



Seroprevalence and awareness of porcine cysticercosis across different pig production systems in south-central Cambodia



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ABSTRACT

Background: Taeniasis/cysticercosis, caused by the pork tapeworm *Taenia solium*, represents an important public health and economic burden in endemic countries. However, there is a paucity of data on infection among pigs in many parts of Southeast Asia, particularly Cambodia. We aimed to estimate seroprevalence of porcine cysticercosis, and investigate husbandry practices and knowledge of the disease among livestock workers, across different pig sector units in south-central Cambodia.

Methods: A cross sectional survey was conducted among pig smallholders, commercial farms, slaughterhouses and traders/middlemen from south-central Cambodia, selected through multi-stage sampling in proportion to local pig populations sizes. Questionnaires were administered to 163 pig workers to obtain data pig production, trading and slaughtering practices. Sera from 620 pigs were tested for *Taenia* antigens using a commercial ELISA-based test. Associations between seroprevalence and pig husbandry practices were assessed using generalised linear mixed models, adjusting for random-effects at herd-level.

Results: Of 620 pigs sampled, 29 (4.7%) tested positive for *Taenia* antigens. Seropositivity was associated with type of pig sector unit ($P = 0.008$), with the highest seroprevalence among pigs sampled from traders/middlemen (16.7%; 95% CI: 4.4%–37.8%), smallholders (7.6%; 95% CI: 3.8%–14.1%) and slaughterhouses (4.1%; 95% CI: 2.0%–7.5%), while none of the pigs sampled from small/medium or large commercial farms tested positive. Although the vast majority of pigs were penned, practices that might facilitate human-to-pig transmission, such as use of household waste and surface water sources to feed pigs, were prevalent among smallholders. However these were not found to be significantly associated with infection. Of 163 interviewed pig workers, 115 (70.5%) were aware of porcine cysticercosis, and 78 (47.8%) also knew it could affect humans. Twenty-six (16.0%) reported having noticed lesions typical of cysticercosis in their pigs.

Conclusions: Despite most pigs being kept confined in pens rather than raised in free-roaming systems, porcine cysticercosis appears to be endemic in south-central Cambodia and is associated

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with smallholder production. Further investigation is needed to identify which *Taenia* species are causing infections among pigs, and how seroprevalence and zoonotic risk may vary across the country, to understand the risks to public health and assess where interventions might be needed.

1. Background

Taeniasis/cysticercosis is a neglected parasitic disease caused by the adult or larval stage of cestodes in the genus *Taenia*. In Southeast Asia, *T. solium*, *T. saginata* and *T. asiatica* causes taeniasis (intestinal tapeworm infection) in humans while *T. solium*, *T. asiatica* and *T. hydatigena* causes cysticercosis in pigs (Conlan et al., 2011). Despite having been declared a potentially eradicable disease in 1992 (Schantz et al., 1993), it remains highly prevalent and a major public health and economic concern in many developing countries in Asia, Africa, and South America (Sarti et al., 1992). An important example of a One Health disease, taeniasis/cysticercosis transmission is dependent on human and animal hosts as well as environmental contamination and socioeconomic factors such as livestock husbandry practices, socioeconomic status, housing conditions, hygiene and eating habits.

Humans are the natural definitive host of *T. solium*, becoming infected through eating raw or undercooked pork contaminated with cysticerci (the larval stage), which then mature into adult tapeworms in the small intestine, causing the condition known as taeniasis. Pigs, the intermediate hosts, become infected through ingestion of the eggs or proglottids produced by adult worms and excreted in the faeces of infected humans. Within the pigs, these stages hatch and migrate to the muscle tissue forming cysticerci, causing porcine cysticercosis (García et al., 2002). Humans can also develop cysticercosis via fecal-oral transmission of *T. solium* eggs or proglottids, for example by ingesting contaminated food or water (Pal et al., 2000), and the cysts can develop in the brain or spinal cord causing neurocysticercosis (White, 2000). Pigs are also the intermediate hosts for two other *Taenia* species: *T. asiatica* (the Asian tapeworm) and *T. hydatigena* (the canine and feline tapeworm), which are also endemic in parts of Asia (Conlan et al., 2012). *T. asiatica* causes taeniasis in humans (the definitive host), but is not thought to cause human cysticercosis (Aung and Spelman, 2016). Meanwhile *T. hydatigena*, for which dogs and cats are the definitive hosts, is not thought to infect humans (Conlan et al., 2012).

Cysticercosis is an important disease in terms of both its public health and economic burden, with an estimated 2.5 million people infected with the *T. solium* tapeworm and 20 million with cysticerci (Bern et al., 1999), and causing an estimated 2.78 million DALYs (Disability Adjusted Life Years) worldwide (Pawlowski et al., 2005; Torgerson et al., 2015). Economic losses result not only from the costs of diagnosis, treatment, and loss of productivity related to human disease (Widdowson et al., 2000; Willingham et al., 2010; Carabin et al., 2005; Roberts et al., 1994), but also from the costs to livestock production. Porcine cysticercosis can decrease the value of pigs and pork meat and often results in total condemnation of carcasses upon meat inspection (Willingham et al., 2010; Ito et al., 2003). Cysticercosis does not usually produce clinical signs in live pigs, but cysts can sometimes be observed on the tongue or eyelids. Other manifestations in pigs include diarrhoea, myositis, emaciation, myocardial failure, abnormal skin sensitivity, seizures and neurological disorders (Urquhart, 1998; Trevisan et al., 2016).

Recommendations for *T. solium* control include improving the use and maintenance of latrines, improvement of pig management practices, and antiparasitic treatment of human taeniasis cases to reduce environmental contamination with, and human and pig exposure to, *T. solium* eggs in human waste. Interventions targeting pig-to-human transmission pathway include treatment of pigs, meat inspection, and thorough cooking of pork (Carabin and Traoré, 2014). A vaccine against porcine cysticercosis has demonstrated effectiveness in preventing the disease in pigs in field trials (Lightowers, 2013). Data on the seroprevalence of, and risk factors for, human and porcine cysticercosis are crucial to assess where such interventions are needed, and how they might be best targeted.

In Cambodia, as in most of the poorer countries in Southeast Asia, epidemiological data on cysticercosis is severely limited (Dorny et al., 2004). However, a seroprevalence of 10% has previously been estimated among humans (Singh et al., 2002), while an abattoir survey found that 10.9% of pig carcasses showed signs of cysticercosis (Sovyra, 2005), suggesting that the burden in this country could be substantial. Furthermore, the supply of pigs to urban areas in Cambodia still relies largely on rural smallholders (Hinrichs and Borin, 2012), where conditions can be conducive for transmission (Schantz, 2002; García-García et al., 1999; Sarti et al., 1997). Increased demand for pork consumption in recent decades in Cambodia, as in many other countries in the region, means that the pig production landscape is changing rapidly, although the implications for cysticercosis risk are unclear.

To help address the paucity of data on cysticercosis in the region, we conducted a cross-sectional survey in south-central Cambodia to estimate the seroprevalence of porcine cysticercosis across different pig production systems, slaughterhouses and traders/middlemen, identify potential pig- and herd-level risk factors associated with infection in pigs, and assess levels of awareness of the disease among pig sector workers.

2. Methods

2.1. Study area

The study was conducted in three provinces of south-central Cambodia, specifically: Phnom Penh (the capital), Kandal and Kampong Speu. The south-central region was chosen due to its varied pig production landscape, allowing for comparisons between

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