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Seroepidemiological evidence for *Taenia solium* taeniasis/cysticercosis in three Venezuelan rural communities

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Abstract

Taenia solium is the most common parasite infection of the brain, causing neurocysticercosis and typically found in rural communities with free-ranging pigs. Identification of transmission in rural areas is essential for its control. Risk factors and transmission of the parasite were evaluated in three rural Venezuelan communities (Valle del Rio and Potrero Largo, Cojedes state; and Palmarito, Portuguesa state) by a questionnaire (112 households) and coprological (492 samples) and serological (433 human and 230 porcine sera) analysis, respectively. Typical risk factors were found in all three communities: free-foraging pig husbandry, deficient sanitary conditions, high open defecation and ignorance of the parasite life cycle. Coprological examinations revealed a high level of soil-transmitted parasites. Importantly, two *T. solium* adult worm carriers were identified in each of the three communities. Anti-metacestode antibodies and the HP10 secreted metacestode glycoprotein were detected at significant levels in human and porcine sera in Valle del Rio, Potrero Largo and Palmarito. In conclusion, these communities may be considered to be endemic for taeniasis/cysticercosis, and the instigation of an appropriate control programme is recommended.

Introduction

The cestode parasite *Taenia solium* is responsible for three clearly defined pathological entities: human taeniasis and neurocysticercosis (NC), and porcine cysticercosis. Humans intestinally infected with the adult *Taenia* worm, are the source of eggs that develop into the larval metacestodes when ingested by pigs (porcine cysticercosis) or man. Porcine cysticercosis is responsible for economic losses by small-scale pig producers. Human cysticercosis is of particular concern as, in addition to establishment of the metacestode in muscle and other organs such as the heart, it is localized in the brain, causing NC (Garcia *et al.*, 2014). Indeed, *T. solium* is the most common parasite infection of the brain, frequently prevalent in poor rural communities without access to medical facilities, and resulting in severe, debilitating, often fatal symptoms (FAO/WHO, 2014).

Taenia solium has a worldwide distribution, with serious public health and agricultural impact in many poor countries of Latin America, Africa and Asia, but also in developed countries, in the latter, mainly due to immigration from endemic countries (Carabin *et al.*, 2017). Current estimates indicate a prevalence of greater than 50 million people for NC, resulting in an impact of 2.8 million disability adjusted life years (DALYs) (Havelaar *et al.*, 2015). Significantly, NC is responsible for 10% of acute case admissions to neurological wards in countries where it is endemic (FAO/WHO, 2014). In Latin America alone, an estimated 75 million people are living in areas of *T. solium* endemicity. Of these, there are between 0.45 and 1.35 million people with symptoms of epilepsy attributed to NC (Bern *et al.*, 1999; Coyle *et al.*, 2012). These endemic areas typically share the obvious risk factors: poverty, free-foraging pigs, an absence of meat inspection and poor or absent sanitation. Indeed, the presence of *T. solium* in a community is unequivocal evidence of deficient socio-economic conditions. In addition to these environmental risk factors, a major barrier to the control of NC is the common lack of information and awareness of the dangers of *T. solium* within the rural population (Willingham & Engels, 2006).

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In Venezuela, cysticercosis has been reported in humans and pigs through serological evidence (Ferrer *et al.*, 2002, 2003; Guzman *et al.*, 2004; Cortez *et al.*, 2010; Toquero *et al.*, 2017; Rojas *et al.*, 2019). In addition, there is coprological evidence for taeniasis (Rojas *et al.*, 2008; Parkhouse *et al.*, 2020). In this report, we present serological, parasitological and socio-epidemiological evidence consistent with endemic transmission of taeniasis/cysticercosis (T/C) in three rural Venezuelan communities: Valle del Rio and Potrero Largo in the state of Cojedes and Palmarito in Portuguesa. Finally, as we have employed the detection of anti-metacestode antibodies and HP10 secreted metacestode glycoprotein to detect cysticercosis, these results do not formally discriminate between somatic cysts and NC.

Materials and methods

General design

The survey of human and porcine cysticercosis was prompted by anecdotal references suggesting possible endemic T/C by *T. solium* in the villages of Potrero Largo and Palmarito and a proven case of adult NC in Valle del Rio, reported by Dr CM Aguilar. Human and porcine cysticercosis was serologically identified through enzyme-linked immunosorbent assay (ELISA) by the detection of anti-metacestode antibodies and the HP10 secreted metacestode glycoprotein. In addition, relevant risk factors were established through an epidemiological survey and a questionnaire.

Study area and population

Valle del Río is located in Cojedes state at 09°49′49.7″N, 68° 29′31.4′W, 588 m above sea level, with 166 inhabitants; Potrero Largo is 4 km away from Valle del Rio and is located at 09° 49′17.8″N, 68°29′53.6″W, 152 m above sea level, with 300 inhabitants; Palmarito (Planahom area) is located in Portuguesa state at 09°44′26.1″N, 69°18′22.3″W, 1050 m above sea level with a population of 114 inhabitants. Mean temperatures range from 25 to 27° C for Valle del Rio and Potrero Largo, and from 12 to 28°C in Palmarito. Annual rainfalls (mm) are 91–107 in Valle del Rio and Potrero Largo, and 700–1000 in Palmarito.

Field procedures

The field procedures have been previously described (Rojas *et al.*, 2019). Briefly, community visits were conducted between 2006 and 2008 (Valle del Rio and Potrero Largo) and in 2015 (Palmarito), by a team consisting of a medical doctor, four bioanalysts and five medical students. Prior to the experimental work, a meeting with the community was organized in order to explain the study objective and to invite their voluntary participation. Home visits were then made in order to provide responses to a structured questionnaire designed to record socio-sanitary information and risk factors for cysticercosis (housing conditions, water and sanitary facilities, public health services, number of pigs per household, recognition of metacestode-infected pigs and observation of proglottids in human faeces). As part of the interview, the inhabitants were shown samples of *T. solium* proglottids and photographs of infected pig meat. Individuals who had lived more than six months in the village were classified as residents. The main occupation of the members of the communities is agriculture and animal farming (chickens, pigs, goat and cows). Domestic pigs were the commonest animals, and the majority were allowed to roam and forage freely in the streets between the houses and their backyards.

Table 1. Socio-sanitary conditions of households in the three studied communities.

	Valle del Rio	Potrero Largo	Palmarito
Total inhabitants	166	300	114
Inhabitants interviewed and faecal sampled provided	144 (86.8)	248 (82.7)	100 (87.7)
Inhabitants' blood samples provided	139	213	81
Illiterate inhabitants	37/144	25/248	39/100
Total households visited[a]	34/35	55/66	23/23
Adobe housing	25	18	16
Brick housing	10	37	7
Latrines	2	27	3
Piped water	34	55	0
Electricity supply	33	50	23
Rubbish outside houses	10	8	19
Rubbish waste burned	25	47	4

[a]Number of households visited/total number of households.

Sample collection and storage

Faecal samples: three stool samples were collected on alternative days in disposable small plastic boxes from all consenting individuals. The villagers were carefully instructed on adequate hygiene to avoid contamination of themselves or the environmental area.

Serum samples: approximately 5 ml of human venous blood was drawn by venepuncture from all consenting villagers aged five years or older. Samples were centrifuged the same day, aliquoted in 1.5-ml vials and frozen until use. Porcine blood was collected by sampling the jugular vein by trained veterinarians or animal health assistants.

The total numbers of participants were 144, 248 and 100 for faecal samples and 139, 213 and 81 for serum samples in Valle del Río, Potrero Largo and Palmarito, respectively.

Parasitological diagnosis

Direct (Lugol and saline solution) and concentration methods (Kato and Willis–Molloy) were used to detect parasite and *Taenia* spp. eggs in the faecal samples (Botero & Restrepo, 2012). *Taenia solium* adults were identified by morphological examination of expelled proglottids.

Antiparasitic treatment

Individuals positive for intestinal parasites were treated with anthelmintic or anti-protozoan medications. The patients found to be positive for *Taenia* spp. eggs in the coprological analysis

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Table 2. Taeniasis/cysticercosis risk factors in the three rural communities.

	Valle del Rio	Potrero Largo	Palmarito
1. Total householders	34	55	23
2. Householders:			
Owners raising pigs	9	32	13
Owners with roaming pigs	3	8	8
Owners with backyard pigs	6	24	5
Pigs fed/domestic waste	9	11	11
Pigs fed/commercial diet	0	21	2
Pigs bred for local sale	7	26	12
Pigs bred for self-consumption	2	6	1
3. Knowledge of cysticercosis/taeniasis by the pig owners			
Seen infected pork	8	24	12
Seen infected pigs at slaughter	8	9	6
Seen proglottids in their own stools	1	4	9
Sought veterinary inspection	0	3	4
4. Knowledge of cysticercosis/taeniasis by the villagers			
Inhabitants interviewed	144	213	63
Seen the 'solitaria'[a]	27	74	23
Seen proglottids in their own stools	13	33	12
Seen infected pork meat	84	143	55
Consumed infected pork	34	51	23

[a]Local name for adult of *Taenia* sp.

were treated within one week of positive diagnosis under medical surveillance, according to the WHO/FAO/OIE (2005) protocol. After fasting for 10 h, a single dose of praziquantel (Cisticide® Merck, FCD Laboratorios, Cd. De México, Mexico)) (10 mg/kg) was given to each patient. One hour later, the patients were purged (Fleet phospho-soda oral) and were then kept on a light diet (juices and soups) for 12 h. Faeces were collected for 6 h and examined for helminth eggs and adult *Taenia* proglottids and scolices. Faecal samples from the positive carrier patients were examined at monthly intervals for four months in order to confirm successful treatment.

Detection of anti-metacestode antibodies and the secreted metacestode glycoprotein HP10 in human and porcine sera

The presence of anti-metacestode antibodies was measured using *T. solium* metacestode vesicular fluid as the antigen target in the ELISA protocol, according to Larralde *et al.* (1986), with minor modifications, as previously described (Cortez *et al.*, 2010). The presence of the HP10 secreted metacestode glycoprotein was measured using an antigen-trapping ELISA as published (Harrison *et al.*, 1989), with minor modifications (Cortez *et al.*, 2010).

ELISA cut-off values for the anti-metacestode antibodies and the HP10 secreted metacestode glycoprotein were calculated from the mean plus three standard deviations (for the antibody ELISA) and three or four standard deviations (for the HP10 antigen ELISA of humans or pigs, respectively) of the optical density readings obtained from analysis of 23 negative human control sera. Thus, 0.140 and 0.160 were the cut-off values for the human antibody ELISA and the HP10 ELISA, respectively. For analysis of porcine sera evaluation, 30 negative porcine control sera were assayed, to give cut-off values of 0.200 and 0.390 for the antibody ELISA and the HP10 ELISA, respectively (Rojas *et al.*, 2019).

Statistical analysis

All the data were entered into an Excel (Microsoft Office Excel 2007 (PC Actual, Madrid, Spain)) spreadsheet and analyses were conducted in Stata 8.0 (http://www.stata.com).

Results

Socio-sanitary conditions and T/C risk factors in the three rural communities studied

Personal, socio-sanitary conditions and T/C risk factors were determined by house-to-house visits through responses to a structured questionnaire (summarized in table 1). All three communities have a basic rural school, but a primary health service was only available in two of the communities, being absent in Potrero Largo. In the absence of paved streets, the houses are connected by earthen pathways. There is neither public transport nor organized disposal of domestic waste, and environmental sanitation is scarce. Thus, latrines were only present in 2/35, 27/55 and 3/23 of the households in Valle del Rio, Potrero Largo and Palmarito, respectively, and the majority of the population

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Table 3. Parasite-positive faecal samples from individuals in the three rural communities studied.

	Valle del Rio	Potrero Largo	Palmarito
Total faecal samples collected	144 (86.8)	248 (82.7)	100 (87.7)
Total parasite positives	124 (86.1)	201 (81.1)	87 (87.0)
Helminths	13 (9.0)	17 (6.9)	1 (1.0)
Protozoa	52 (36.1)	123 (49.6)	66 (66%)
Helminths and protozoa	57 (39.6)	59 (23.8)	18 (18%)
Taenia solium adult	2 (1.4)	2 (0.8)	2 (2.0)

Faeces were collected, processed and analysed as described in the Materials and Methods section. Total faecal samples collected = the number of individuals that gave faeces, with the percent of the total population of each village in brackets. Total parasite positives: the number of positive samples for a given parasite infection, with the percent of faeces analysed in brackets. Protozoa include: *Giardia intestinalis*, *Entamoeba histolytica/E. dispar*, *E. coli*, *Iodamoeba bütschlii*, *Endolimax nana*, *Blastocystis* sp., *Isospora belli*. Helminths include: *Ascaris lumbricoides*, *Trichuris trichiura*, *Ancylostoma* sp., *Enterobious vermicularis*, *Hymenolepis nana*, *Taenia solium*.

routinely defecated in the open. Piped water was intermittently available in Valle del Rio and Potrero Largo, but the only source of water in Palmarito was a stream. Finally, the illiteracy level among the inhabitants was 25.7% in Valle del Rio, 10.1% in Potrero Largo and 39% in Palmarito.

Risk factors for T/C in the communities

The risk factors for the three communities studied are presented in table 2. The number of householders raising pigs was nine, 32 and 13 in Valle del Rio, Potrero Largo and Palmarito, respectively, at the time of the study. The pigs were free-roaming or kept in backyard areas close to the houses. Only two families (in Potrero Largo) had an appropriate pigpen.

Particularly relevant, some inhabitants admitted to having consumed infected pig meat (locally known as 'frutica') and others to having observed expulsed proglottids in their own stools. In spite of these observations, all of those interviewed were ignorant of the parasite life cycle and attendant risk factors. An important observation was that in all of the three communities all the pig owners sacrificed the animals themselves in the yard of their houses and without any sanitary or veterinary surveillance.

Intestinal parasite infections in the three rural communities

The coprological examination of faecal specimens presented in table 3 indicates a very high level of soil-transmitted parasites in the three communities: 86.1%, 81.1% and 87.0% total parasitized individuals in Valle del Rio, Potrero Largo and Palmarito, respectively, many being infected with *Trichuris trichiura* and Ancylostoma sp. (table 4). All the parasitized patients were given anti-parasite treatment.

One important finding was the observation of *Taenia* spp. eggs in the faeces of two individuals in Valle del Rio, two individuals in Potrero Largo and two individuals in Palmarito. These six patients were treated with praziquantel and a purge. Their faeces were examined; the expelled parasite material (proglottids and scolices) was analysed, resulting in the formal identification of *T. solium* in all six patients. The other parasites present in the faeces from infected individuals are specified in tables 3 and 4.

Table 4. Protozoa and helminth species identified in faecal samples from individuals in the three rural communities studied.

	Valle del Rio	Potrero Largo	Palmarito
Total faecal samples collected	144 (86.8)	248 (82.7)	100 (87.7)
Total parasite positives	124 (86.1)	201 (81.1)	87 (87.0)
Protozoa			
Blastocystis sp.	75 (52.1)	146 (58.9)	67 (67)
Giardia intestinalis	15 (10.4)	27 (10.9)	11 (11)
Entamoeba histolytica /dispar	3 (2.1)	14 (5.6)	1 (1)
Endolimax nana	80 (55.6)	119 (48.0)	50 (50)
Entamoeba coli	35 (24.3)	49 (20.1)	10 (10)
Iodamoeba bütschlii	15 (10.4)	37 (15.0)	17 (17)
Isospora belli	1 (0.7)	0	0
Helminths			
Ascaris lumbricoides	3 (2.1)	29 (11.7)	6 (6.0)
Trichuris trichiura	40 (27.8)	10 (4.0)	13 (13.0)
Ancylostoma sp.	57 (39.6)	47 (19.0)	0 (0.0)
Enterobious vermicularis	1 (0.7)	0 (0.0)	0 (0.0)
Hymenolepis nana	0 (0.0)	0 (0.0)	4 (4.0)
Taenia solium adult	2 (1.4)	2 (0.8)	2 (2.0)

Detection of anti-metacestode antibodies and HP10 secreted metacestode glycoprotein in human and porcine sera

As can be seen, the positive serological evidence clearly indicated endemic human and porcine (table 5) cysticercosis in all of the three studied communities. Thus, the HP10 secreted metacestode glycoprotein was detected in 36.0%, 12.2% and 29.6% human sera from Valle del Rio, Potrero Largo and Palmarito, respectively, and anti-metacestode antibodies were detected in 46.0%, 19.2% and 27.2% of the samples of human sera from Valle del Rio, Potrero Largo and Palmarito, respectively.

Similarly, in the pig serum samples, we observed anti-metacestode antibodies in 31.6%, 68.9% and 64.0% of the sera and HP10 secreted metacestode glycoprotein in 26.3%, 14.9% and 48.0% of the pig sera in Valle del Rio, Potrero Largo and Palmarito, respectively.

Discussion

The study of the three communities was prompted by anecdotal references of possible *T. solium* transmission and a proven case of NC in Valle del Rio.

We first determined the presence of the typical risk factors for T/C in the three communities. All communities were characterized by their obvious high level of poverty, with poorly structured villages and houses, a large absence of latrines, scarce public services, an absence of waste disposal services, irregular or absent

Table 5. Anti-metacestode antibody and HP10 glycoprotein levels in human and porcine sera in three rural communities.

	Valle del Rio		Potrero Largo		Palmarito	
	Human	Porcine	Human	Porcine	Human	Porcine
Tested/total	139/166	57/60	213/300	148/169	81/114	25/70
Abs	46.0 (64/139)	31.6 (18/57)	19.2 (41/213)	68.9 (102/148)	27.2 (22/81)	64.0 (16/25)
HP10Ag	36.0 (50/139)	26.3 (15/57)	12.2 (26/213)	14.9 (22/148)	29.6 (24/81)	48.0 (12/25)

water supply and significant illiteracy. Given these conditions, the observed high levels of soil-transmitted parasites (helminths and protozoa) were not a surprise: 86.1%, 81.1% and 87.0% in Valle del Rio, Potrero Largo and Palmarito, respectively. Similar risk factors have been reported for other rural Venezuelan communities (Toquero *et al*., 2017; Rojas *et al*., 2019) and in other countries with endemic cysticercosis (Ng-Nguyen *et al*., 2018; Openshaw *et al*., 2018). Indeed, the socio-economic conditions in these communities constitute a perfect panorama for the establishment of diverse infectious diseases, collectively called Neglected Tropical Diseases, and sustained by a vicious cycle of poverty, disease and underdevelopment (Ault, 2007; WHO, 2010).

Specifically, and in relation to T/C, we observed routine human defecation in the open, and free-roaming pigs killed locally without veterinary inspection and for local consumption. These conditions not only favour the perpetuation of the *T. solium* transmission cycle, but also provide an informal route for entry of infected pig meat into urban areas (Bern *et al*., 1999). Perhaps our most depressing observation was that some people had seen *Taenia* sp. proglottids (in their faeces) and/or metacestodes in pork, but never associated these observations with the disease.

An important aspect of our study was the identification of two *T. solium* adult worm carriers in each of the three communities. Their subsequent treatment is not only expected to diminish local *T. solium* transmission, but may also provide an objective lesson to the inhabitants through highlighting the presence and danger of *T. solium* carriers in their communities.

In addition to the presence of adult worm carriers and the classical T/C risk factors, high levels of anti-*T. solium* metacestode antibodies and HP10 secreted metacestode glycoprotein were observed in both humans and pigs. While it is true that these serological procedures do have limitations (Carabin *et al*., 2017; Cortez *et al*., 2018; Parkhouse *et al*., 2018), they are the only currently feasible practical tools available for the economically identification of cysticercosis in rural communities of low-income countries. Imaging technology, unfortunately, is not a practical solution for the diagnosis of poor rural populations because of its non-availability and high cost. The detection of porcine cysticercosis has been suggested as a possible alternative to serology for the identification of endemic human cysticercosis. Pigs are infected early in life and are usually slaughtered at, or before, one year of age (Bern *et al*., 1999). Thus, porcine sero-surveys may be the fastest, least expensive way to determine the level of ongoing transmission of cysticercosis.

Transmission of cysticercosis has also been reported for other rural Venezuelan communities. Thus, Ferrer *et al*. (2002, 2003), using the same approach, found anti-metacestode antibodies in an Amerindians population (Amazonas state) and in rural communities (Lara and Carabobo states). A significant seroprevalence has also been reported in an indigenous population of Zulia state (Freites *et al*., 2015) and in two rural communities of Anzoátegui state (Toquero *et al*., 2017).

In conclusion, we have observed the classical risk factors for the transmission of cysticercosis and taeniasis in all three of the communities studied. In addition, there was clear evidence for the transmission of cysticercosis through the identification and treatment of carriers of the adult *T. solium*, and through serological evidence for both cases of human and porcine cysticercosis. This study constitutes the first step towards eradication of the diseases in these communities.

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Conflicts of interest. None.

Ethical approval. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. Signed informed consent was obtained for all adult participants, and parents or legal guardian of minors. Also, the authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional guides on the care and use of laboratory animals. Animals were handled following good animal practice, as defined by OIE'S Terrestrial Animal Health Code for use in research and education (https://www.oie.int/fileadmin/Home/eng/Health_standards/tahc/current/chapitre_aw_research_education.pdf) and the guidelines provided by the National Centre for Replacement, Refinement and Reduction of Animals in Research.

References

Ault SK (2007) Pan American Health Organization's regional strategic framework for addressing neglected diseases in neglected populations in Latin America and the Caribbean. *Memorias do Instituto Oswaldo Cruz* **102**, 99–107.

Bern C, Garcia HH, Evans C, *et al*. (1999) Magnitude of the disease burden from neurocysticercosis in a developing country. *Clinical Infectious Diseases* **29**, 1203–1209.

Botero D and Restrepo M (2012) *Parasitosis humanas*. 5th edn. 719 pp. Medellin, Colombia, Corporación para Investigaciones Biológicas.

Carabin H, Wrinkler A and Dorny P (2017) *Taenia solium* cysticercosis and taeniosis: Achievements from the past 10 years and the way forward. *PLoS Neglected Tropical Diseases* **11**(4), e0005478.

Cortez MM, Rojas GC and Parkhouse RME (2018) The HP10 *Taenia* monoclonal antibody-based ELISA detects a similar protein in the vesicular fluid of *Taenia hydatigena*. *Tropical Animal Health & Production* **50**, 697–700.

Cortez MM, Boggio G, Guerra M, *et al.* (2010) Evidence that active transmission of porcine cysticercosis occurs in Venezuela. *Tropical Animal Health and Production* **42**, 531–537.

Coyle CM, Mahanty S, Zunt JR, *et al.* (2012) Neurocysticercosis: neglected but not forgotten. *PLoS Neglected Tropical Diseases* **6**(5), e1500.

Ferrer E, Cortez MM, Perez H, *et al.* (2002) Serological evidence for recent exposure to *Taenia solium* in Venezuelan Amerindians. *American Journal of Tropical Medicine and Hygiene* **66**, 170–174.

Ferrer E, Cabrera Z, Rojas G, *et al.* (2003) Evidence for high seroprevalence of *Taenia solium* cysticercosis in individuals from three rural communities in Venezuela. *Transactions of the Royal Society Tropical Medicine and Hygiene* **97**, 522–526.

Food and Agriculture Organization of the United Nations/World Health Organization (FAO/WHO) (2014) Multicriteria-based ranking for risk management of food-borne parasites. Microbiological Risk Assessment Series No. 23. Rome. 302 pp. Available at https://apps.who.int/iris/bitstream/handle/10665/112672/9789241564700_eng.pdf;jsessionid=82BB8B550E5232E6B9460DC355D993EA?sequence=1 (accessed 25 July 2019).

Freites A, García ME, Díaz-Suárez O, *et al.* (2015) Anti-cysticercus immunity in an Amerindian community from western Venezuela. *Kasmera* **43**, 56–65.

Garcia HH, Nash TE and Del Brutto OH (2014) Clinical symptoms, diagnosis, and treatment of neurocysticercosis. *Lancet Neurology* **13**(12), 1202–1215.

Guzman M, Guilarte del V and Urdaneta H (2004) Seroprevalence of teniasis and cysticercosis in school children from Peñón, Sucre, Venezuela. *Kasmera* **32**, 108–116.

Harrison LJ, Joshua GW, Wright SH, *et al.* (1989) Specific detection of circulating surface/secreted glycoproteins of viable cysticerci in *Taenia saginata* cysticercosis. *Parasite Immunology* **11**, 351–370.

Havelaar AH, Kirk MD, Torgerson PR, *et al.* (2015) World Health Organization global estimates and regional comparisons of the burden of foodborne disease in 2010. *PLoS Medicine* **12**(12), e1001923.

Larralde C, Laclette JP, Owen CS, *et al.* (1986) Reliable serology of *Taenia solium* cysticercosis with antigen from cyst vesicular fluid: ELISA and haemagglutination test. *American Journal of Tropical Medicine and Hygiene* **35**, 965–973.

Ng-Nguyen D, Stevenson MA, Breen K, *et al.* (2018) The epidemiology of *Taenia* spp. infection and *Taenia solium* cysticerci exposure in humans in the central highlands of Vietnam. *BMC Infectious Diseases* **18**, 527.

Openshaw JJ, Medina A, Felt SA, *et al.* (2018) Prevalence and risk factors for *Taenia solium* cysticercosis in school-aged children: a school based study in western Sichuan, People's Republic of China. *PLOS Neglected Tropical Diseases* **12**(5), e0006465.

Parkhouse RME, Carpio A, Campoverde A, *et al.* (2018) Reciprocal contribution of clinical studies and the HP10 antigen ELISA for the diagnosis of extraparenchymal neurocysticercosis. *Acta Tropica* **178**, 119–123.

Parkhouse RME, Rojas G, Aguilar CM, *et al.* (2020) Diagnosis of taeniosis in rural Venezuelan communities: preliminary characterization of *Taenia solium* specific monoclonal (VP-1) Coproantigen ELISA. *Acta Tropica* **207**, 105445.

Rojas G, Aguilar CM, Alviarez Y, *et al.* (2008) *Control de teniasis por identificación de portadores de taenia solium y T. saginata en la región Centro Occidental, Venezuela. VI Congreso de Investigación*. Valencia, Carabobo,Venezuela, Universidad de Carabobo, pp. 337–341.

Rojas G, Patiño F, Pérez J, *et al.* (2019) Transmission of porcine cysticercosis in the Portuguesa state of Venezuela. *Tropical Animal Health and Production* **51**, 165–169.

Toquero M, Morocoima A and Ferrer E (2017) Seroprevalencia y factores de riesgo de cisticercosis en dos comunidades rurales del norte del estado Anzoátegui, Venezuela. *Biomédica* **37**, 66-74.

Willingham AL 3rd and Engels D (2006) Control of *Taenia solium* cysticercosis/taeniosis. *Advances in Parasitology* **61**, 509–566.

World Health Organization (2010) Working to overcome Neglected Tropical Diseases. Available at www.who.int/neglected_diseases/resources/9789241564090/en/ (accessed 25 July 2019).

World Health Organization/Food and Agriculture Organization of the United Nations/World Organization for Animal Health (WHO/FAO/OIE) (2005) Guidelines for the surveillance, prevention and control of taeniosis/cysticercosis. Murrel KD (*Ed.*). Available at www.who.int/iris/handle/10665/43291 (accessed 18 January 2006).