentil lectin-bound glycoproteins (LLGP) extracted from *Taenia solium* cysticerci. The test is reliable, but purification process of antigens is difficult to transfer to other laboratories because of expensive nature of the equipment and technical expertise [27]. This has proven to be effective in the detection of neurocysticercosis with 16.7–92.2% prevalence rates with a sensitivity ranging from 97 to 98% and a specificity range from 97 to 100% to detect circulating antibodies to *T. solium* in human serum and considered positive when at least one of the specific glycoproteins from *T. solium* metacestodes is recognized by the serum [28].

iii. Copro-PCR (Multiplex, Nested, and RT-PCR): Multiplex, Nested, and Real-Time PCR assay is developed to target *Tso31* gene for specific diagnosis of cysticercosis due to *T. solium*. The estimated sensitivity of this test was reported to be 82.7% with a specificity of 99% for real-time polymerase chain reaction assay (copro-PCR) 99% (95% CI: [98.2–99.6]) for copro-PCR [29]. These methods are more sensitive than microscopy but cross-react with *T. saginata*. However, the differentiation of *T. solium* and *T. saginata* is based on the morphological characteristics of the scolex or gravid proglottids [30].

iv. Microscopy: Human intestinal infectivity with adult *T. solium* worms can be diagnosed by microscopic examination of stool samples and identification of ova or proglottids are present in ≤50% of stool samples from patients with cysticercosis, which has very low sensitivity and specificity [31].

10. Prevention, control, and treatment of cysticercosis

10.1 Mass treatment

Mass treatment of human decreases logistic costs and increases feasibility with high-advantage interventions around the geohelminths regions requiring less field visits and concern raised about environmental contamination [14].

10.2 Community health education

Health education of the target population most captured educational design of control/elimination programs to increase sustainability. Individuals without knowledge of infected meat have a higher risk of getting taeniasis by mis-ingestion and may subsequently get cysticercosis [32]. Community education in combination with a multipronged approach consisting of vaccination of pigs is necessary.

10.3 Targeted treatment of infected persons

Targeted treatment is effective to decrease the source of infection, finding infected individuals with informed intervention choice of treatment and drug optimization.

10.4 Meat radiation and freezing

The use of gamma-radiation and meat freezing for more than 1–3 days as proposed by Verster et al. [33] and Sotelo et al. [34] killed cysts before pork consumption and minimized the use of expensive and sophisticated equipment discussed in Gilman et al. [14].

10.5 Personal hygiene

Personal hygiene and sanitary health measures are critical to avoid human feco-oral contamination where indiscriminate defecations are identified as a risk factor for cysticercosis. Individuals with such poor defecating habits generally have poor hygienic behaviors and thereby increase the high risk of cysticercosis. Regular handwashing with soap and running tap water, proper washing of fruits, vegetables before eating, and washing of cutleries/utensils reduces the risk of infectivity [3, 10, 32, 35] (**Table 1**).

10.6 Treatment

Cysticercosis if treated include immediate measures to prevent morbidity and mortality, and following surgical to control seizures, corticosteroids to control inflammation, and anthelminthic medications to kill cysts as outlined below:

i. Corticosteroids (Prednisolone, Dexamethasone) are disintegrated tables used to treat and reduce inflammatory bowel disease conditions and adrenal gland disorders.

ii. Antiepileptic/Anticonvulsant medications (Phenytoin, carbamazepine) to reduce and prevent the risk of seizures.

iii. Antiparasitic medications (Albendazole, Praziquantel) are often used to kill cyst infections.

iv. Surgery to removal of cysts or to put in a tube to redirect the fluids in the brain induced by the presence of cysticerci.

Globally, studies for circulating human cysticercosis antigen were 5.52% in positive cases and 14.20% for antibodies. Although, the incessant use of pig feces

Country or region	Assay	Percentage (%)	Reference
Latin America	Ag-ELISA	0.94–9.12	Coral-Almeida et al. [26]
	Ab-ELISA or EITB	1.82–31.22	Bruno et al. [36]
Asia	Ag-ELISA	15.7–41.8	Ar Kar et al. [37]
	Ab-ELISA	4.0–26.7	Coral-Almeida et al. [26]
	EITB	46.7–66.7	Bizhani et al. [38]
Africa	Ag-ELISA	0.7–21.63	Gulelat et al. [39]
	Ab-ELISA	1.3–45.3	Coral-Almeida et al. [26]
	EITB	6.9–16.7	Shonyela et al. [29]
	CT Scan	23.2–54.6	Praet et al. [40]
	Copro-PCR (or Copro-ELISA)	5.2–14.8	Praet et al. [40]
West Africa	Ag-ELISA	4.6–11.9	Shonyela et al. [29], Weka et al. [41]
	Ab-ELISA or EITB	24.7–51.6	Edia-Asuke et al. [42]
Nigeria	Ab-ELISA or EITB	9.6–14.3	Weka et al. [41]

Table 1.
The global estimated prevalence rates of human cysticercosis.

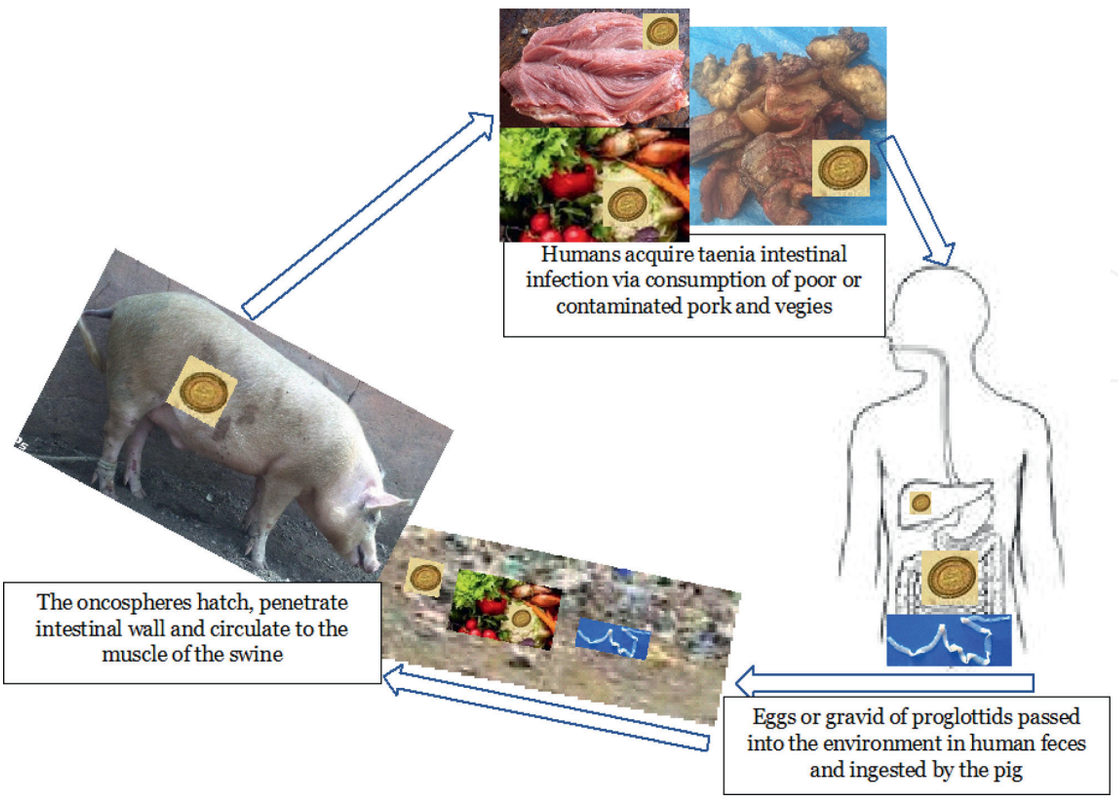

Figure 1.
Life cycle of Taenia solium (human cysticercosis).

as fertilizer has become imperative to farmers and poses the risk of cysticerci food contamination, thereby supporting encystment. However, heavy infectivity calls for the carcass's complete condemnation despite the provision for freezing treatment, though pending approval in light or moderate infestation (**Figure 1**).

11. Conclusion

Despite WHO having focused on developing a policy and promoting measures to avoid the cause of seizures by Taenia/Cysticercosis impacting human health, leading to stigmatization and increasing public initiatives because of the challenges of human cysticercosis. The increasing risk of human cysticercosis in developing countries is reported to be significantly associated with the consumption of the parasites' cysts in raw, infected pork, or contaminated food and water. Understanding the epidemiology of human cysticercosis will help to expose critical information about the transmission of the disease, thereby intensifying efforts for effective low assessable control and prevention measures.

Declaration of interest

We declared that there is no conflict of interest whatsoever that could affect this work, leading to bias but recognized the materials used in this article are well cited and referenced appropriately.

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