

The Global Impact of *Taenia Solium*

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In 2009 the World Health Organisation (WHO) designated cysticercosis a neglected disease. It should be focussed upon by world communities to reduce *Taenia solium* related morbidity and mortality.¹

Taenia solium is a human intestinal cestode tapeworm. Humans serve as the obligate definitive host, whereas pig species and humans can both serve as the intermediate host.

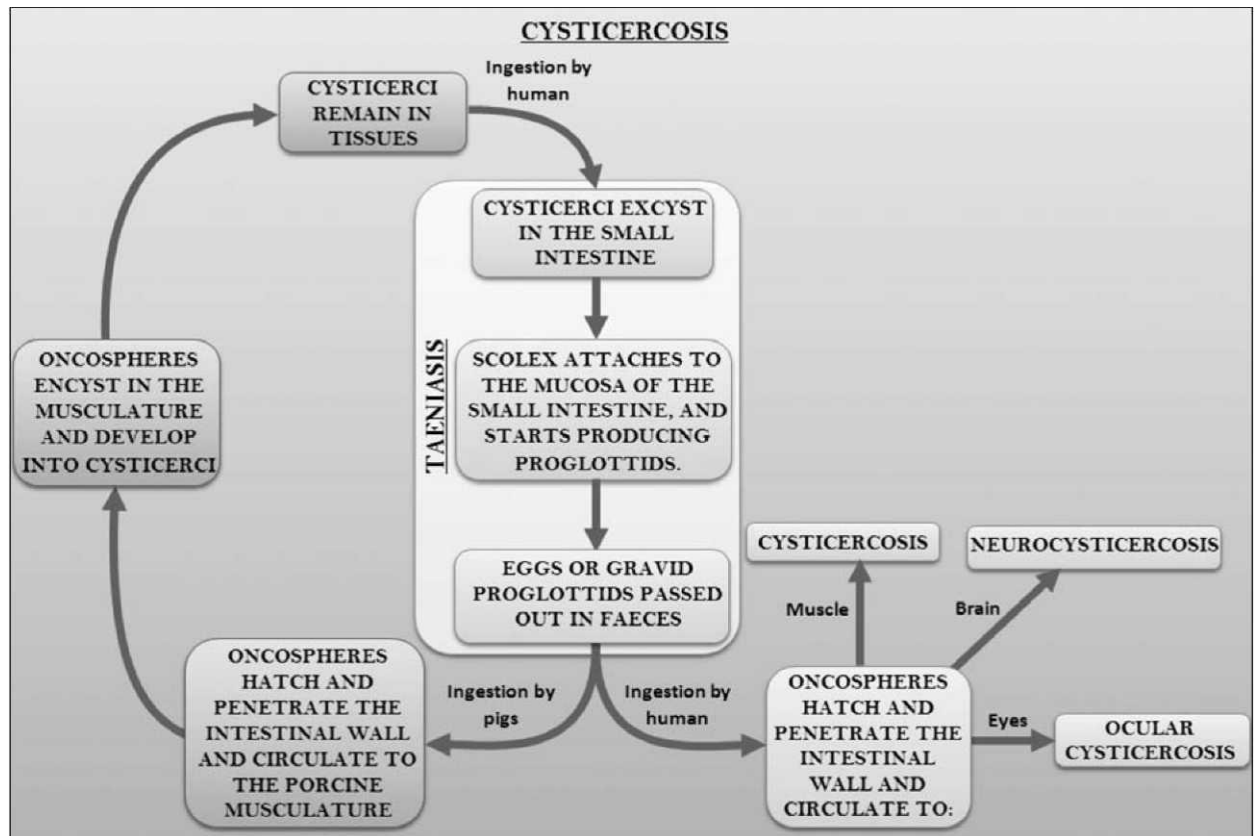


Figure 1:

Lifecycle of *Taenia solium*. Red boxes: stages within the porcine host; White boxes: stages within the human host; Yellow box: the part of the lifecycle referred to as taeniasis; Blue box: stages in the development of cysticercosis

One Organism, Many Diseases

Taenia solium causes two infections in humans: taeniasis and cysticercosis. Both are linked predominantly to under developed and rural communities, where sanitation is poor, pigs are in contact with human faeces and the ingestion of undercooked and raw pork is common.² Prevalence is high in Latin America, Eastern Europe, sub-Saharan Africa, India and Asia, see **Figure 2**.² However, it is also increasingly being seen in developed countries with increases in migration and tourism.

Taeniasis

Taeniasis describes the condition whereby humans act as the definitive host having eaten infected meat. The presence of the tapeworm in the lumen of the gut may not cause disease,^{3,4} although mild symptoms of abdominal pain, distension, diarrhoea, nausea, weight loss, and a loss of appetite have been described.⁵ The gravid proglottids of *T. solium* are small and amotile making them less noticeable as they pass in the faeces.⁴

Human Cysticercosis

in the intermediate porcine or human host *T. solium* hatches from the egg under the influence of gastric acid, and the oncosphere penetrates the gut wall and by haematogenous spread encyst in body tissues to form cysticerci, **Figure 1**. The effect of the cysticerci depends on the location in which they encyst.

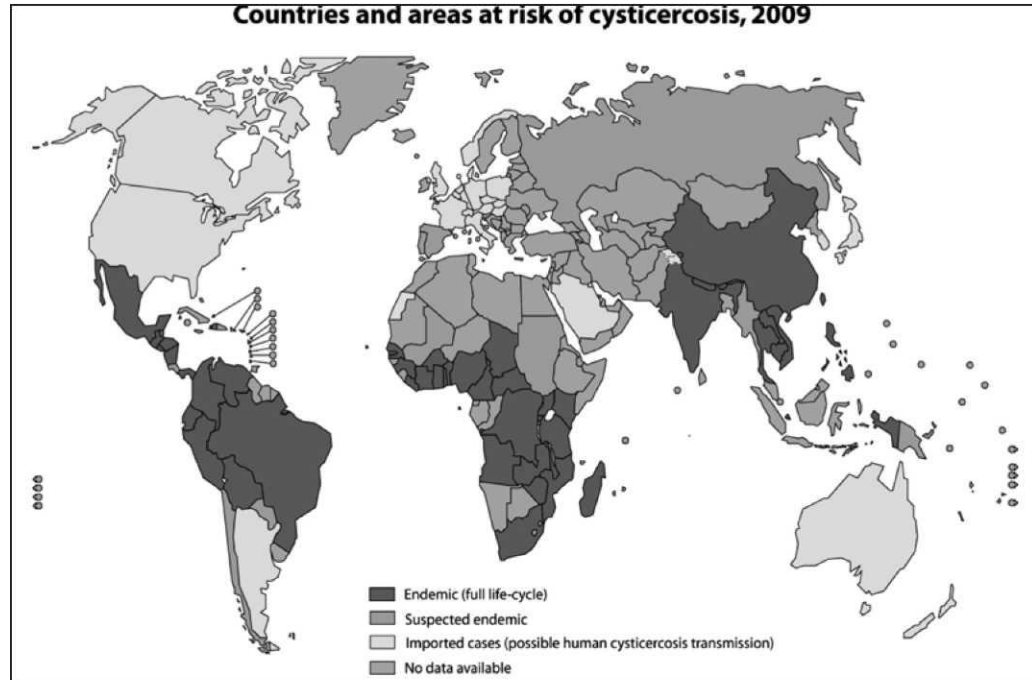


Figure 2:

Map showing the worldwide distribution of cysticercosis (Taken from WHO¹)

Muscular cysticercosis is commonly found on radiographs in prevalent regions, particularly distributed in the muscles of the arms and thighs.⁵ Although generally asymptomatic, in high parasite burden the muscle bulk appears to be enlarged, known as muscular pseudohypertrophy. Subcutaneous cysticercosis is identifiable by painless mobile nodules under the skin, found most commonly on the trunk and the arms.⁵

Ocular cysticercosis

Ocular cysticercosis accounts for about 1-3% of cysticerci infections⁵ but is incidentally found in cases of neurocysticercosis or subcutaneous cysticercosis. The cysticerci are commonly found in the subconjunctival space, the anterior chamber, the lens or the vitreous cavity.⁶ Rarely, the parasites may encyst in the extraocular muscles and surrounding tissues.⁷ Ocular cysticerci are associated with diplopia, pain and swelling of the eye, as well as some loss of visual acuity.⁷

Neurocysticercosis

Neurocysticercosis, according to the WHO, is the commonest cause of secondary epilepsy, and is the commonest helminthic infection of the central nervous system (CNS).¹ The signs and symptoms of the condition are dependent upon the position, developmental stage and number of the cysts present as well as the body's immune response to the cyst. The commonest presentation (50-80% of cases) of the neurocysticercosis is seizures, however it may present on the spectrum of asymptomatic to sudden death.⁸

Cysts can be found within the parenchyma, sub-arachnoid space or the interventricular system of the CNS. Epilepsy is more common with parenchymal disease, and causes generalised tonic-clonic or simple partial seizures.⁹ The seizures are usually associated with the immune system's inflammatory reaction to the dying cyst, but may occur at any stage in the cyst's lifetime, see **Figure 3**.⁹ Maintenance

of epilepsy has been strongly attributed to the eventual calcification of cysts with perilesional oedema.^{9,10} Other manifestations of parenchymal disease include associations with psychiatric illness, such as depression or psychosis.⁹

Raised intracranial pressure can result from intense acute inflammation in cysticercotic encephalitis, or by the obstructive effect of a large cyst. These can be life-threatening if not treated rapidly.^{9,11}

in extraparenchymal disease, cysticerci do not follow the same growth pattern as in parenchymal disease, instead they become the racemose form,¹¹ where the larvae form a cyst of multiple unencapsulated bladders which grow unconfined in the cisterns, and put pressure on the surrounding tissues; this can lead to hydrocephalus or arachnoiditis.^{9,11}

Subarachnoid infection can also lead to both transient ischaemic attacks and strokes as a result of neurocysticercosis induced cerebral arteritis.^{9,11}

Diagnosis and Treatment of cysticercosis

The diagnosis of cysticercosis is based on clinical findings, cysticercus-specific igG antibody level as determined with an enzyme-linked immunoelectrotransfer blot assay (EiTB); an ELISA of serum or cerebrospinal fluid (CSF); and CT or MRi imaging of the area concerned.¹²

Treatment with the cysticidal agents praziquantel or albendazole has been shown to be effective.^{9,12} This is used in conjunction with corticosteroids to reduce the oedema associated with the death of the cysticerci, and anti-epileptics,^{12,13} as much of the pathology related to neurocysticercosis is as a result of an inflammatory response.¹² This treatment is particularly effective in earlier phases of the condition⁹ but might not fully rid the patient of seizures, particularly in disease with a high number of cysts. These patients will require long term anti-epileptic treatment.¹³ Surgical intervention might be required if hydrocephalus is present or in ventricular or sub-arachnoid disease.⁹

Oncosphere reaches parenchyma

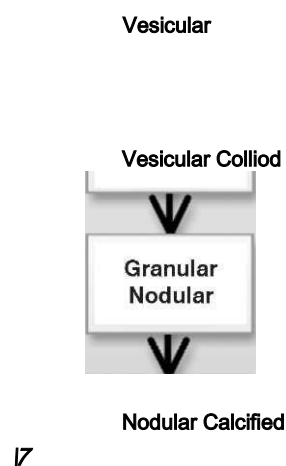


Figure 3:

Stages of parenchymal neurocysticercosis. Vesicular disease represents little or no immune response to the presence of the parasite, viewed as a fluid filled cyst. As the immune response to the parasite increases the fluid leaks into the surrounding tissues and the cyst passes through the stages until it has calcified, and the parasite is no longer viable. All stages can cause symptoms.^{8,1}*

Porcine cysticercosis

Porcine cysticercosis is the sustainable intermediate form which allows transmission to the human host via ingestion of the cysticerci infected meat. it is contracted through the ingestion of *Taenia solium* eggs or gravid proglottids, present in the environment from contamination with human faeces. The

cysticerci in the pig develop in the muscles of the heart, tongue, masseter, shoulder, and intercostals, rarely they are found in the brain and liver of the animal.¹⁴

The risk factors associated with the presence of porcine cysticercosis in a community include: the lack of latrines, free ranging nature of pig rearing, the lack of pork inspection, barbecuing of the meat, and home slaughtering of the animals.¹⁵ As well as the age of the pig, with older pigs having greater number of cysticerci.¹⁵

Table 1:
Comparing the Sensitivity and Specificity of the techniques for porcine cysticercosis^{16,17}

Diagnostic technique	Specificity %	Sensitivity %
Antemortem lingual palpation	100	7-21
Post-mortem meat inspection	100	22
HP10 Ag-ELISA serology	94.7	70.4-86.7
Ab-ELISA serology	91.7	35.8

Diagnosis of porcine cysticercosis is important in the prevention of transmission to the human host. Methods of detection and their specificities and sensitivities are seen in **Table 1**. The poor sensitivity of the lingual palpation and meat inspection is due to cysts only becoming visible in heavy infections. A combination of all tests yields the most reliable results for prevalence screening of porcine cysticercosis, but is not financially viable for a farmer concerned about the health of his stock. Education into bettering improving the cheaper diagnostic techniques of lingual palpation and meat inspection should be the focus of improving diagnosis.

Cysticidal treatment of infected animals with a single weight-adjusted dose of oxfendazole, has shown to be more than 95% effective.¹⁸ However, previous infection confers no immunity, and reinfection can occur almost immediately.¹⁹ Treated and killed cysticerci still are visible in the meat which can make the meat unsellable, despite being no longer infective.¹⁹

Global Impact

it is evident that *Taenia solium* has individual and public health impacts as well as socioeconomic implications. Although predominantly in developing countries, there is concern that with increasing migration and tourism that it will become endemic in more developed countries.

Porcine Cysticercosis

Meat inspection and lingual palpation in Western and Central Africa suggests prevalence of Porcine cysticercosis levels ranging from around 1% in Burkina Faso and Senegal, to an estimated 40% of pigs infected in Burundi.²⁰

infected meat is unfit for human consumption and this level of infection has significant consequences for the livelihood of the farmers. in many African countries, legislation dictates that infected meat should be destroyed, this however is not enforced. As such, Due to the lack of meat inspection as well as a high level of slaughtering that takes place outwith abattoirs the majority of the infected meat is consumed or reaches the market and sold at a discounted rate, up to 50% from the original value.²⁰ Zoli et al. estimated a resulting loss of over €25 million annually (about £21million) in ten West and Central African countries.²⁰ As well as this financial impact, there is also the public health impact of selling infected meat, and promoting the life cycle of *Taenia solium*.

in the Americas porcine cysticercosis is better policed. One estimate of the cost of the disease in Mexico placed the annual loss at over \$43million USD in 1982,¹⁹ this total was more than half of the total national investment into swine production.

Cysticercosis

The human disease not only has financial implications, but also has implications for individuals affected and wider public health implications.

Epilepsy is more common in the developing world, much attributed to neurocysticercosis.²¹ in endemic regions, the seroprevalence for cysticercosis has been estimated between 10-25%.⁵ Taeniasis in endemic regions is estimated to be around 6%.⁵ The discrepancy is due to the large egg output

from adult tape-worms, making identifying an adult carrier extremely important. In Mexico 50% of patients with secondary epilepsy in one study were diagnosed to have as having neurocysticercosis.²²

In endemic regions local beliefs may make diagnosis difficult and may affect compliance to the medication. There is often stigma associated with the epilepsy of neurocysticercosis. Some cultures view those suffering from epilepsy as shamans, whilst others view the seizures as the possession by a malign spirit. In the northern Laos Hmong culture, their word for epilepsy translates as "the spirit that catches you and you fall down".²³

In a study from Nigeria, 16.5% of persons asked believed that seizures were caused by the possession of evil spirits and the preferred treatment was spiritual healing,²⁴ a belief common among much of African society, with sufferers being cast out of communities believing that it is contagious and shameful.²⁰ Epilepsy is still viewed in many parts of the world as a reason to avoid marrying a person, and to annul a marriage.^{24,25}

It is estimated that a patient with cysticercosis is hospitalised for 8 days, and incurs 19 day wage loss. One estimate for Cameroon, where the prevalence of neurocysticercosis is only 0.7%, put the loss as a result of treatment at over €13.5 million.²⁰

In non-endemic countries the disease is more commonly seen in the migrant populations. For example, in the USA persons who have migrated from Latin America are found in large numbers in Los Angeles, New Mexico, and San Diego. In these regions neuroimaging of patients who suffered seizures revealed higher proportions of neurocysticercosis, with 10% and 6% of seizures being attributed to the parasite in Los Angeles and New Mexico respectively.⁵

As well as the public health implications of neurocysticercosis, the financial cost is important in the parasite's global impact. The 1992 estimated annual cost of hospital admissions in Mexico was quoted to be \$89million USD, which rose to \$195 million USD when taking into account the lost wages from those with the condition.²⁶ However, these figures do not account for the cost of continuing anti-epileptic treatment required.

In the USA the 1992 estimate for financial consequences of neurocysticercosis was nearly \$8.8million USD.²⁶ There is little information for the incidence of the disease in the UK, however there are reports of cases seen in UK hospitals.²⁷

Rates in non-endemic countries are likely to rise with expedition or adventure tourism, as well as medical aid work to endemic rural regions. The increase of migration from endemic countries to non-endemic countries will further increase the incidence in non-endemic regions, as highlighted by the story of an Orthodox Jewish community in New York in 1991.

Symptomatic neurocysticercosis was diagnosed in four unrelated members of the community and seropositive findings for cysticercosis in their immediate families. None of those affected had travelled to endemic regions, and due to religious reasons none ate pork. What they all had in common was the employment of housekeepers that had emigrated from Latin America, some of whom were shown to be positive for an active infection or a past infection.²⁸

Preventing the Spread

Although clinically important, the forms of human cysticercosis are a dead end for the parasite's lifecycle. As such, finding ways of identifying and treating both human carriers and infected pigs, as well as preventing the infection of both humans and pigs are the key to reducing the global impact of *Taenia solium*. All eradication strategies must take into account economic feasibility to be effective and sustainable.²⁹

Due to its innocuous nature, taeniasis is difficult to diagnose and is further hindered due to: the poor visibility of the eggs and proglottids in stool samples and due to the morphological similarities between the eggs of *T. solium* and *T. saginata*, which, although important cannot cause cysticercosis.⁵ Coproantigen ELISA detection of stool samples detects *Taenia*-specific molecules to identify tapeworm carriers with 95% sensitivity and >99% specificity.⁵ Treatment involves a single dose of niclosamide.⁵ Treatment has the benefit of interrupting the disease lifecycle, however, even successful treatment confers no immunity, and reinfection can occur.²⁹

Taenia solium was eradicated in more developed countries as a result of the improving animal husbandry, food inspection, and sanitation and latrine facilities, thus blocking the exposure of the animals to the eggs contained within the human excrement.²⁹ The simple step of corralling or tethering the animals, and preventing the foraging nature of the animal can lead to a decrease in porcine cysticercosis. In a Peruvian village the seroprevalence of pigs dropped dramatically after the introduction of a rice field led to the tethering of the animals to prevent them from ruining the crop, inadvertently preventing them from ingesting the *T. solium* eggs in the environment.²⁹

Prevention of taeniasis relies upon improvements in meat inspection to ensure that infected meat does not enter the consumer market. Previously, the WHO suggested that this was where the control measures should be focussed. Tighter control of slaughter houses would prevent transmission of not only *T. solium*, but other forms of taeniasis. However, this strategy was not well implemented and drove an increase in black market and illegal slaughtering, as in many endemic countries no compensation is paid to the farmer if his pig is found to be infected.²⁹ This is a non-sustainable solution.

The best hope of an achievable solution to prevention lies with the development of a vaccine for pigs in endemic regions to prevent infection. The most promising is the TSOL18 vaccine against the oncosphere stage of the lifecycle,³⁰ which has shown high levels of protection (99.3-100%) in field and experimental trials in Mexico, Cameroon, Honduras and Peru.^{30,31} This, when combined with a single dose of antihelminthic treatment of both animals and humans, could prove to be a sustainable and successful means of preventing *T. solium* transmission in endemic regions.³⁰

Conclusion

Although the international spread of human cysticercosis poses the most immediate personal health concern, the international spread of taeniasis has greater long term public health and cost implications due to the almost silent nature of infection and the long period of egg shedding. A carrier of taeniasis not only risks infecting cohabitants and close contacts with the devastating effects of cysticercosis in its many forms, but, perhaps more seriously, has the potential for introducing the parasite to the native pig population, and reinitiating the *Taenia solium* life-cycle in regions and countries where the parasite has not been seen for many decades. For this reason interrupting the lifecycle and preventing the spread of the parasite is essential for both local and global health.

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