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Taenia solium Cysticercosis in Sub-Saharan Africa: Perspectives for a Better Control

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Abstract

For decades, *Taenia solium* cysticercosis (TSC) has remained an important constraint for public health and economic well being of the predisposed communities. Despite the fact that the disease is easily preventable, humans remain foci for transmission. They harbour the mature form of the parasite (*Taenia solium*) which may be curable at this stage and also easily prevented from contaminating pig feeds and environment with eggs of the parasite to break the cycle. Researchers, knowledgeable communities and international organisations such as the World Health Organisation work hard to make the disease a history. Nevertheless, persistence of the disease in endemic regions such as sub Saharan Africa is kept on increasing. While TSC in human may serve as a silent killer as it can go unnoticed for years, the immanent social cultural settings and lifestyles of the communities in endemic areas form the main concern on the epidemiology of the disease. Unless lifestyles change in endemic regions, front line research might rarely find its way into applications in an area of huge societal and economic impact, the TSC epidemiology. Sincerely, transmission of TSC is favoured by poor sanitation and hygiene which is motivated by lifestyle and poverty. What is perhaps missing is the knowledge on "why is the communities involved ease indiscriminately while almost every member of the community in endemic areas knows that indiscriminate defecation may harm their health? What social drivers are behind this motive (bush defecation)? How best can the disease be controlled and monitored? This review recommends for developing and implementing an interdisciplinary OneHealth community-based control mechanism and monitoring (surveillance) programme as standpoints towards eliminating TSC in sub-Saharan Africa and the rest endemic regions.

Keywords

Taenia solium Cysticercosis, Epidemiology, Sub Saharan Africa

1. Background

Taenia solium cysticercosis (TSC) is one of the emerging infectious zoonotic diseases of poverty with global public health concerns [1]. TSC is a vicious worm which its persistence is related with poverty, ignorance and disproportionately affects the poor. It causes considerable health impacts in endemic countries [2]. However, because of globalisation and increased tourism, the disease crosses borders and poses threat worldwide [3] [4]. TSC is a chronic disease which among other body organs and tissues, infects human brain resulting into epilepsy, headaches and even death [2] [5].

The disease mainly affects the health and livelihoods of subsistence farming communities in developing countries of Africa, Asia and Latin America. It also reduces the market value of pigs and cattle, and makes pork unsafe for human consumption. This is to say the global burden of TSC remains indispensable. It is a leading cause of deaths from food-borne diseases with a considerable total of 2.8 million disability-adjusted life-years (DALYs) [6] [7]. *T. solium* cysticercosis is the cause of 30% of epilepsy cases in endemic areas as such over 80% of the world's 50 million people who are affected by epilepsy live in low and lower-middle income countries where people and roaming pigs live in close proximity [8].

Transmission of TSC follows ingestion of *T. solium* eggs from the parasite's carrier through contaminated water and foods causing human cysticercosis (HCC) in man and porcine cysticercosis (PCC) in pigs. The parasite, *T. solium* metacestodes, in man can infect the central nervous system resulting into neurocysticercosis (NCC). Neurocysticercosis produces long-term health problems [8]. It is one of the major causes of acquired epilepsy in endemic areas [2] [9] [10] [11] and the most common helminthic disease of the central nervous system [12]. The disease is ranked as the first on the global scale of foodborne parasites [13]. About 0.2% - 0.3% of the population in sub-Saharan Africa suffer from NCC related epilepsy [12]. Based on the epidemiological criteria, TSC is reasonably eradicable: a single definitive host (human tapeworm carrier) and the sole source of infection for intermediate hosts; domestic animals (pigs) as main intermediate hosts; no important wild reservoirs; and availability of interventions for control [14]. Socioeconomic, behavioural and environmental factors impede the reduction of the disease in many endemic areas.

2. Epidemiology of TSC

TSC in sub-Saharan Africa causes severe health and economic problems [15]. TSC is a zoonotic disease that occurs worldwide primarily in rural and poor urban communities in developing countries of Latin America, Sub-Saharan Africa and Asia where pigs are raised under free-range systems with poor sanitation [16]. Humans are infected by the adult worm of *T. solium* following ingestion of the cysticercus in undercooked infected pork. The cysts contained in the undercooked pork evaginate and attach to the small intestine by their scolex [17].

Adult tapeworms develop up to 7 m in length; reside in the small intestine of the human host for over 20 years (if not treated) producing about 1000 proglottids, each with about 40,000 - 100,000 eggs [18] [19]. The tapeworm (*T. solium*) sheds 8 - 10 proglottids daily [19] by which an infected person can contaminate the environment by 320,000 - 1,000,000 *T. solium* eggs daily. High environmental contamination rate by *T. solium* eggs just from a single tapeworm carrier may pose a high risk to TSC infection in human from the community involved.

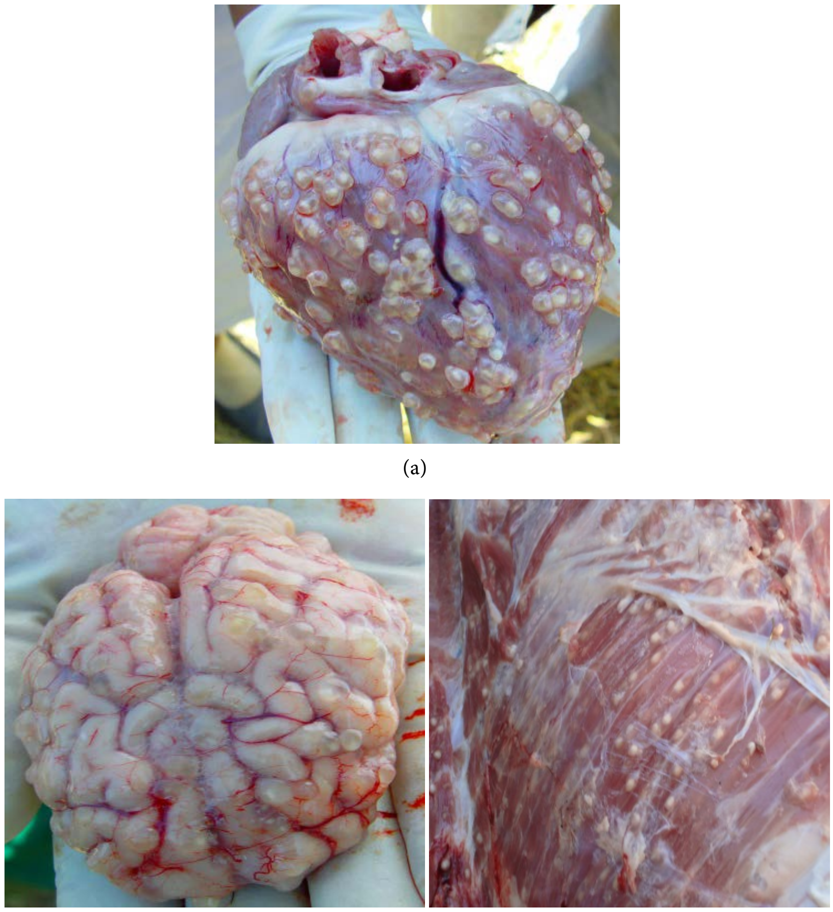
Although dogs, cats and sheep may harbour the larval forms, pigs are the natural intermediate host for *T. solium* [20]. Following ingestion of eggs or gravid proglottids of *T. solium* by both pigs and humans, the eggs hatch into oncospheres in the intestine. The oncospheres invade the intestinal wall and migrate to cardiac and striated muscles, then to the brain and conjunctiva where they develop into cysticerci. When *T. solium* cysts localize in muscles, they result into myositis whereas in the central nervous system (CNS) they cause NCC. The cyst can also settle in the conjunctiva where they cause ophthalmic cysticercosis whereas, if they localise under the skin, they lead to dermatitis.

TSC is characterized by a fluid-filled bladder that is 0.5 cm to 1.5 cm in length with an invaginated scolex [21]. The severity of TSC in human depends on location of larvae, size and number in tissues, as well as the host immune response [22]. In symptomatic cases, NCC may be accompanied by headaches, dizziness and occasional seizures and dementia or hypertension in more severe cases [23]. Other NCC symptoms include sensory deficits, involuntary movements and brain system dysfunction. *Taenia solium* cysticerci in human inhibit humoral and cellular immune responses as well as inflammatory reaction and cytokines, particularly IFN-γ and IL-2, and to a lesser degree IL-4 production [22] [24]. Live metacestodes also secrete cysteine and serine proteases that deplete CD4+ cells (T helper cells) that send signals to other types of immune cells, including CD8 killer cells that destroy and kill the infection. The elucidation of these molecules provides insights into the mechanisms by which *T. solium* metacestodes evade host immunological attack and are able to survive long periods of time [22]. Nevertheless, even if one develops neurological symptoms in early stages, it is difficult to link it with human cysticercosis.

3. Diagnostic Methods and Impact on Epidemiology

PCC can be diagnosed by ante-mortem through lingual palpation, conjunctival examination, postmortem examination, serological and or immunological tests [25]. In postmortem examination, cysticerci can be obtained from striated and cardiac muscles [26]. The masseter, ham-spring, lingual and cardiac muscles are the most preferred predilection sites for cysticerci. However, cystation in the brain has also been observed (**Figure 1**). While pigs can be infected with both *T. hydatigena* and *T. solium*, the Ag ELISA does not differentiate between the two species [27].

On the other hand, detection of the disease in human can rely on identification of *T. solium* proglottids or eggs in human faeces. The techniques have both


(a)

(b) (c)

Figure 1. (a) Cysts in the pig cardiac muscle; (b) in the brain of an 8-month-old pig and (c) in the abdominal muscles of a pig [30].

low sensitivity and specificity though it is regarded as confirmatory of infection by the adult stage of the parasite [28]. Deoxyribonucleic acid (DNA) based technologies are sensitive and specific [29], but their use is not common. On the other hand, the diagnosis of HCC can be achieved through enzyme-linked immunosorbent assay (ELISA), Cysticercus IgG Western Blot Assay, computed tomography (CT) scan and magnetic resonance imaging (MRI). CT scan and MRI are highly efficient, however, they are very expensive and not available or inaccessible in most endemic areas where accurate serological tests become indispensable [30] [31] [32]. Also, the tools are few and so spread far apart in a country with few experts, and that people have to travel long distances to get help thus increasing expenses even if medication is free. But also that they are old models, at the end of their life span, are frequently broken taking months or years to get repaired. Thus increasing the expenses for the people who visit hospitals for a scan but only to be told that the machine is out of order, you have to wait for some months, and come again; Reason: expertise for repair is not resident in endemic developing countries but overseas; so it takes time to bring them to the developing world.

4. Review Approach

The review was based on peer-reviewed studies of TSC from sub saharan Africa from 1960 to 2018; TSC epidemiological reports and theses limited to sub Saharan Africa and; the World Health Organisation (WHO) and the Organisation for Animal Health (OIE) reports. Literature search using advanced search engines such as Google Scholar (http://www.google.com), library catalogues and electronic databases. Some databases include PubMed (http://www.ncbi.nlm.nih.gov/pubmed/), Elsevier (https://www.journals.elsevier.com/the-lancet-infectious-diseases/), Veterinary Parasitology (http://www.sciencedirect.com/science/journal/). Also health related journals websites such as https://www.hindawi.com/, and http://www.sciencedirect.com/science/journal/ were used for this review. The key words are "*Taenia solium* cysticercosis", "human cysticercosis", "neurocysticercosis", "porcine cysticercosis", "epidemiology", "risk factors", "diagnosis", and "control". The search was restricted to research articles, reports, academic outputs such as dissertations and theses in English language from sub Saharan African countries. The search style adopted and modified from that of Shonyela *et al.* [33] as follows: TSC OR Human cysticercosis OR Neurocysticercosis OR Porcine cysticercosis (OR Risk factors of …* OR Diagnosis of …* OR Epidemiology of …* OR Control of …*) AND (Angola OR Benin OR Botswana OR Burkina Faso OR Burundi OR Cameroon OR Central African Republic OR Chad OR Congo OR Zaire OR Cote d'Ivoire OR Ivory Coast OR Djibouti OR Egypt OR Equatorial Guinea OR Eritrea OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR Guinea-Bissau OR Kenya OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Rwanda OR Senegal OR Sierra Leone OR Somalia OR South Africa OR South Sudan OR Sudan OR Swaziland OR Tanzania OR Togo OR Tunisia OR Uganda OR Zambia OR Zimbabwe). Prevalences and diagnostic techniques were key to maping the extent of TSC across sub Saharan Africa. In addition, references found in suitable articles were also investigated to compile all known studies on the presence of TSC (**Table 1**).

Table 1. Prevalence of TSC in sub Saharan Africa.

Countries	Prevalence of PCC	Method(s) of Diagnosis	References	Prevalence of HCC	Method of Diagnosis	References
Angola	0% - 6.8%	Meat Inspection	[34] [35]	ND	ND	ND
Benin	1.8% - 2.04%	Lingual Inspection	[36]	1.3%	ELISA	[37]
Botswana	ND	ND	ND	ND	ND	ND
Burkina Faso	0.57% -39.6%	Meat inspection; Ag-ELISA	[35] [38] [39] [40] [41]	0.0% - 11.5%	B158/B60 Ag-ELISA	[42]
Burundi	2% - 39%	Meat Inspection; ELISA	[40] [43]	2.8% - 41%	Serology	[44] [45]
Central Africa Republic				2.9%	Hospital study	[46]

Continued

Cameroon	11% - 39.8%	Tongue examination, Post mortem, ELISA	[33] [43] [47]	0.4% - 3%	Ab-ELISA	[48]
Chad	6.8% - 25.7%	Tongue examination, Post mortem, Serology	[33] [49]	ND	ND	ND
Cote d'Ivoire	2.5% - 3.6%	Tongue examination, Post mortem examination	[49] [50] [51]	ND	ND	ND
D. R. Congo	0.1% - 41.2%	Tongue examination, Post mortem, Serology	[44]	3%	Autopsy	[52]
Eritrea	ND	ND	ND	ND	ND	ND
Ethiopia	ND	ND	ND	ND	ND	ND
Gabon	ND	ND	ND	ND	ND	ND
Gambia	4.8%	Ag-ELISA	[53]	1.74%		[54]
Ghana	11.7% - 18.8%	Post mortem	[35] [55] [56] [57]	Case Report		[58]
Guinea	ND	ND	ND	ND	ND	ND
Kenya	5.6% - 37.6%	Lingual examination, Ag-ELISA	[59]-[66]	2.4%, 6.6%	Serology, HP10 Ag-ELISA	[66] [67]
Madagascar	2.3% - 4.6%	Ag-ELISA, Post mortem examination	[68] [69]	7% - 21%	ELISA (Western blot)	[70]
Malawi	ND	ND	ND	ND	ND	ND
Mali	ND	ND	ND	ND	ND	ND
Mauritania	ND	ND	ND	ND	ND	ND
Mozambique	6% - 34.9%	Ag-ELISA, Post mortem examination, Tongue palpation	[33] [61], [71] [72]	8% - 71.9%	Ab-ELISA, Ag-ELISA, CT scan	[15] [45]
Namibia	ND	ND	ND	51.41%	CT scan	[73]
Niger	ND	ND	ND	ND	ND	ND
Nigeria	2.4% - 46%	Ag-ELISA, Post mortem examination, Tongue palpation	[35] [49] [74], [75] [76] [77]	9.6% - 14.3%	IgG antibodies (ELISA)	[78] [79]
Rwanda	6.8% - 20%	Ag-ELISA, Post mortem examination	[43] [49] [80]	12.1% - 21.8%	Ab. ELISA, CT scans, PCR	[81]
Senegal	0.2% - 26.7%	Lingual examination, Ag-ELISA	[33] [49] [53] [57]	7.69%	Ab-ELISA	[82] [83]
Somalia						
Republic of South Africa	11.9% - 64.4%	Ag-ELISA, Lingual and Post mortem examination	[59] [61] [84], [85] [86] [87]	30% - 51%	Ab-ELISA, CT scan	[88]
Sudan	ND	ND	ND	ND	ND	ND
Swaziland	ND	ND	ND	ND	ND	ND
Tanzania	4.5% - 33.3%		[45] [59] [89]-[95]	2.8% - 76%	CT scans, Ab-ELISA, Ag-ELISA, EITB	[2] [30], [96] [97]
Togo	17%	Meat inspection	[35] [98]	2.4%	Ag-LISA	[98]
Uganda	8.6% - 39.5%	Serology, Antemortem and Postmortem Inspections	[61] [99] [100], [101] [102]	9% - 15%	Ab-ELISA, Ag-ELISA, EITB	[33] [103]
Zambia	20% - 56.6%	Post mortem inspection, Ante mortem inspection, ELISA	[59] [61]	10% - 38.5%	Ag/Ab ELISA	[45] [104]
Zimbabwe	2.7% - 28.6%	ELISA, Post mortem inspection	[33] [61] [105] [106]	11% - 12%	X-ray	[45]

5. Transmission Life Cycle of *Teania solium*

In humans, adult tapeworms grow sexually and release mature proglottids containing between 30,000 to 50,000 eggs [107]. Proglottids shed in human feaces become the ultimate source of infections to both humans (definitive host) and pigs (intermediate host). Pigs become infected by ingesting *T. solium* eggs or gravid proglottids contaminated in water and or food items. Ingested eggs hatch into oncospheres that invade the intestinal wall, migrating via blood circulatory system and lymphatic system to striated muscles, brain, liver and other tissues where they develop to form cysticerci. Cysticerci can be transmitted to human through consuming raw or undercooked pork infected with cysticerci. However humans can serve as accidental intermediate hosts through ingestion of contaminated water and food containing *T. solium* eggs or gravid proglottids. When the cysticerci infect Human Central Nervous System (CNS) may cause neurocysticercosis [108].

6. Risk Factors for TSC

It is worth mentioning TSC as a disease of poverty whose persistence is exacerbated by ignorance. The disease is endemic in most resource-poor countries where sanitation is inadequate and free-range pig farming is practiced [108]. However, as a result of migrations, tourism and globalisation, TSC has been reported in industrialised countries [3] [4] where sanitation is adequate. Also, there have been case reports of HCC among communities of Muslims [109] and Orthodox Jews [4] [110] that the risk of infection spares no world.

The risk factors which is associated by the transmission of TSC include indiscriminate defaecation and improper use of toilets; free-range system of keeping pigs; indiscriminate or unregulated slaughtering and inadequate meat hygiene and inspection; consumption of undercooked and porcine cysticerci infected pork; social structure and roles; and proximity of a tapeworm carrier [111] [112] [113] [114] [115]. The immanent social cultural settings and lifestyles of the communities in endemic areas form the main concern on the epidemiology of the disease.

7. Control Strategies and Challenges

Pig keeping and pork consumption are primarily increasing due to increased meat protein (pork) demand in urban [116] and rural areas. Unfortunately, due to ignorance, inadequate sanitation, poor personal hygine, poor pig management practices and lack or absence of meat hygiene, cysticercosis remains an important constraint for public health, nutrition and economic well being of the predisposed communities [116]. While the life cycle of cysticercosis cannot be maintained in areas that have adequate sanitation, personal hygiene and good animal husbandry practices, thus, social cultural settings, poverty and ignorance would form a barrier in eradicating this easily preventable disease.

If people would know how diseases are transmitted and how to improve their hygiene and sanitary behaviour, it would have an important impact on minimizing the risk factors. A knowledgeable public as an early warning system reporting cases in humans and pigs would play a key role in managing the existing risks of importing/exporting *T. solium.* The route can be through tourism, migration of tapeworm carriers or indirectly through transportation of infected pigs, or pig meat to urban settings. Because of the complex nature of TSC epidemiology, its control requires a multidisciplinary and multilevel approach [117].

Theoretically and scientifically points of view, interruption of the transmission of TSC looks very easy. Because one would simply prevent pigs from consuming human faeces; treat human carriers to break cycle of the adult forms of the parasite; prevent humans from consuming infected pork or autoinfection. The umbrella behind all these falls under sanitation which is the key point to stop TSC transmission from human to pigs by providing latrines and clean water to prevent open defecation; ensuring hygienic animal husbandry practices; stop transmission from pigs back to humans through veterinary sanitary measures such as regulation of meat inspection practices and not eating raw pork [118].

However, in practice, it has been difficult to achieve these control measures. Some of the difficulties that contribute to the extent that eradication of TSC still being a long way might be limitations on facilities required for diagnosis; the unnoticed long-life of the parasite in the human body and low public awareness on the transmission drivers for the disease [119].

8. Conclusions

The volume of studies on TSC in sub-Saharan Africa has been encouraging that one might think efforts towards eradication of the disease are fruitful. A significant number of the research is the front line which rarely finds its way into applications. Bridge cutting-edge science and application, in an area of huge societal and economic impact, TSC control is imperatively important. This is because over decades today, the high prevalence of human (neuro) cysticercosis and the accompanied epilepsy cases are increasingly observed even in areas of the world which TSC disease was considered history; PCC is now observed in areas which were considered free from the disease; diagnosis challenges and; globalisation. The solution towards breaking and therefore eradicating the TSC transmission cycle must be a bottom-up and community-based control (CBC) programme which would critically address the concept of "One Health".

Sincerely, transmission of TSC is favoured by poor sanitation. What is perhaps missing is the knowledge on "why is the communities involved ease indiscriminately while almost every household in endemic areas owns toilet? What social drivers are behind this motive (bush defecation)? How best can the disease be controlled and monitored? Developing and implementing an interdisciplinary CBC and monitoring (surveillance) programme are standpoints towards eliminating TSC in sub Saharan Africa and the rest endemic regions.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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