MONETARY IMPACT OF TAENIA SOLIUM CYSTICERCOSIS IN FOUR COUNTRIES

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Abstract The societal monetary burden of cysticercosis in the Eastern Cape Province, South Africa, Honduras, India and the United States of America were estimated. Data on the frequency of infection and on associated morbidity in both human and pig populations and their costs were collected. Decision trees were used to assess the frequency of medical care and loss of value of pigs with their monetary impact. All results are in 2004 US$. The societal monetary cost of T. solium cysticercosis was estimated to US$13.4 million (95% CI: US$45.3 million-US$262.3 million) in India, US$20.0 million (US$6.2 million-US$37.6 million) in Honduras, US$24.8 million (95% CI = $10.5 million, $49.0 million) in the Eastern Cape Province, and US$3.1 million (95% CI $1.2 million, $6.4 million), in the United States. Porcine cysticercosis is a preventable infection that produces a very important monetary burden for some regions of the world.

Introduction Neurocysticercosis (NCC), infection of the human brain by the larvae of the zoonotic parasite Taenia solium, is considered the most important parasitic infection of the human central nervous system and is estimated to cause between 20% and 50% of all late-onset epilepsy cases globally (Bern et al., 1999). Epilepsy is a syndrome with considerable social, psychological, economical and physical impact in a community, and affected individuals and their families are often stigmatized, leading to decreased productivity and increased costs to the society. Taenia solium requires humans and pigs as definitive and intermediate hosts, respectively, to complete its life cycle. The larval stage of the parasite can cause disease in both humans and pigs with potentially large economical impact in areas where the disease is endemic. In areas where meat inspection is present, infected pig carcasses are totally or partially condemned, leading to important income losses to the pig’s owner. These losses are also likely to impact on local, regional, national and even international trade.

The probability of a person being diagnosed or treated for NCC, the impact of the disease on his/her productivity and the probability of affected pig carcasses being condemned are likely to vary nationally and internationally. The costs associated with these elements are also likely to vary. Until recently there has been no concerted effort to assess these probabilities and costs on a global scale, and therefore a thorough assessment of the burden of disease and impact of T. solium cysticercosis has been impeded (Engels et al. 2003). Because this information was previously unavailable, NCC remains a “neglected” disease at the global level in spite of evidence indicating that it is a significant problem in many poor countries around the world.

The purpose of this analysis is to estimate the societal monetary burden of cysticercosis in the Eastern Cape Province, South Africa, Honduras, India and the United States of America.

Materials and Methods Epidemiological data Quantifying the monetary burden of cysticercosis requires obtaining valid data on the frequency of infection and on associated morbidity outcomes in both human and pig populations and their associated costs. In pigs, most economical losses occur when pigs are condemned in slaughterhouses. To our knowledge, there are no productivity losses associated with porcine infection. The major health consequences to humans of cysticercosis infection occur with NCC. The most common symptom is seizures, and an unknown proportion of persons with NCC will go on to develop chronic, remote symptomatic seizures (i.e. epilepsy). Thus, epilepsy was chosen as the primary outcome for the burden assessment. Data on the prevalence of cysticercosis infection, NCC or epilepsy in each of the 4 study countries were obtained from a variety of sources; most came from published sources, but some unpublished data and experts’ opinions
were also used. When determining which data to use, preference was given to studies done in well defined, representative samples of a population, that used appropriate and fully described serological methods, clearly stated and accepted definitions of epilepsy, and neuroimaging assessments for NCC. Information on population frequencies of infection with cysticercosis and associated diseases was gathered and organized with decision trees (Haddix, 2003, Pettiti, 2000; Carabin et al., 2005). Figure 1 illustrates an example of a decision tree estimating the monetary burden of human cysticercosis in Honduras.

**Costs data** We used a societal approach to value the monetary burden of *T. solium* cysticercosis, which means that cysticercosis is assumed to have a monetary burden to all the individuals of a population. The monetary effects of human losses are very useful indicators because, in the case of zoonoses, they can be combined with the concomitant animal health and production losses to estimate the total economic losses to society.

**Animal health costs** Direct costs of cysticercosis infection in pigs will most often result in the condemnation of the whole carcass at the slaughterhouse (Zoli et al., 2003). However, in poor countries most pigs are slaughtered without any meat inspection (Joshi et al., 2003) and some parts of the infected animals may still be sold, usually at a lower price (Zoli et al., 2003). This information was very difficult to gather and estimates had to be made by our local collaborators in most cases. In some instances, pigs are not sent to the abattoir at all, because in areas where cysticercosis is endemic the carcasses would be rejected. In such situations there is a missed opportunity for the farmers to improve their financial wellbeing. We did not attempt to estimate any indirect cost associated with porcine cysticercosis as there is, to our knowledge, no available data on the effect of *T. solium* on swine productivity in terms of growth, fertility and/or fecundity.

**Human health costs** We divided the human monetary burden into health provider costs (HPC) and non-health provider costs (non-HPC). An effort was made to include all costs associated with the diagnosis, treatment and follow-up of theoretical “average” cases who would not seek medical attention, those who would seek medical attention, and those who would be hospitalised in each country. Non-HPC represent out-of-pocket money that patients lose due to their conditions. We used the average salary of a farmer to estimate the productivity losses, assuming that the majority of cases of NCC would be living in small holder farming communities. We attributed the same average salary for men and women and to mothers of affected children. Throughout, we estimated the costs of NCC for one year. In all countries, if costs data were available from a previous year, they were updated to their current values using local health CPI for HPC (when available) and average CPI for salaries. Updated values were then transformed to 2004 US dollars using average 2004 currency exchange values.

**Uncertainty and sensitivity analyses** Estimates of the frequency of porcine or human cysticercosis from epidemiological studies or national data are very uncertain. We carefully reviewed the literature to identify the study population and source population in order to avoid an overestimation of the national prevalence of the infection for the countries reviewed. There is also a large amount of uncertainty related to the proportion of infected cases that will develop different symptoms or experience productivity losses, mainly because no cohort or nested case-control studies have been conducted to date to estimate these values. This is true for animal and human cases. Finally, the monetary values attributed to the diagnosis and treatment of each symptom and, for example, the daily salary of a farmer or a homemaker in a low-income country that would be lost with a reduction in productivity, are always uncertain. To deal with the uncertainty inherent in the available data, we used @Risk which is an add-in to Excel that uses Monte Carlo sampling to represent the uncertainty.

**Results** Table 1 shows HPC, non-HPC and overall costs estimated for Honduras, India, Eastern Cape Province, South Africa and the United States of America. In India, the human health sector costs were estimated using three methods, two of which used estimates of the costs of epilepsy previously published (Sawhney et al., 1996; Thomas et al., 2001). The third method was based on epidemiological and costs estimates provided by one of the co-authors (VR).

In all the sensitivity analyses, one of the most influential parameters was the proportion of active epilepsy cases and/or seizure cases due to NCC. This parameter should be a priority in future research in order to obtain better estimates based on clearly defined and validated diagnoses. Since this proportion is likely to vary from country to country, such studies may need to be conducted on a country-by-country basis. Another parameter of interest is the prevalence of epilepsy, which has
not been measured very well in communities other than the U.S.. We have made an effort in this analysis to use estimates of the prevalence of epilepsy derived from the whole community. Finally, the time loss associated with epilepsy and NCC needs to be better estimated.

Discussion This study is the first to report a comprehensive estimate of the monetary burden of cysticercosis on the health and agricultural sectors in 4 regions of the world (Latin America, North America, Africa and Asia).

The estimate of the monetary burden for Honduras is equivalent to 1% of the purchasing power parity per capita. This is an enormous burden for these people. In Eastern Cape Province, South Africa, our estimate of the monetary burden per capita is US$ 3.49, which is considerable when compared to annual health expenditures of US$ 41.26 for people living in poor dwellings in Eastern Cape Province (Statistics South Africa 2004). The estimate of the burden for India was not as important on a per capita basis, but the absolute value of the monetary burden was impressive (US$ 634 million). In addition, if we consider that 93% of Indians are Hindus and Muslims (CIA, 2004) and do not consume pork meat, those that do eat pig meat must be spreading the infection very efficiently. The estimate from the United States was negligible compared to the wealth of most of its citizens. However, most of the cases are immigrants for whom NCC could be devastating financially. The only other recent value of the monetary burden for Africa is a very rough estimate of losses associated with porcine cysticercosis in Cameroon (Zoli et al. 2003). These authors estimated that with a nationwide prevalence of porcine cysticercosis of 9.25% and assuming the value of each infected pig was reduced by 50, the total losses associated with porcine cysticercosis were 2,062,125 (US$2,334,490) in 2003. This is less than our average annual estimate of US$5 million for Eastern Cape Province.

This analysis has several limitations. Few well-designed community-based epidemiological studies have been published, resulting in very uncertain estimates for the epidemiological data. Information on treatments received by NCC cases and their work loss were mostly based on experts’ opinions due to the lack of published data. We included known ranges of uncertainty for the economical data, but more needs to be done to improve these estimates. Estimates of work lost are also extremely difficult to obtain. Reduction in the value of pig carcasses is not known, has not been systematically measured, and may vary from place to place. Considering the increasing trend of pig keeping and pork consumption in many developing countries, the burden and impact of cysticercosis are expected to increase even further in the coming years. Another limitations is that in most instances, the only costs to humans that were considered were those associated with epilepsy. Other neurological manifestations of NCC, although less common, may also carry a significant societal burden, but these were generally not included in the estimates due to the absence of useable data relating to the other manifestations of NCC. Therefore, we believe that our estimates are conservative and that the true impact of cysticercosis may be even greater.

Conclusions Human and porcine cysticercosis is a preventable infection that produces monetary burden to both agricultural and public health sectors for some regions of the world. More needs to be done to raise awareness and encourage collaborations between these two sectors to control this preventable cause of epilepsy.

References


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Table 1. Estimates of the average and 95% Credible Interval health provider (direct) and non-health provider (indirect) and overall monetary burden (in millions of 2004 US$) of Taenia solium cysticercosis in Honduras, India, Eastern Cape Province of South Africa and the USA.

Figure 1. Example of a decision tree used for estimating the monetary burden of Taenia solium cysticercosis in Honduras.