Evaluating Urban Taeniasis as a Threat to Cysticercosis Elimination in Northern Peru

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Abstract. Reintroduction of *Taenia solium* into a region in Peru where it had been eliminated prompted evaluation of the possibility of reintroduction from an urban reservoir of taeniasis. In a cross-sectional study of an adjacent urban area, we found low prevalence of taeniasis (4/1,621; 0.25%), suggesting minimal risk of parasite reintroduction into rural areas through this route.

Neurocysticercosis (NCC) is a leading cause of preventable epilepsy in the developing world and one of seven diseases identified as eradicable by the International Task Force for Disease Eradication.^{1–3} It is caused by *Taenia solium*, a zoonotic cestode that has obligate life stages in both humans and pigs. The most prolific lifecycle stage is taeniasis, a typically asymptomatic infection by the adult tapeworm in the human intestinal tract. As a hermaphroditic organism, a single *T. solium* adult tapeworm can produce tens of thousands of infectious eggs each day over a life span of months to years.⁴ These eggs, which are shed into the environment through feces, may in turn infect foraging pigs with the larval stage (cysticercosis), or humans with NCC. The lifecycle completes when undercooked pork contaminated with *T. solium* cysts are consumed, as these may develop into an adult tapeworm. In a typical endemic community, a low prevalence of taeniasis (1–2%) is able to sustain endemic transmission.⁵ The complete endemic lifecycle typically occurs in rural regions where pigs roam freely within villages and are able to access and consume human feces containing infectious tapeworm eggs. Migration of a human with taeniasis into a region where the parasite has been cleared could potentially reestablish endemic transmission.

Between 2005 and 2012, the Cysticercosis Elimination Demonstration Program successfully eliminated *T. solium* from the region of Tumbes, Peru (Figure 1).⁶ This intensive program, which relied upon mass chemotherapy and vaccination, focused exclusively on rural communities which comprise about half of the region's total population. Urban areas were not included because conditions required for ongoing transmission, that is, free roaming pigs and open defecation, are uncommon in the cities. However, this approach left the possibility of persistent cases of taeniasis in the urban settings, which could theoretically reestablish transmission in the rural areas through migration and travel. In 2016, *T. solium* was found to have reestablished endemic transmission in two adjacent rural villages in the elimination zone, where the prevalence of taeniasis and seroprevalence of porcine cysticercosis (Lentil Lectin-bound Glycoproteins Enzyme-linked Immunoelctrotransfer Blot) were 1.2% and 37.7%, respectively (S.E. O'Neal, pers. comm.). These villages are connected to the nearby city of Zarumilla (population 20,000) by a single paved road, over which there is daily human

movement for commerce and travel (Figure 1). We conducted a cross-sectional study in Zarumilla to determine whether there was an urban reservoir of taeniasis and the importance of including urban control measures in future elimination efforts.

We acquired permission to conduct the study from the Municipality of Zarumilla and approval from the institutional review boards at Universidad Peruana Cayetano Heredia and Oregon Health & Sciences University. We used online maps (<http://www.openstreetmap.org/>) to generate a random sample of city blocks to include in our study. All residents within these selected blocks were invited to participate through door-to-door visits. We used a questionnaire to collect demographic information, history of travel to a rural area, and sanitation practices while traveling. All participants aged older than 2 years were offered a single oral dose of niclosamide in accordance with their weight, and asked to provide a stool sample the following day to verify infection status. Female participants aged older than 12 years were offered pregnancy tests before treatment. Stool samples were preserved in 5% formalin and then evaluated for the presence of *Taenia* sp. coproantigens as previously described elsewhere.⁷ Participants diagnosed with taeniasis received a second round of treatment and follow-up testing to ensure cure.

A total of 65/182 (36%) city blocks were visited; 636/1,113 (57%) households were inhabited and had one or more individuals agree to participate in a census. Of 2,340 individuals in participating households, 2,273 (97%) were eligible based on age; 2,061 (88%) received treatment; and 1,621 (71%) provided a posttreatment stool sample. There was no significant difference in demographic characteristics by participation status (Table 1). Four participants were diagnosed with taeniasis, representing a crude prevalence of 0.25% (95% confidence interval [CI] 0.08, 0.64). All four reported travel to a rural village within the past year; three reported open defecation in the village and three reported seeing free-roaming pigs (Table 2). None owned pigs and the most frequent consumption of pork meals was one time per month. Two cases (a mother/son pair) occurred in the same household, and both required a second round of treatment to cure their infection.

The impetus for this study was to evaluate one potential route that *T. solium* could have been reintroduced into a rural region where the parasite had previously been eliminated. Given that an adjacent urban center did not receive interventions under the elimination program, we wanted to evaluate whether there was an urban reservoir of taeniasis and whether this posed sufficient risk of reintroduction through travel to rural areas to warrant inclusion of urban areas in future

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FIGURE 1. Map of the city of Zarumilla, Peru, in relation to Matapalo villages (Tutumo and Nuevo Progreso), that were included in the Cysticercosis Elimination Demonstration Program but where *T. solium* is now known to have re-established transmission. The image to the left depicts Peru's location in South America and indicates the department of Tumbes in the square. The second and center image is a close-up of the department of Tumbes where all rural areas excluding the Tumbes National Reserve were part of the *T. solium* elimination program containing 80,000 people in 107 rural villages. The third quadrant depicts the urban areas, Tumbes and Zarumilla, that were excluded from elimination efforts. It is a magnification of the square from the central quadrant and depicts the portion of Tumbes that provided rationale for this study. Note that Matapalo is geographically isolated by a river composing the border of Ecuador and that highways to the main city are most proximal to Tumbes. This figure appears in color at www.ajtmh.org.

elimination efforts. We found that there was indeed taeniasis in our urban sample and that city dwellers with taeniasis reported risk behavior (i.e., travel to and open defecation in a rural region where roaming pigs are present) that could potentially lead to parasite reintroduction. However, the prevalence of taeniasis was low (0.25%), suggesting that the risk of reintroduction through urban–rural migration is relatively low.

Elimination is an intensive and expensive endeavor, at least in the short term. The 1-year program in Peru involved three rounds of mass treatment of humans, five rounds of mass treatment of pigs, and two rounds of pig vaccination in a rural population > 80,000.⁶ The underlying premise is that intensive efforts will ultimately provide substantial cost savings compared with nonintervention. This premise assumes, however, that the elimination area can be protected against parasite reintroduction. Given the high stakes involved, extending a single round of mass treatment with niclosamide into adjacent urban areas might be justifiable. Alternatively, those resources may be better applied toward extending control interventions as a buffer in adjacent rural endemic areas (to prevent rural-to-rural introduction) or in robust surveillance to rapidly detect

and treat new cases of pig or human infection if they arise in the elimination zone. Further exploration of the risk of reintroduction through rural–rural migration, or through a persistent reservoir of infectious eggs in the soil, is warranted. We believe rural–rural migration to be the most likely explanation for reintroduction in this region, as the villages in question have grown markedly in recent years because of resettlement from the adjacent endemic region of Piura. However, we have no data to directly support this hypothesis. Development and testing of post-elimination surveillance systems is critically needed if elimination efforts are to be replicated and sustained in multiple countries by 2020 as called for by the World Health Organization.⁸

The results of this study also confirmed that endemic transmission in the city of Zarumilla is extremely unlikely as few households raised pigs and the vast majority are connected to closed sewer sanitation. Given that only four cases of taeniasis were found, we were unable to evaluate risk factors for infection. It is possible that these individuals acquired taeniasis while traveling in endemic rural areas, although it is also possible that they acquired their infection through contaminated pork introduced into the city. A case–control study

TABLE 1

Characteristics of participants and nonparticipants in study activities in Zarumilla, Peru

Individual characteristics	Census (N = 2,340)	Treated (N = 2,061)	Tested (N = 1,621)
Household size, mean (SD)*	3 (1.4)	3 (1.3)	3 (1.3)
Age (years), mean (SD)*	27 (20)	27 (20)	29 (20)
Female, n (%)	1,270 (54)	1,102 (54)	919 (57)
Rural area travel (past 3 months), n (%)	290 (12)	260 (13)	200 (12)
Open defecation in a rural area, n (%)	125 (5)	114 (6)	90 (6)
Born outside of Zarumilla, n (%)	433 (19)	394 (19)	310 (19)
Own pigs in household, n (%)	132 (6)	108 (6)	107 (7)

* Standard deviation.

TABLE 2

Characteristics of participants diagnosed with taeniasis

	Patient one	Patient two	Patient three	Patient four
Gender	M	F	M	M
Age (years)	11	51	19	26
Travel to rural area	Yes	Yes	Yes	Yes
Defecated in the open	Yes	No	Yes	Yes
Free-roaming pigs present	Yes	Yes	No	Yes
Owens pigs	No	No	No	No
Pork consumption	1 per month	< 1 per month	2 per month	< 1 per month

conducted out of the health centers, where cases of taeniasis occasionally arise, would be a better approach for risk factor analysis in this setting. Other limitations of this study include generalizability, as conditions for transmission and reintroduction are likely to vary substantially for other urban environments. Although a large number of households did not participate in this study, our sample size was robust and we have no reason to suspect differential prevalence of taeniasis among nonparticipants.

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