

Control of cysticercosis in Madagascar: beware of the pitfalls

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***Taenia solium* cysticercosis is a zoonosis of public health importance in areas where the disease is endemic, with significant economic impacts on human health and the swine industry. Several gaps remain in the epidemiology of the parasite and the strategies of control in developing countries. We detail the key factors to consider in Madagascar in terms of the porcine husbandry system, *Taenia* transmission cycle, and diagnosis of cysticercosis in pigs, in order to better estimate the sanitary and economic impacts of this parasitic disease as well as to define an integrated control program.**

Taeniasis and cysticercosis: what to do?

Cysticercosis is a zoonosis caused by *Taenia solium*, which affects both humans and pigs [1]. Pigs are infected by eggs emitted in human feces and develop cysticercosis due to the larval stage (see Glossary). Humans are the definitive host of the adult tapeworm but can also develop cysticercosis in muscles, the brain, and eyes [2], either through self-contamination by eggs emitted from a current tapeworm infection or by ingestion of food contaminated by human feces [3]. Neurocysticercosis (NCC) is one of the most prevalent parasitic infections of the brain and the most common cause of seizure in adults in tropical countries [1]. The computed tomography (CT) scan is a reference method for diagnosis of NCC in humans, but is not widely available in resource-limited areas [4,5]. Serological methods thus remain the most utilized diagnostic tool.

This foodborne parasite affects more than 50 million people worldwide, and Madagascar is a hotspot for cysticercosis [6,7]. In most countries in Africa, Asia, India, and Central and South America, porcine cysticercosis is also highly prevalent [6,8]. Infection by *T. solium* has been eradicated in most European countries, mainly through industrialization of pig rearing and development of

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Glossary

Abattoir/slaughterhouse: place where animals are killed, and meat is prepared by a butcher for sale.

Adult stage (cestode): long, single plate worm located in the human digestive tract; for *Taenia solium*, it can be several meters long. The head is attached to the epithelial barrier by six hooks. The body of the worm is composed of thousands of independent segments (proglottis), and distal segments detach from the worm and are emitted with feces.

ASF: African swine fever.

Cerebrospinal fluid (CSF): fluid that fills the brain cisterns and where antibodies are secreted to protect the brain.

Collectors: people who go to the villages to buy pigs from farmers to sell them again to butchers at slaughterhouses in town.

CT scan: computed tomography (CT) scanning using X-ray.

Cysticercosis: infection due to the larval stage of *T. solium*. In pigs, it is due to ingestion of contaminated human feces; in humans, it is related to carriage of adults in the intestinal tract with autoinfection or orofecal contamination by eggs (contaminated food, etc.).

Egg: emitted on the soil with feces after rupture of the proglottis; they are ingested with contaminated food. The four hooks can be seen in the eggs (used for species determination). Taenid eggs are activated by the acid pH in the stomach and transform into microscopic larvae, which actively cross the intestinal barrier.

Enzyme-linked immunosorbent assay (ELISA): detection of antigens by antibodies; antigens are immobilized on plastic plates, and antigen-antibody complexes are revealed by colorimetric reaction.

Epidemiological cycle: a diagrammatic illustration of the interaction between disease determinant factors.

Larval stage (cysticercus): cystic round parasite form (1–5 mm), containing the head (scolex) of the future worm; they can be transported throughout the body by blood flow but are mainly located in muscles, the heart, and the brain.

Loop-mediated isothermal amplification (LAMP): a molecular method that amplifies DNA by using four specific primers and *Bst* DNA polymerase in less than 1h under isothermal conditions.

Magnetic resonance imaging (MRI): medical imaging using stimulation of water molecules by a powerful magnetic field to obtain a map of these molecules in the body.

Neurocysticercosis (NCC): infection of the brain by a cysticercus; it can be detected by CT scan. The presence of the larvae can induce seizure or mass effect, perturbing the normal function of the brain according to their position in the brain.

Qualicode cysticercose IgG: ELISA kit using crude cysticercus antigens to detect IgG in serum.

Smallhold pig farming: rearing of pigs is mainly conducted by farmers who each have only one to three pigs.

Taeniasis: infection by the adult stage of a cestode.

Ultra peripheral regions of Europe: islands belonging to the European Union but far from the European continent, e.g., La Réunion, French Guiana, Mayotte, Madeira, and the Canary Islands.

Value chain: all the elements of the commercial process from herd to meat, which determine the price of the final meat and the gain obtained by each stakeholder.

Western blot/electroimmunotransfer blot (EITB): detection of antigens by antibodies on a nitrocellulose membrane, after separation of the antigenic preparation by electrophoresis on an acrylamide gel and electrotransfer of the protein to the nitrocellulose membrane.

Wildlife (or sylvatic) cycle: part of a life cycle of a pathogen involving wild animals.

sanitation measures [9,10]. However, data are lacking for more than one-third of the Member States, and pig cysticercosis still occurs in Eastern Europe and Portugal [11]. In the same line, ultra peripheral regions of Europe, such as Mayotte and La Reunion, two French overseas departments in the southwestern Indian Ocean region, are concerned by NCC due to the regular movements of populations between neighboring countries.

Although data are sparse, a high prevalence of cysticercosis in swine and humans was reported in Madagascar [12–14]. However, its natural history and the epidemiological situation of pig herds are poorly documented. The burden is probably vastly underestimated, as the visual inspection of carcasses at slaughterhouses is not a very sensitive metric. Detection of infection in livestock is therefore a priority.

We therefore address these foremost issues in Madagascar and the lever-points that can be mobilized to control the disease, at the farm and along the pork meat value chain levels. The pitfalls with which health services and research institutes must struggle are also discussed. Because the economic issue may be the major keystone to decrease the reservoir of *T. solium* in the country, we underline the role that smallhold pig farmers can play in controlling cysticercosis in their herds.

Disease burden of cysticercosis

Prevalence of porcine cysticercosis

During the 2008 to 2012 period, the ‘official’ cysticercosis prevalence in Madagascar ranged from 0.5% to 1% in pork carcasses [15]. However, this low prevalence, reported in the absence of any specific control program, may question the reliability of the meat inspection system. By comparison, in Central and South America prevalence of cysticercosis in pigs ranges from 0.5% to 35% after meat inspection [16]. This discrepancy might also occur in Madagascar considering that most pigs are not slaughtered in abattoirs, where carcasses are examined for sanitary control [17]. Over the past 10 years, partial results reported 336 farms with cysticercosis-positive pigs (Figure 1) [15]. Central highlands such as Vakinankaratra, Haute Matsiatra, Analamanga, and Bongolava are the regions declaring most of the infections reported (48%, 12%, 10%, 7% of cases, respectively; Figure 2B).

Risk factors associated with porcine cysticercosis

In rural countries such as Madagascar, semi-confined pig production by smallholders, spread over very large areas that are poorly connected by roads, is a fast growing practice. Assistant veterinarians recruited among villagers provide most of the healthcare to the herds in remote

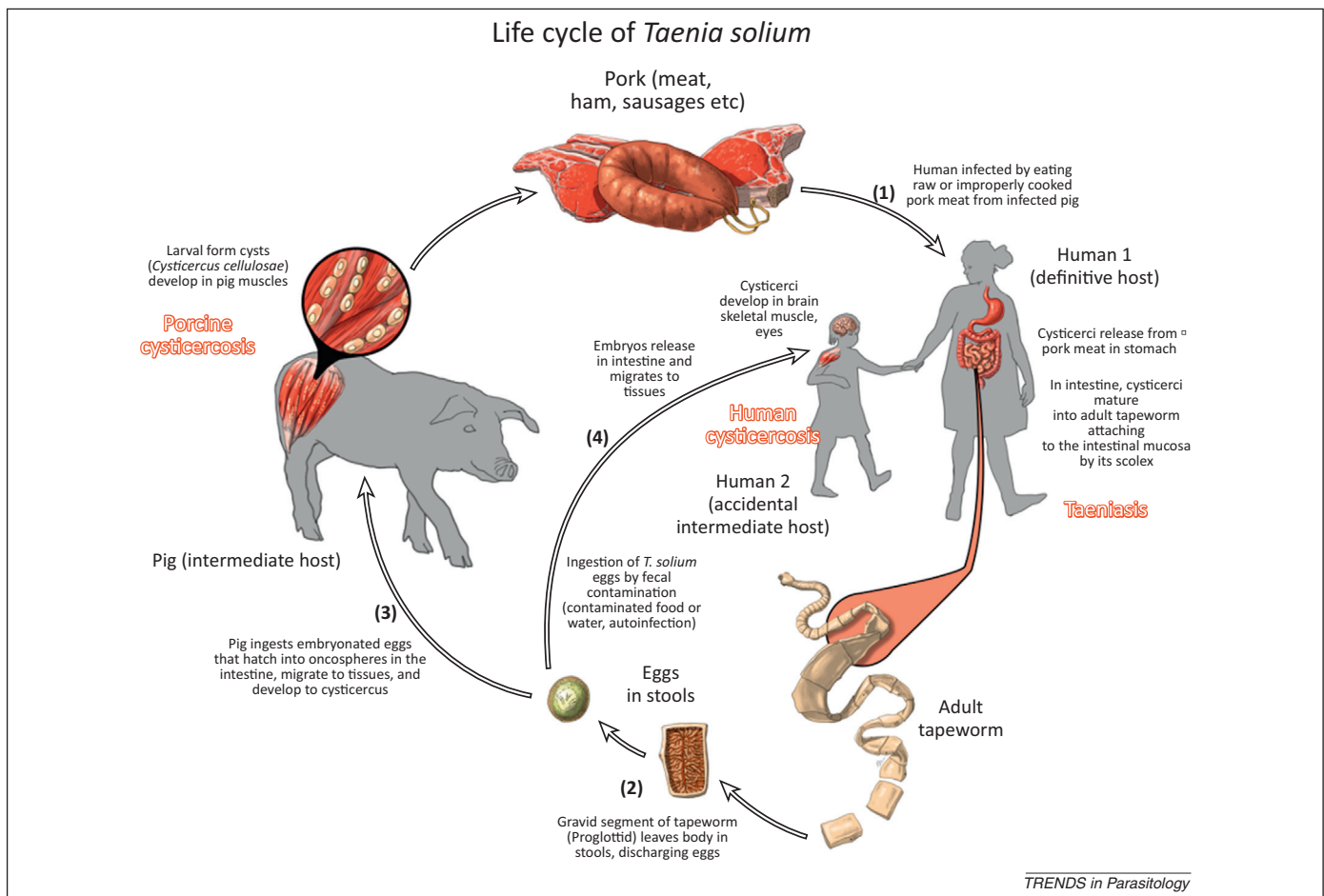


Figure 1. Epidemiological life cycle of *Taenia solium*. Adult stages (cestode) are located in the human digestive tract; human carriers of *T. solium* are contaminating the environment as eggs are emitted on the soil with feces after rupture of the proglottis. Eggs are then ingested with food contaminated by human feces. In the human or pig stomach, taenid eggs are activated by the acid pH and transform into microscopic larvae, which actively cross the intestinal barrier. Larval stages (cysticercus) are round parasite forms (1–5 mm) containing the head (scolex) of the future worm; they can be transported everywhere by the blood flow but are mainly located in muscles, the heart, and the brain.

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