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Economic implications of three strategies for the control of taeniasis

Anu Alexander[1], K. R. John[1], T. Jayaraman[2], Anna Oommen[2], M. Venkata Raghava[1], Pierre Dorny[3,4] and Vedantam Rajshekhar[2]

1 *Department of Community Health, Christian Medical College, Vellore, India*
2 *Department of Neurological Sciences, Christian Medical College, Vellore, India*
3 *Department of Animal Health, Institute of Tropical Medicine, Antwerp, Belgium*
4 *Laboratory of Parasitology, Faculty of Veterinary Medicine, Ghent University, Ghent, Belgium*

Summary

OBJECTIVE To evaluate the cost-effectiveness of three strategies for the control of taeniasis in a community, in terms of cost per case treated.

METHODS A study was conducted in South India to determine the prevalence of taeniasis by screening stool samples from 653 randomly chosen subjects, for coproantigens. The costs incurred in the project were used to estimate the cost per case screened and treated. A one-way sensitivity analysis was carried out for varying rates of taeniasis, different screening strategies and mass therapy. Further sensitivity analysis was carried out with different manpower and test costs.

RESULTS The rate of taeniasis as detected by ELISA for coproantigen was 3 per 1000 (2 of 653 samples). Our study showed that mass therapy without screening for taeniasis would be the most economical strategy in terms of cost per case treated if field workers are employed exclusively for either mass therapy or screening. For each strategy, costs per case treated are higher at low prevalence of taeniasis, with a sharp rise below 15%.

CONCLUSIONS In places that are endemic for taeniasis and neurocysticercosis, mass therapy or screening for taeniasis should be considered. Screening by stool microscopy is not cost-effective in terms of cost per case of taeniasis treated owing to its low sensitivity. Although the cost per case of taeniasis treated is high at low prevalence of taeniasis for all options, incorporating mass therapy into existing mass drug distribution programmes might prove to be the most cost-effective control strategy.

keywords taeniasis, screening, mass therapy, costs

Introduction

Persons who harbour the adult *Taenia solium* worm are an essential link in the transmission of cysticercosis in a community. Thus, one of the strategies for the control of cysticercosis is to identify and treat taenia carriers in the community. One approach is screening for taeniasis using either the simpler but less sensitive stool microscopy (Young *et al.* 1979; Allan *et al.* 1993, 1996) or the highly sensitive ELISA for coproantigens (Wilson & Nakane 1978; Allan *et al.* 1996; Rodriguez-Canul *et al.* 1999), followed by targeted therapy for those who test positive. The second approach is universal treatment with niclosamide or praziquantel in areas where the prevalence of taeniasis is high (Allan *et al.* 1997; Sarti *et al.* 2000; Sarti & Rajshekhar 2003; Garcia *et al.* 2006).

Studies from rural communities in India have shown prevalence of taeniasis of 9.7% (Vora *et al.* 2008) and 18.6% (Prasad *et al.* 2007) by stool microscopic examination. These rates are higher than those reported from other developing countries such as Peru (Garcia *et al.* 2003), Mexico (Sarti *et al.* 2000), Guatemala (Allan *et al.* 1997) and Vietnam (Somers *et al.* 2006). A cross-sectional study conducted in Vellore district in South India showed a prevalence of active epilepsy of 3.04/1000 and a prevalence of neurocysticercosis of 1.02/1000 population, indicating that it is a major public health problem (Rajshekhar *et al.* 2006). In this area, 24.2% of the population consume pork and 63.2% live in pig-rearing localities. Pigs being reared in these areas and those being sold for consumption were sampled for cysticercus antibodies by enzyme-linked immunoelectrotransfer blot (EITB) assay (Tsang *et al.* 1989; Prabhakaran *et al.* 2004) and circulating cysticercus

antigen by antigen detection ELISA (Dorny *et al.* 2004). The EITB results demonstrated infection (more than three bands positive) in 9.7% (11/112) and exposure to the parasite (1–3 bands positive) in 49.6% (56/112). Circulating antigens were found in 7.1% (8/112) of porcine sera (unpublished data). A research study to estimate the prevalence of taeniasis in this area forms the background for this cost analysis. The aim of this study was to estimate the cost for control of taeniasis using targeted therapy of taenia carriers detected with one of two screening techniques or mass therapy without screening.

Methods

Study population

The study was conducted in Kaniyambadi, a rural block in Tamil Nadu, South India, with an area of 184 km^2, 82 villages and a population of 105 886 in 2008 (Census by department of Community Medicine, Christian Medical College, Vellore) and adjoining Vellore town with 300 000 people. Four clusters were selected from 14 clusters (Rajshekhar *et al.* 2006), which had either pig-rearing communities or freely roaming pigs. From these four clusters, 386 families were selected by random sampling from the database. In the selected families, there were 1305 persons between 2 and 60 years of age who were considered eligible for the study by the criteria of age. Of these, 653 consented and gave stool samples for testing.

Sample collection

Two health workers were involved in visiting the families and identifying eligible subjects. Participants were given stool boxes and disposables for stool collection. Picture models of *Taenia* segments were also shown to the subjects who were asked whether they had passed similar segments in their stools at any point of time. The stool samples were collected on the next day by health workers and transported to the laboratory on the same day. The process of recruitment and screening was completed in 6 months.

Coproantigen assay and stool microscopy

Antibodies to *T. solium* somatic antigens were raised in rabbits and purified over Protein A-Sepharose in the laboratory. An aliquot of purified IgG was coupled to horse radish peroxidase (Wilson & Nakane 1978). Antibody titres were optimized for capture of coproantigens with six normal stool samples spiked with 0–1 μg protein of *T. solium* somatic antigens.

The samples were assayed for coproantigens by a capture ELISA using rabbit antibodies to *T. solium* somatic antigens by the method of Allan *et al.* (sensitivity of 98%, specificity of 99.2%) (Allan *et al.* 1996; Rodriguez-Canul *et al.* 1999). A positive result for coproantigen ELISA was taken for a value of 1.6-fold greater than mean + 3SD of six negative control samples on each ELISA plate. The stool samples were also tested by microscopy of formalin ethyl acetate concentrates (sensitivity of 38–56%) (Young *et al.* 1979; Allan *et al.* 1993, 1996).

Treatment for taeniasis

Persons who were positive on the coproantigen assay were administered niclosamide 2 g (Yomesan™, Bayer) per os along with a laxative (Exelyte; monobasic sodium phosphate + sodium hydrogen phosphate). They were hospitalized for 24 h, for the collection of stools to confirm the diagnosis by examining the stools for *Taenia* segments.

Costing analysis

We considered three ways to reduce the burden of taeniasis and calculated the costs per case detected and treated for each. All costs are in US dollars for the year 2008 (1 US$ = 39.4 Indian Rupees).

Screening with coproantigen assay and targeted therapy. The first strategy is screening of stool samples for coproantigens by ELISA and therapy for those who are positive according to the criteria described earlier. The costs were calculated using actual costs incurred during our study. As various studies related to cysticercosis were conducted at the same time, the time spent by the health workers on the collection of stool samples was estimated to be one-fourth of the total travel for the project, and therefore, the cost was one-fourth of the project's total travel cost. The cost thus obtained was divided by the average cost of hiring a vehicle, to derive a figure for the estimated distance travelled for this study on taeniasis.

As our study was for research purposes, the stool-positive persons were hospitalized for confirmation of diagnosis after a stool purge. For a community wide screening programme, this step may be omitted and persons who are positive for coproantigens directly administered oral niclosamide. Therefore, in our cost analysis, we have not considered the additional cost of hospitalization for the above step, which was US $ 30 per stool-positive subject in our study.

Screening with stool microscopy and targeted therapy.
The second strategy is universal screening using only stool microscopy of formalin ethyl acetate concentrates followed by targeted therapy of stool-positive persons.

Mass therapy without any screening.
The third option would be mass treatment with oral niclosamide, a drug that acts on the intestinal parasite alone, avoiding the side effects possible because of action on the cysts in the brain. A study in Guatemala, where treatment coverage of 75% was achieved for mass treatment with niclosamide, showed significant reduction in taeniasis 10 months after treatment (Allan *et al.* 1997). The cost of this option for the 653 subjects in our study was calculated assuming that the time, travel and manpower costs would be half of the screening options (3 months), as an additional visit to collect stool samples would be avoided. Sensitivity analysis was also carried out to account for possible variation in rates of taeniasis and inputs for the control strategies (Drummond *et al.* 2005).

The study on taeniasis was approved by the Institutional Review Board and Ethics Committee of Christian Medical College, Vellore.

Results

None of the 653 subjects had noticed *Taenia* segments in their stools.

Coproantigen screening and stool microscopy

Two (0.3%) of 653 samples tested positive for coproantigens. Both subjects were treated for taeniasis as described above. However, *Taenia* segments were not recovered from their stool samples, which were also negative for *Taenia* ova by stool microscopy.

Costing analysis

Screening with coproantigen assay and targeted therapy.
The cost per person screened by stool testing for coproantigens was US $ 12, and the cost per case of taeniasis detected was US $ 4051 (Table 1).

Screening with stool microscopy and targeted therapy.
The cost per person screened was US $ 10.8 (Table 2) assuming all costs were the same as for option 1 except for the cost of the stool microscopy. As there were no stool-positive cases by microscopic examination in our study, the cost per case of taeniasis treated was not calculated.

Table 1 Screening using coproantigen ELISA testing of stool samples and targeted taeniasis therapy using niclosamide

Item	Costs/unit* (US $)	Number of units	Total (US $)
Field workers' salaries	339/month	2 workers, 6 months	4063
Materials			
Pens	0.4	5	2
Stickers	0.013	1000	13
Soap bottle	1.3	1	1.3
Stool boxes	0.038	1000	38
Plastic sheets	0.012	1000	12
Wooden spatula	0.018	1000	8
Picture models for survey	0.5	4	2
Coproantigen ELISA tests	5	653	3480
Cost of treatment with niclosamide, (Yomesan™, Bayer)	5	2 subjects	10
Transport	0.2/km	2329 km	473
Total cost			8102
Number tested			653
Number who were stool positive			2
Cost/person screened			12
Cost/case taeniasis treated			4051

1 US $ = 39.4 Indian Rupees.

Table 2 Screening using stool microscopy and targeted therapy for stool-positive subjects

Item	Costs/unit (US $)	Number of units	Total (US $)
Stool microscopy test	3.8	653	2486
Other costs as in strategy 1 (excluding drug costs)			4612
Number who were stool positive		0	
Total cost			7098
Cost/person screened			10.8

Mass therapy without screening.
This option may be more cost-effective per case of taeniasis treated than the others (Table 3), but the acceptability, feasibility and actual costs in India would have to be explored.

Table 3 Mass treatment with niclosamide without a screening programme

Item	Costs/unit (US $)	Number of units	Total (US $)
2 g niclosamide (Yomesan™, Bayer)	5	653 persons	3315
Manpower		2 workers, 3 months	2031
Travel			236
Total Cost			5582
Number of persons treated		653	
Cost/person treated			8.5
Number of cases of taeniasis who would be treated			2
Cost/case of taeniasis treated			2791

Costs at different prevalence rates and input costs

If the results of prevalence of taeniasis from the other Indian studies (Prasad *et al.* 2007; Vora *et al.* 2008) are applied after adjusting for the sensitivity of stool microscopy (38%) and coproantigen ELISA (98%) (Allan *et al.* 1996), the cost per case detected falls with rising prevalence and is lowest for a mass treatment programme (Table 4). This was confirmed by a sensitivity analysis with prevalence of taeniasis varying from 1% to 100% and assuming a lower monthly salary of US $ 254 for field workers exclusively involved in the control strategies (data not shown).

If the activities performed by the field worker are incorporated into the routine rural primary care activity, the cost of manpower can be reduced further and only travel costs included in the model. Assuming each worker would spend 2 h a day for 6 months, for either screening or mass therapy, a salary of US $ 63 was taken as a lower estimate of manpower costs. A two-way sensitivity analysis was carried out for each control strategy varying the monthly salary of field workers as US $ 254, US $ 63 or nil salary at various rates of taeniasis (Figures 1 and 2). The cost per case treated of screening by microscopy followed by targeted therapy was higher than mass therapy and screening by coproantigen ELISA at all rates of taeniasis. Cost analysis was also performed varying the cost of stool microscopy to US $ 1.9/test, which is half the rate charged at the tertiary centre where our laboratory analysis was carried out.

Even with lower costs of stool microscopy and manpower, the cost of screening using microscopy would be higher per case detected than mass therapy or screening for stool coproantigens (Figure 3). Mass therapy would be the most economical option for all rates of taeniasis in terms of cost per case treated. However, sensitivity analysis showed that if the sensitivity of stool microscopy is above 68%, cost per case treated for screening by microscopy would be the most economical option, for rates of taeniasis below 20% (data not shown).

The monetary benefit of control of taeniasis was also estimated with the assumption that a patient with epilepsy because of neurocysticercosis would incur a cost of US $ 355 per year, based on a previous study on the economic burden of epilepsy (Thomas *et al.* 2001), for 3 years. It was also assumed that a third of epilepsy is because of neurocysticercosis (Rajshekhar *et al.* 2006). Sensitivity analysis was carried out for various rates of taeniasis and neurocysticercosis calculated based on our study and another study carried out in a community with high rates of these conditions (18.6% taeniasis and 6.6% epilepsy) (Prasad *et al.* 2007), assuming a linear relationship between taeniasis and neurocysticercosis (Garcia *et al.* 2003). It was found that at a prevalence of neurocysticercosis above 5.5/1000 (estimated to correspond to a prevalence of taeniasis of 5%), monetary benefits gained would exceed the cost of mass chemotherapy at the lower limits of manpower costs assumed in our analysis. The monetary benefits would exceed costs of screening by

Table 4 Sensitivity analysis of cost per case of taeniasis treated at various values of prevalence of taeniasis, for different control strategies

Prevalence of taeniasis from various studies and tool used	Options for screening using stool samples		Mass therapy with niclosamide without screening
	Coproantigen ELISA and targeted therapy*	Microscopy and targeted therapy	
If prevalence = 0.3% (this study), Cases = 2 (Coproantigen ELISA)	US $ 4051	No cases detected	US $ 2791 (2 cases treated)
If prevalence = 9.7% (Vora *et al.* 2008), Cases = 63 (stool microscopy)	US $ 54 (assuming 164 cases detected)	US $ 118	US $ 34 (assuming 167 cases treated)
If prevalence = 18.6% (Prasad *et al.* 2007), Cases = 121 (stool microscopy)	US $ 31 (assuming 315 cases detected)	US $ 64	US $ 18 (assuming 321 cases treated)

*Assuming coproantigen ELISA (98% sensitivity) detects 2.6 times the number of cases as microscopy (Allan *et al.* 1996).

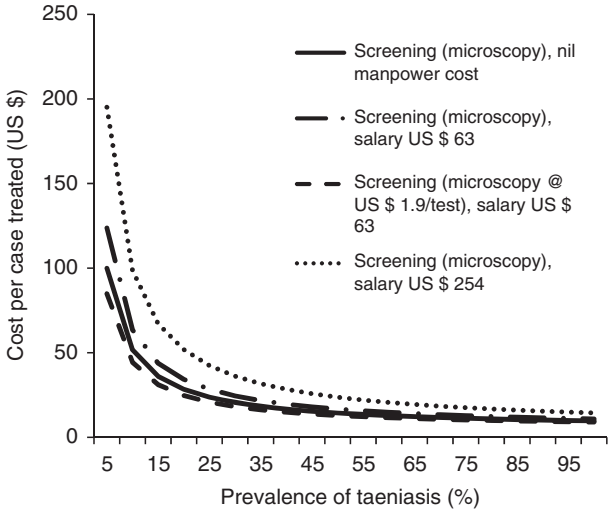

Figure 1 Cost per case of taeniasis treated at various values of prevalence of taeniasis and manpower costs, for screening by stool microscopy.

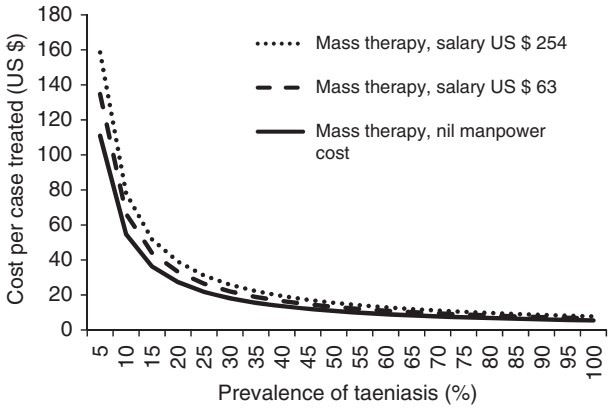

Figure 2 Cost per case of taeniasis treated at various values of prevalence of taeniasis and manpower costs, for mass treatment.

coproantigen ELISA if the prevalence of neurocysticercosis is above 7.7/1000 (corresponding to a taeniasis rate of 7%). As microscopy would not detect many cases of taeniasis because of low sensitivity, we could not estimate the number of cases of neurocysticercosis prevented and monetary benefits gained.

Discussion

Reducing the burden of taeniasis is an important method of controlling the problem of neurocysticercosis. The burden of taeniasis varies widely in India as seen from our study as

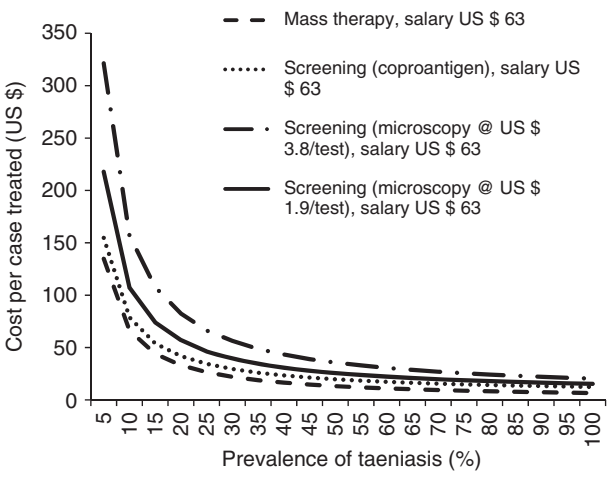

Figure 3 Sensitivity analysis of various control strategies at different rates of taeniasis and costs of microscopy, assuming field workers' monthly salary as US $ 63.

well as other Indian studies. Although the prevalence of taeniasis in this study was low, the burden of epilepsy and neurocysticercosis was high (Rajshekhar *et al.* 2006). This fact may justify measures to control taeniasis in such areas, albeit at a higher cost per case treated than in places with higher rates of taeniasis.

Both the options of mass therapy or screening for taeniasis would have to be conducted repeatedly to eradicate cysticercosis. As the coverage of either mass therapy or screening is unlikely to be 100%, more than 11 rounds of intervention may be required at a frequency of 90 days (Gonzalez *et al.* 2002).

Testing stool samples for coproantigens by ELISA would be an ideal method of screening for taeniasis as it has a high sensitivity, but as seen from our study does not seem to be an economically feasible option for adoption in other parts of the country.

Mass therapy for taeniasis

If a programme similar to our study is to be replicated using field workers exclusively for either mass therapy or collection of samples for screening, mass therapy would be more economical in terms of cost per case treated. As niclosamide has a good safety profile, it could possibly be given as regular mass treatment along the lines of the programme for the distribution of drugs against filariasis. However, mass therapy would be justifiable only after it has been proved through surveys that the region is endemic for cysticercosis/taeniasis.

The other option for taenicidal therapy would be praziquantel instead of niclosamide, as it is cheaper and

more widely available. However, there is a possibility of occurrence of neurological symptoms following treatment in persons with occult neurocysticercosis (Flisser *et al.* 1993; Sarti *et al.* 2000).

Screening by stool microscopy and targeted therapy

Although screening by stool microscopy would be easier to implement in primary care and cheaper than screening by coproantigen ELISA or mass therapy, it is not cost-effective per case of taeniasis treated.

Even with lower manpower costs and stool microscopy charges than required for our study, screening using stool microscopy would not be cost-effective per case of taeniasis treated. This is because of the low sensitivity (38–56%) of the test, as fewer than half of the tapeworm carriers would be detected (Allan *et al.* 1993, 1996). However, improving the sensitivity to above 68% may make microscopy a cost-effective screening tool. The other drawback of screening using stool samples is the low response rate, which if improved would also decrease costs per case treated.

Mass therapy for taeniasis along with the filariasis control programme

Lymphatic filariasis is endemic in most of the states in India (Sabesan *et al.* 2000), and the government has a programme of regular mass administration of albendazole and diethylcarbamazine as per the WHOs recommended strategy for control of lymphatic filariasis (WHO 2001). Incorporation of mass therapy for taeniasis along with this existing programme may further reduce costs, by avoiding extra costs for travel and manpower. However, research would be required on the safety of giving niclosamide along with albendazole in a mass programme.

Limitations

If the response rate for obtaining stool samples was higher, the cost per case treated would be lower for all the strategies. Mass and individual health education may be used to improve the response rate in a screening programme rather than increasing the number of field visits.

As the burden of neurocysticercosis prevented or lives saved by treating *Taenia* carriers detected by stool microscopy was not known, monetary benefits gained by this method of screening could not be estimated. Thus, a full economic evaluation comparing costs and benefits of all control options could not be estimated. As our study was a research study on estimating the prevalence of taeniasis, the costs involved are probably higher than would be expected in programme settings. We have tried to adjust for the differences by sensitivity analysis, varying the costs of manpower and stool microscopy.

There is also a possibility that the persons who were positive for coproantigens in our study may have been falsely positive, as we did not recover *Taenia* segments from the stool samples after treatment or detect *Taenia* ova by microscopy. However, the probability of this is low as the specificity of the test is 99.2% (Allan *et al.* 1996).

Health education as part of screening for taeniasis

Another alternative that was not explored in this study is screening using interview technique for detecting those who have a history of having passed tapeworm segments in the stool (Sarti & Rajshekhar 2003). Although the interview method alone has a reported sensitivity varying from 2% to 60% (Sarti *et al.* 1994; Allan *et al.* 1996), it might be improved by intensive education on taeniasis. The education should include suggestions on safe disposal of stools for tapeworm carriers, sanitation, personal hygiene, safe pig-rearing and pork consumption practices. This strategy may prove to be the most cost-effective method to bring down the carrier rate for taeniasis in India and thereby decrease the burden of neurocysticercosis.

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Corresponding Author **Vedantam Rajshekhar,** Department of Neurological Sciences, Christian Medical College, Vellore 632 004, India. Fax: +91 416 2232103; E-mail: rajshekhar@cmcvellore.ac.in