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Control of *Taenia solium* taeniasis/cysticercosis: The best way forward for sub-Saharan Africa?

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ABSTRACT

Taenia solium taeniasis/cysticercosis is a neglected parasitic zoonosis with significant economic and public health impacts. Control measures can be broadly grouped into community health education, improvements in hygiene and sanitary conditions, proper meat handling at household and community level, improved standards of meat inspection, pig management, treatment of individual patients and possibly human populations, and treatment and/or vaccination of porcine populations. This manuscript looks critically into currently existing control options and provides suggestions on which (combination of) tools would be most effective in the control of *T. solium* taeniasis/cysticercosis in sub-Saharan Africa.

Field data and disease transmission simulations suggest that implementation of a single intervention control strategy will not lead to a satisfactory reduction of disease morbidity or transmission. A feasible strategy to combat *T. solium* taeniasis/cysticercosis would include a combination of approaches focussing on both human (health education and treatment) and animal host (management, treatment and vaccination), which can vary for different communities and different geographical locations. Selection of the specific strategy depends on cost-effectiveness analyses based on solid field data, currently unavailable, though urgently needed; as well as on health priorities and resources of the country.

A One Health approach involving medical, veterinary, environmental and social sectors is essential for *T. solium* to be controlled and eventually eliminated. Finally the success of any intervention is largely dependent on the level of societal and political acceptance, commitment and engagement.

1. Introduction

Taenia solium taeniasis/cysticercosis is a neglected parasitic zoonosis with significant economic and public health impacts. It has been ranked first on the global scale of foodborne parasites by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) in 2014 (FAO and WHO, 2014). It affects mostly low and middle income countries in Latin America, sub-Saharan Africa (SSA), South and South East Asia (Murrell et al., 2005), though an increasing number of cases are detected in the United States and Europe (Gabriël et al., 2015), primarily because of increased human migration.

As the final host, a human can be a carrier of the tapeworm (taeniasis), and release infective eggs via the stool into the environment (Fig. 1). When a pig (normal intermediate host) ingests these eggs via its coprophagic behaviour or contaminated feed/water, the metacestode larval stage (cysticercus) develops in muscle, subcutaneous, and other tissues (cysticercosis) (Murrell et al., 2005). In human, consumption of undercooked infected pork leads to the development of a tapeworm. People can also act as accidental dead-end intermediate hosts and develop cysticercosis after ingestion of eggs. In humans, the cysticerci have a predilection for the central nervous tissue causing neurocysticercosis (NCC). Neurocysticercosis is a human-to-human infection (human tapeworm carriers will cause NCC), which leads to various neurological symptoms, most commonly epileptic seizures and chronic headaches (Carabin et al., 2011; Murrell et al., 2005). It is estimated that NCC is responsible for 30% of acquired epilepsy in endemic areas (Ndimubanzi

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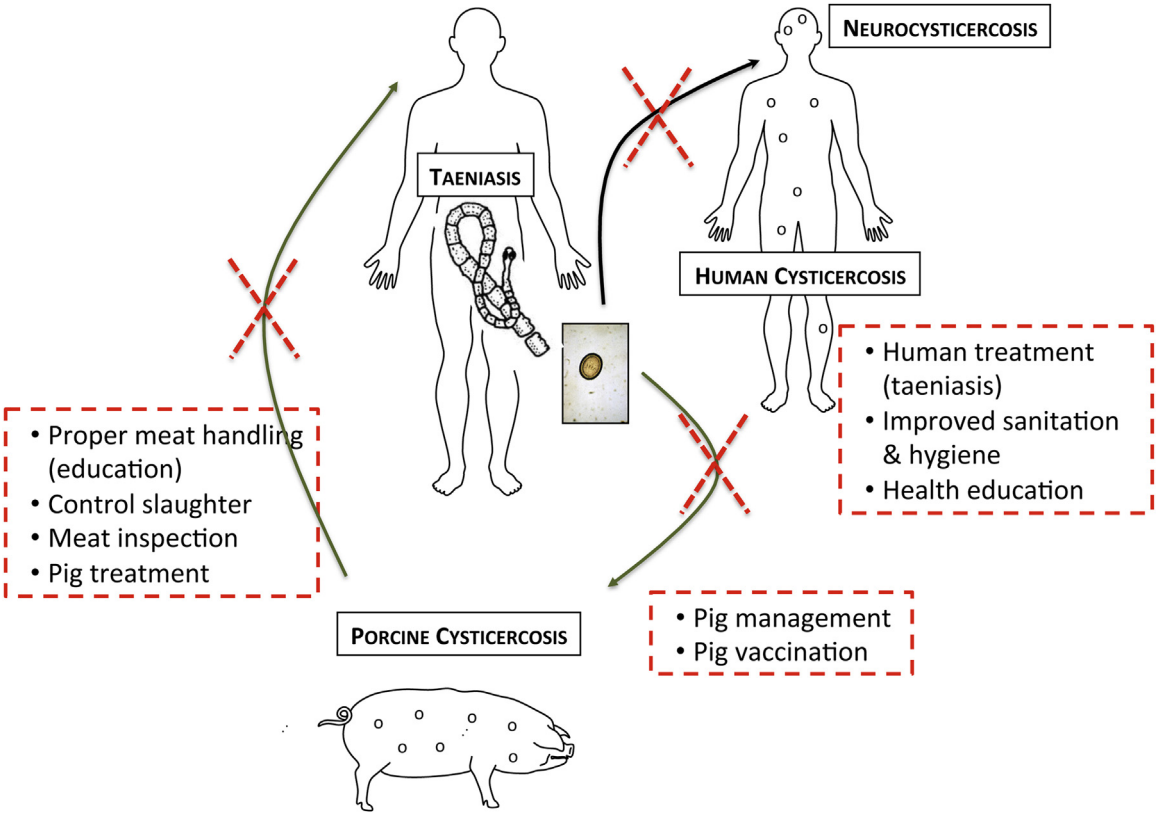

Fig. 1. Life cycle and control options of *Taenia solium* in endemic areas.

et al., 2010). In endemic areas, transmission is clearly related to low standards of personal hygiene, poor environmental sanitation with inadequate disposal or containment of human stool, poor pig management with widespread occurrence of free roaming pigs, lack of and/or inadequate meat inspection, absence of control measures at all levels of the market chain, as well as lack of knowledge on the mode of transmission of *T. solium* in endemic communities (Mwanjali et al., 2013; Ngowi et al., 2008; Sikasunge et al., 2007).

T. solium is suspected to be present in all SSA countries. During the last decade an increasing number of reports on human *T. solium* taeniasis/cysticercosis in SSA has been published, reporting taeniasis prevalence between 0% and 13.9%, and cysticercosis prevalence between 0.68% and 34.5%, depending on the region, study population and diagnostic technique used (Coral-Almeida et al., 2015; Mwanjali et al., 2013). Whether this increased number of reports reflects a rise in occurrence of *T. solium* or an increased focus and assessment of cases is difficult to gauge. Indeed, diagnostic tools have become more available in the region, helped by the establishment of a regional reference laboratory in Zambia. Also the establishment of the regional network (CWGESA: Cysticercosis Working Group for Eastern and Southern Africa) has broadened the knowledge and interest of researchers. On the other hand, a larger pork demand, and more than 200% increase in pig production has been observed in SSA (Phiri et al., 2003). Considering that these animals are managed mostly under traditional free-range production systems, with almost non-existent meat inspection, an increased risk for *T. solium* transmission is expected. This combined with prevailing conditions of poor hygiene and sanitation with open defecation often being the norm, and a lack of knowledge of local communities and (veterinary) public health services about the parasite, its risk factors, and ways to control it could indeed cause an increase in occurrence of *T. solium*.

Estimating public health and economic impacts of this zoonosis has proven difficult because of the lack of good quality data. Murray et al. (2012) in their presentation of the Global Burden of Diseases, Injuries, and Risk Factors Study 2010, estimated that 503,000 Disability-Adjusted Life Years (DALYs) were related to cysticercosis (Murray et al., 2012). Probably this is an underestimation, as the proportion of epilepsy DALYs attributed to cysticercosis and the methodology adopted were unclear (Torgerson et al., 2014). Additionally, severe chronic headache and psychiatric disorders—two other major symptoms of NCC, remain to be assessed and included in the true burden of NCC (Winkler et al., 2009).

From an economic aspect, *T. solium* represents important losses, though again, it is difficult to have accurate estimates because good quality data is lacking (Carabin et al., 2006; Schantz, 2006). Economic losses in the public health sector are related to human cysticercosis, especially NCC; however, the agricultural sector further contributes to considerable losses. The latter is mainly due to reduced value of infected pork and carcass condemnation. In Eastern Cape Province, South Africa the cost was estimated to be 5 million USD in 2004 for the agricultural sector alone, with an overall cost estimated to vary from 18.6 million USD to 34.2 million USD (Carabin et al., 2006). In a study in West Cameroon, the total annual cost due to *T. solium* cysticercosis was estimated to be over 10 million EURO. The direct (such as hospital costs) and indirect (such as costs of inactivity) losses due to human cysticercosis represented the most important part of this amount (95.3%), losses in pig husbandry accounted for 4.7% (Praet et al., 2009).

It is clear that there is an urgent need to control, eliminate and, if possible, eradicate this zoonosis. This was also recognised and re-confirmed by the World Health Assembly with the adoption of resolution WHA66.12 on May 23, 2013 (WHO, 2013), and by a recent WHO informal consultation reporting the assembly of a