Survey of Obstetrician-Gynecologists in the United States about Taeniasis and Cysticercosis

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Abstract. An estimated 50 million persons worldwide are infected with cysticerci, the larval forms of the *Taenia solium* tapeworm. Neurocysticercosis can cause seizures, epilepsy, and hydrocephalus, and fatal cases have been reported in the United States in immigrants and in travelers returning from endemic countries. Pregnant women with symptomatic neurocysticercosis present treatment challenges, whereas those with the adult tapeworm infection (i.e., taeniasis) can put their infants and other family members, as well as obstetrician-gynecologists and their staff, at risk for cysticercosis. A questionnaire developed by the American College of Obstetricians and Gynecologists was sent to a representative sample of 1,000 physicians to assess their awareness of *T. solium* infection and the potential for it to be encountered in an obstetrics and gynecology setting. In total, 31.4% of respondents correctly answered that taeniasis is caused by eating undercooked pork containing *T. solium* cysts (95% confidence interval [CI] = 26.6–36.5). While only 14.5% (95% CI = 11.0–18.6) of respondents correctly answered that cysticercosis is acquired by ingesting tapeworm eggs shed in human stools, twice that number (30.3%; 95% CI = 25.5–35.3) correctly answered that a mother with taeniasis can cause cysticercosis in her infant. Practicing in a state in which cysticercosis was reportable at the time of the survey was not significantly associated with answering any of the 12 knowledge questions correctly. Overall, knowledge of *T. solium* infection among U.S. obstetricians-gynecologists is limited. This may result in missed opportunities to diagnose and treat pregnant women with taeniasis, which may put family members and obstetrics clinical staff at risk for cysticercosis.

INTRODUCTION

Taenia solium causes cysticercosis in pigs and both cysticercosis and taeniasis in humans, depending on whether the egg or larval stage of the parasite is ingested. Taeniasis is a human intestinal infection with the adult *T. solium* tapeworm that results from consumption of undercooked pork containing larval cysts. Cysticercosis is a tissue infection with the larval form of the parasite that is acquired via ingestion of *T. solium* eggs shed by tapeworm carriers. Pigs acquire cysticercosis when they consume human feces containing the eggs. Humans acquire cysticercosis when they ingest substances that have been contaminated by infected feces from a human adult tapeworm carrier who has poor hand hygiene practices. Tapeworm carriers can acquire cysticercosis via autoinfection.¹ Neurocysticercosis occurs when larvae encyst in the central nervous system. Women with taeniasis can transmit cysticercosis to newborns postpartum or, theoretically, even intrapartum by exposing the neonates to infective *T. solium* eggs during delivery. As with other diseases spread via the fecal/oral route, when there are lapses in standard infection control procedures, transmission of cysticercosis is possible in clinical settings, such as during gynecological examinations or labor and delivery. We are not aware of any documented cases of cysticercosis transmission in an obstetrics and gynecology (OB/GYN) practice to date, but due to the extended incubation period of cysticercosis (i.e., months to years), exact exposures are difficult to determine.

Taenia solium infection is found worldwide in areas that lack sufficient sanitation and where domestic pigs live in close contact with humans, including much of Latin America, Asia, and sub-Saharan Africa.^{1,2} In endemic villages in Latin

America, the seroprevalence of cysticercosis can be greater than 10%;¹ a 2006 study found a seroprevalence of 23.4% to 35.9% in an endemic region in Peru.³ The prevalence of taeniasis in Latin America may be up to 5%, based on fecal antigen detection and morphologic examination of stool.^{1,4,5}

In the United States, cysticercosis is mostly reported among persons who emigrate from endemic areas, though there have been reports of cases in travelers to endemic areas, and 78 U.S.-acquired cases published between 1954 and 2005 were described in a recent review.^{6–8} Although most U.S. cases have been reported in persons migrating from Mexico and other Latin American countries,⁶ cases may also occur among resettled refugees from outside of the Americas. One retrospective study found *T. solium* antibody levels of 18.3–25.8% in serum collected from refugees of three Asian and one sub-Saharan African country during predeparture screening.⁹ Data used to estimate neurocysticercosis incidence and prevalence in the United States are based on a few population-based surveillance studies in California and Oregon and suggest an annual incidence or incidence of hospitalization of 0.2–1.1 cases per 100,000 persons in the general population, and 1.5–5.5 cases per 100,000 persons in the Hispanic population.^{6,10–14} A more recent study that reviewed data from the National Inpatient Sample, which represents about 20% of the U.S. hospitalized population, found 0.8 hospitalizations annually per 100,000 people in the general population. Annual hospitalizations in the Hispanic population were 3.48 per 100,000 people; in the 18- to 44-year-old population, there were 1.2 per 100,000 people; and in the female population, there were 0.7 per 100,000 people.¹⁵ No figure was available for the female Hispanic population. Data from the National Center for Health Statistics from 1990 to 2002 were used to estimate the U.S. mortality rate due to cysticercosis.¹⁶ The age-adjusted mortality rate was 0.06 per million population, with 62% of reported deaths occurring among persons born in Mexico, and 15% occurring among persons

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born in the United States. Epidemiologic data on taeniasis in the United States are limited. The two published population-based studies, in which the majority of both populations were born in Mexico, reported a prevalence of taeniasis of 0.5–3.0%.^{6,17,18}

Most *T. solium* taeniasis cases are asymptomatic, but nonspecific gastrointestinal symptoms such as abdominal pain and weight loss can occur.¹⁹ Most cysticercosis infections outside of the central nervous system are asymptomatic, although small painless nodules may be noted in the arms or chest, which may become inflamed and tender before gradually disappearing.¹ Neurocysticercosis can cause severe morbidity and death, and is one of the most important causes of acquired epilepsy in developing countries.¹ In addition to the human burden of morbidity and mortality due to this preventable disease, the cost of hospitalizations for neurocysticercosis can be a burden on states in which many cases occur.⁶ Two studies using hospital discharge data in California found the average charge (which was used to estimate actual cost) per patient hospitalized for neurocysticercosis to be \$37.6 thousand during 1991–2008 and \$57.8 thousand during 2009.^{10,20} The total charges per year averaged \$7.9 million during 1991–2008 and exceeded \$17 million in 2009.

Published reports of neurocysticercosis in pregnancy have described patients presenting with severe headaches and seizures,^{21–26} some with coma.^{25,27,28} In one case report, a woman with intraventricular neurocysticercosis had a severe headache and change in mental status.²⁹ The signs and symptoms and resulting treatment regimens for neurocysticercosis depend on the number, size, location, and stage of the cysts in the brain.³⁰ Neurocysticercosis signs and symptoms can mimic those of eclampsia, and several cases initially presenting as eclampsia have been reported in the literature.^{25,28,31}

Obstetrician-gynecologists in the United States may encounter neurocysticercosis patients in their practices, particularly those in U.S.–Mexico border states or in areas with large Latino populations. Pregnant women with *T. solium* infection present treatment challenges because the benefits of treatment of the mother and child must be weighed against the potential toxicity of the drugs to the developing fetus. To the best of our knowledge, this is the first study to assess U.S. obstetrician-gynecologist knowledge about human *T. solium* infection, including risk factors for infection, and diagnosis, prevention, and treatment.

MATERIALS AND METHODS

A questionnaire about cysticercosis and taeniasis was developed in 2010 by the American College of Obstetricians and Gynecologists (ACOG) in consultation with the Centers for Disease Control and Prevention (CDC). The first part of the questionnaire collected the following demographic information and information related to the respondent's clinical practice setting: gender, age, year of birth, state of practice, number of years since residency, clinical practice setting, and medical specialty(-ies). The second part consisted of 12 questions that tested the respondent's knowledge of the routes of transmission, diagnosis, and treatment of taeniasis and cysticercosis, particularly in the context of pregnancy.

In December 2010, the survey was mailed to a total of 1,000 ACOG members, 400 of whom were members of the Collaborative Ambulatory Research Network (CARN). CARN members are practicing obstetrician-gynecologists who volunteer to participate in periodic research surveys on ambulatory care issues that are relevant to ACOG. The quasi-random sample of CARN and non-CARN members was chosen as follows: the CARN membership list was stratified into groups of 100, each of which was representative of the ACOG membership in terms of age and gender. Four of those groups were then randomly selected. Non-CARN members were chosen for the survey in the same way, except six groups were chosen in anticipation of a lower response rate compared with the CARN group. Follow-up mailings were sent in February, April, and June of 2011. Surveys were excluded from analysis if they were returned without responses to any of the knowledge questions or if the respondent reported currently practicing outside of the United States and its territories. Data were compiled and entered at ACOG headquarters in Washington, DC.

Data were analyzed at the CDC using Statistical Analysis Software version 9.3 (SAS Institute Inc., Cary, NC). Response proportions were calculated for both the total respondent population and separately for the CARN and non-CARN respondent groups. Clopper–Pearson confidence intervals (CIs) were calculated for the pooled responses, and differences in the proportions of CARN and non-CARN responses were calculated using Fisher's exact test. Logistic regression was used to examine associations between individual respondent characteristics and providing correct responses to the knowledge questions, but not to create a predictive model per se. Effect modification of CARN status on gender and experience was first assessed by calculating Cochran–Mantel–Haenszel odds ratios (ORs) and using the Breslow–Day test for homogeneity of the OR. Interaction terms were included as needed, and a generalized logit model was fit to account for the variable levels having no inherent ordering. Significant values were those with $P \leq 0.05$. The Hosmer–Lemeshow goodness-of-fit test was used to evaluate the fit of models (none had P values < 0.1 , indicating acceptable fit). Demographic or clinical practice variables that were significantly associated with correctly answering at least one of the questions correctly in univariate analysis were included in the multivariate model.

This survey was determined to be exempt from review by the ACOG and CDC institutional review boards.

RESULTS

The overall response rates were 52% (208/400) for CARN members and 28% (165/600) for non-CARN members. Surveys from 11 respondents were returned without responses to any of the 12 taeniasis/cysticercosis knowledge questions and were therefore excluded from analyses. Two respondents reported practicing in Canada, and their surveys were also excluded. The analyses included 203 CARN and 157 non-CARN respondents from 45 states ($N = 359$) and Puerto Rico ($N = 1$). Demographic characteristics of respondents are listed in Table 1. There were no significant differences among CARN and non-CARN members with respect to age, gender, or U.S. Census region

TABLE 1
Demographic characteristics of respondents to an ACOG survey about taeniasis and cysticercosis, 2010

Question	Answer	n (%)	(95% CI)
Gender (N = 360)	Male	185 (51.4)	(46.2–56.6)
	Female	175 (48.6)	(43.4–53.8)
U.S. Census region* (N = 329)	Midwest	73 (22.2)	(17.7–26.7)
	New England	64 (19.5)	(15.1–23.8)
	South	119 (36.2)	(31.0–41.4)
	West	73 (22.2)	(17.7–26.7)
	No answer	1 (0.3)	(0.0–0.8)
Practice setting (N = 360)	Solo private practice	76 (21.1)	(16.9–25.3)
	Group private practice	191 (53.1)	(47.9–58.2)
	Academic	48 (13.3)	(9.8–16.9)
	Government-funded clinic	5 (1.4)	(0.2–2.6)
	Hospital	21 (5.8)	(3.4–8.3)
	Other	19 (5.3)	(3.0–7.6)
	No answer	1 (0.3)	(0.0–0.8)
Specialty (N = 360)	General OB/GYN	263 (73.1)	(68.5–77.7)
	Gynecology only	44 (12.2)	(8.8–15.6)
	Obstetrics only	4 (1.1)	(0.0–2.2)
	Urogynecology	6 (1.7)	(0.3–3.0)
	Maternal/fetal medicine	30 (8.3)	(5.5–11.2)
	Reproductive endocrinology and infertility	10 (2.8)	(1.1–4.5)
	Other	2 (0.6)	(0.0–1.3)
	No answer	1 (0.3)	(0.0–0.8)

ACOG = American College of Obstetricians and Gynecologists; OB/GYN = obstetrics and gynecology.

*Excludes Puerto Rico, which is not in a U.S. Census region.

(i.e., northeast, south, midwest, or west). The region was missing for 30 (18.8%) of the respondents, 15 (7.4%) of 203 CARN members, and 15 (9.6%) of 157 non-CARN members, and the region was not counted for the non-CARN respondent from Puerto Rico because U.S. territories are not part of any U.S. Census region. The median age of respondents was 53 years, and 51% were male. Respondents had been in practice for a median of 19 years, with almost three-quarters (73%) in general OB/GYN, and just over half (53%) working in a group practice. Sixty-five (18%) of the respondents were practicing in states where cysticercosis was a reportable disease as of 2010† (i.e., Arizona, California, New Mexico, Oregon, and Texas).

Overall, 87% (N = 312) of respondents answered at least one question correctly, whereas only one respondent answered all 12 correctly. The median number of correct responses was four. Summing the responses to all of the knowledge questions, the most frequent response was “not sure” (42%), followed by the correct response (32%) and incorrect response(s) (26%). The median percentages of “not sure,” correct, and incorrect responses per question were 34%, 31%, and 26%, respectively.

The responses to the knowledge questions for the entire survey population and stratified by CARN membership are given in Table 2. In total, only 31.4% of respondents correctly answered that taeniasis is caused by eating undercooked pork containing *T. solium* cysts (95% CI = 26.6–36.5), 14.5% correctly answered that cysticercosis is acquired by ingesting tapeworm eggs shed in human stools (95% CI = 11.0–18.6), and 30.3% of respondents correctly answered that a mother with taeniasis can cause cysticercosis in her infant (95% CI = 25.5–35.3). Non-CARN members correctly responded significantly more frequently than CARN members that cysticercosis

can be spread by an infected food handler or household member with inadequate personal hygiene (58% versus 47%, $P = 0.032$) and that taeniasis cannot be transmitted from person to person (21% versus 12%, $P = 0.019$). Non-CARN members also correctly responded significantly more frequently than CARN members that taeniasis diagnosis is best assisted by examination of human stool samples (56.7% versus 46.0%, $P = 0.029$); that if an infant or another person in a household is found to have cysticercosis, persons living in the same household should be evaluated for taeniasis and cysticercosis (74% versus 64%, $P = 0.030$); and that cysticercosis is a common cause of acquired epilepsy in Latin America and areas of the United States with large Latino immigrant populations (50% versus 34%, $P = 0.001$). There were no significant differences in frequency of correct response by CARN status for the remaining seven questions.

Characteristics associated with correct responses are given in Table 3. Having completed residency at least 20 years prior was significantly associated with correctly identifying stool examination as the best way to diagnose taeniasis (univariate OR = 2.34, $P < 0.005$; multivariate OR = 2.55, $P < 0.005$), knowing that cysticercosis is acquired by ingesting tapeworm eggs shed in human stools (multivariate OR = 2.13, $P < 0.05$), knowing that infected food handlers or household contacts can be sources of cysticercosis (univariate OR = 1.59, $P < 0.05$; multivariate OR = 1.58, $P < 0.05$), and knowing that if an infant or another person in a household is found to have cysticercosis, persons living in the same household should be evaluated for taeniasis and cysticercosis (univariate OR = 1.61, $P < 0.05$). Time since completing residency was inversely associated with correctly identifying serologic testing or radiologic imaging as the best ways to diagnose cysticercosis (multivariate OR = 0.60, $P < 0.05$). Male gender was significantly associated with knowing that a mother with cysticercosis cannot be the cause of taeniasis in the infant (univariate OR = 1.72, $P < 0.05$), knowing that if an infant or another person in a household is found to have

†Cysticercosis became reportable in Alaska in 2015; therefore, for this analysis, Alaska is not considered a state in which cysticercosis is reportable.

TABLE 2
Responses from U.S. obstetrician-gynecologists to a survey about taeniasis and cysticercosis

Question or statement*	Total (N = 360)		CARN (N = 203)		Non-CARN (N = 157)		P value†
	n	Percent (95% CI)	answered yes		answered yes		
			n (%)	n (%)	n (%)	n (%)	
Taeniasis caused by the pork tapeworm (<i>T. solium</i>) is acquired by which of the following?							
Ingesting tapeworm eggs shed in human stools (fecal-oral infection)	16	4.4 (2.6–7.1)	8 (3.9)	8 (5.1)	0.167		
Eating undercooked contaminated pork‡	113	31.4 (26.6–36.5)	59 (29.1)	54 (34.4)			
Ingesting tapeworm eggs shed in pig stools	5	1.4 (0.5–3.2)	1 (0.5)	4 (2.5)			
All of the above	151	41.9 (36.8–47.2)	88 (43.3)	63 (40.1)			
Not sure	75	20.8 (16.8–25.4)	47 (23.2)	28 (17.8)			
Taeniasis diagnosis is best assisted by							
Examination of human stool sample§	182	50.7 (45.4–56.0)	93 (46.0)	89 (56.7)	0.029		
Serologic testing	15	4.2 (2.4–6.8)	10 (5.0)	5 (3.2)			
CAT scan or MRI	5	1.4 (0.5–3.2)	0 (0.0)	5 (3.2)			
Both serologic testing and CAT scan/MRI	42	11.7 (8.6–15.5)	24 (11.9)	18 (11.5)			
Not sure	115	32.0 (27.2–37.1)	75 (37.1)	40 (25.5)			
Cysticercosis, which can be associated with the infection of numerous internal organs, is acquired by which of the following?							
Ingesting tapeworm eggs shed in human stools (fecal-oral infection)‡	52	14.5 (11.0–18.6)	25 (12.3)	27 (17.3)	0.119		
Eating undercooked contaminated pork	72	20.1 (16.0–24.6)	42 (20.7)	30 (19.2)			
Ingesting tapeworm eggs shed in pig stools	5	1.4 (0.5–3.2)	2 (1.0)	3 (1.9)			
All of the above	118	32.9 (28.0–38.0)	69 (34.0)	49 (31.4)			
Not sure	112	31.2 (26.4–36.3)	65 (32.0)	47 (30.1)			
Infected food handlers or household members with inadequate personal hygiene could potentially be a source of taeniasis							
True	203	56.4 (51.1–61.6)	111 (54.7)	92 (58.6)	0.019		
False‡	58	16.1 (12.5–20.3)	25 (12.3)	33 (21.0)			
Not sure	99	27.5 (23.0–32.4)	67 (33.0)	32 (20.4)			
Infected food handlers or household members with inadequate personal hygiene could potentially be a source of cysticercosis							
True‡	186	51.8 (46.5–57.1)	96 (47.3)	90 (57.7)	0.032		
False	50	13.9 (10.5–17.9)	26 (12.8)	24 (15.4)			
Not sure	123	34.3 (29.4–39.4)	81 (39.9)	42 (26.9)			
A mother with taeniasis can infect her infant, causing cysticercosis in the infant							
True‡	108	30.3 (25.5–35.3)	61 (30.3)	47 (30.1)	0.563		
False	63	17.6 (13.8–22.0)	28 (13.9)	35 (22.4)			
Not sure	186	52.1 (46.8–57.4)	112 (55.7)	74 (47.4)			
A mother with cysticercosis can infect her infant, causing taeniasis in the infant							
True	76	21.5 (17.3–26.1)	41 (20.5)	35 (22.7)	0.503		
False‡	84	23.7 (19.4–28.5)	47 (23.5)	37 (24.0)			
Not sure	194	54.8 (49.5–60.1)	112 (56.0)	82 (53.2)			
If an infant or other family member is found to have cysticercosis, family members living together should be evaluated for taeniasis and cysticercosis§							
True‡	244	68.3 (63.2–73.1)	128 (64.0)	116 (73.9)	0.030		
False	7	2.0 (0.8–4.0)	2 (1.0)	5 (3.2)			
Not sure	106	29.7 (25.0–34.7)	70 (35.0)	36 (22.9)			
(continued)							

(continued)

TABLE 2
Continued

Question or statement*	Total (N = 360)		CARN (N = 203)		Non-CARN (N = 157)		P value†
	n	Percent (95% CI)	answered yes	n (%)	answered yes	n (%)	
Cysticercosis is a common cause of epilepsy in Latin America and areas of the United States with many Latin American immigrants							
True‡	146	41.1 (36.0–46.4)		68 (34.0)		78 (50.3)	0.001
False	17	4.8 (2.8–7.6)		9 (4.5)		8 (5.2)	
Not sure	192	54.1 (48.7–59.4)		123 (61.5)		69 (44.5)	
Cysticercosis diagnosis is best assisted by							
Examination of human stool samples	58	16.2 (12.5–20.4)		30 (14.9)		28 (17.8)	0.401
Serologic testing	12	3.4 (1.7–5.8)		7 (3.5)		5 (3.2)	
CAT scan or MRI	41	11.5 (8.3–15.2)		18 (9.0)		23 (14.6)	
Both serologic testing and CAT scan/MRI‡	124	34.6 (29.7–39.8)		68 (33.8)		56 (35.7)	0.512
Not sure	123	34.4 (29.4–39.5)		78 (38.8)		45 (28.7)	
Taeniasis may be treated with (select all that apply)¶							
Praziquantel‡	90	25.1 (20.7–30.0)		43 (17.8)		47 (23.9)	0.512
Albendazole	78	21.8 (17.6–26.4)		42 (17.4)		36 (18.3)	
Niclosamide‡	32	8.9 (6.2–12.4)		15 (6.2)		17 (8.6)	
Corticosteroids in association with a primary drug	18	5.0 (3.0–7.8)		9 (3.7)		9 (4.6)	0.731
Not sure	220	61.5 (56.2–66.5)		132 (54.8)		88 (44.7)	
Regarding medications used to treat taeniasis							
They can be given in the first trimester without concern**	20	5.6 (3.5–8.5)		8 (4.0)		12 (7.7)	0.731
They can be given after the first trimester‡	47	13.2 (9.9–17.2)		28 (13.9)		19 (12.3)	
They should not be used any time during pregnancy	13	3.7 (2.0–6.2)		4 (2.0)		9 (5.8)	
Not sure	276	77.5 (72.8–81.8)		161 (80.1)		115 (74.2)	

CARN = Collaborative Ambulatory Research Network; CAT = computerized axial tomography; MRI = magnetic resonance imaging. Significant P values are shown in bold.

*Missing responses excluded from denominator.

†P-values compare CARN and non-CARN response proportions. Left-sided Fisher's exact P value giving probability that frequency of correct answers by CARN members is less than or equal to the observed frequency.

‡Correct answer.

§Testing for cysticercosis should occur only in persons with compatible neurologic signs and symptoms.

¶The correct response for the purpose of calculating the P value was choosing both praziquantel and niclosamide (N = 15). Any other response or combination of responses was considered incorrect.

**Praziquantel and niclosamide are pregnancy category B drugs. Although observational studies seem to suggest they are safe to administer during the first trimester, there have been no clinical trials in pregnant women. Therefore, these drugs should only be administered during the first trimester when clinically warranted.

TABLE 3
Characteristics associated with correct responses about taeniasis and cysticercosis

Question or statement*	Correct response n (%)	Incorrect response (number n (%))	OR (95% CI)	aOR† (95% CI)
Taeniasis caused by the pork tapeworm (<i>T. solium</i>) is acquired by eating undercooked contaminated pork				
Male gender	N = 113 59 (52.2)	N = 247 (75) 126 (51.0)	1.05 (0.67–1.64)	0.98 (0.60–1.59)
Non-CARN member	54 (47.8)	103 (41.7)	1.28 (0.82–2.00)	1.33 (0.83–2.11)
≥ 20 years since completing residency	54 (51.4)	112 (48.7)	1.12 (0.70–1.77)	1.14 (0.70–1.85)
Taeniasis diagnosis is best assisted by examination of human stool samples				
Male gender	N = 182 97 (53.3)	N = 177 (115) 88 (49.7)	1.15 (0.76–1.75)	0.85 (0.53–1.35)
Non-CARN member	89 (48.9)	68 (38.4)	1.53 (1.01–2.33)	1.63 (1.04–2.55)
≥ 20 years since completing residency	101 (59.8)	64 (38.8)	2.34 (1.51–3.64)§	2.55 (1.60–4.07)§
Cysticercosis is acquired by ingesting tapeworm eggs shed in human stools				
Male gender	N = 52 26 (50.0)	N = 307 (112) 158 (51.5)	0.94 (0.52–1.70)	0.68 (0.36–1.31)
Non-CARN member	27 (51.9)	129 (42.0)	1.49 (0.83–2.69)	1.55 (0.83–2.88)
≥ 20 years since completing residency	30 (62.5)	136 (47.4)	1.85 (0.99–3.47)	2.13 (1.09–4.13)‡
Infected food handlers or household members with inadequate personal hygiene could not potentially be a source of taeniasis				
Male gender	N = 58 35 (60.3)	N = 302 (99) 150 (49.7)	1.54 (0.87–2.73)	1.42 (0.76–2.64)
Non-CARN member	33 (56.9)	124 (41.1)	1.90 (1.07–3.34)‡	1.75 (0.97–3.16)
≥ 20 years since completing residency	29 (53.7)	137 (48.8)	1.22 (0.68–2.19)	1.13 (0.61–2.10)
Infected food handlers or household members with inadequate personal hygiene could potentially be a source of cysticercosis				
Male gender	N = 186 102 (54.8)	N = 173 (123) 83 (48.0)	1.32 (0.87–1.99)	1.12 (0.71–1.77)
Non-CARN member	90 (48.4)	66 (38.2)	1.52 (1.00–2.31)	1.64 (1.05–2.55)‡
≥ 20 years since completing residency	96 (54.9)	69 (43.4)	1.59 (1.03–2.44)‡	1.58 (1.00–2.50)‡
A mother with taeniasis can infect her infant, causing cysticercosis in the infant				
Male gender	N = 108 58 (53.7)	N = 249 (186) 125 (50.2)	1.15 (0.73–1.81)	1.04 (0.64–1.70)
Non-CARN member	47 (43.5)	109 (43.8)	0.99 (0.63–1.56)	1.02 (0.64–1.63)
≥ 20 years since completing residency	55 (53.9)	108 (47.0)	1.32 (0.83–2.11)	1.31 (0.80–2.13)
A mother with cysticercosis cannot be the cause of taeniasis in the infant				
Male gender	N = 84 52 (61.9)	N = 270 (194) 131 (48.5)	1.72 (1.05–2.85)‡	1.73 (0.99–3.00)
Non-CARN member	37 (44.1)	117 (43.3)	1.03 (0.63–1.69)	1.13 (0.67–1.90)
≥ 20 years since completing residency	43 (56.6)	117 (46.3)	1.52 (0.90–2.54)	1.30 (0.75–2.24)
If an infant or other family member is found to have cysticercosis, family members living together should be evaluated for taeniasis and cysticercosis				
Male gender	N = 244 136 (55.7)	N = 113 (106) 48 (42.5)	1.71 (1.09–2.68)‡	1.51 (0.92–2.48)
Non-CARN member	116 (47.5)	41 (36.3)	1.59 (1.01–2.52)‡	1.55 (0.95–2.51)
≥ 20 years since completing residency	122 (53.0)	42 (41.2)	1.61 (1.01–2.59)‡	1.47 (0.90–2.42)
Cysticercosis is a common cause of epilepsy in Latin America and areas of the United States with many Latin American immigrants				
Male gender	N = 146 78 (53.4)	N = 209 (192) 104 (49.8)	1.16 (0.76–1.77)	1.06 (0.66–1.68)
Non-CARN member	78 (53.4)	77 (36.8)	1.97 (1.28–3.02) §	1.77 (1.13–2.76)‡
≥ 20 years since completing residency	67 (50.0)	95 (48.5)	1.06 (0.69–1.65)	1.08 (0.68–1.72)
Cysticercosis diagnosis is best assisted by both serologic testing and CAT Scan/MRI				
Male gender	N = 124 70 (56.5)	N = 234 (123) 114 (48.7)	1.37 (0.88–2.11)	1.78 (1.10–2.90)‡
Non-CARN member	56 (45.2)	101 (43.2)	1.08 (0.70–1.68)	1.00 (0.63–1.59)
≥ 20 years since completing residency	49 (43.8)	115 (52.0)	0.72 (0.45–1.13)	0.60 (0.37–0.98)‡

(continued)

TABLE 3
Continued

Question or statement*	Correct response n (%)	Incorrect response (number "not sure") n (%)	OR (95% CI)	aOR† (95% CI)
Taeniasis may be treated with praziquantel or niclosamide	N = 15	N = 343 (220)		
Male gender	6 (40.0)	178 (51.9)	0.62 (0.22–1.77)	0.55 (0.18–1.72)
Non-CARN member	7 (46.7)	150 (43.7)	1.13 (0.40–3.17)	1.35 (0.46–3.98)
≥ 20 years since completing residency	9 (64.3)	155 (48.6)	1.91 (0.62–5.81)	2.30 (0.72–7.38)
Medications used to treat taeniasis can be given after the first trimester	N = 47	N = 309 (276)		
Male gender‡	31 (66.0)	153 (49.5)	1.04 (0.47–2.30)	1.24 (0.53–2.90)
Non-CARN member	19 (40.4)	136 (44.0)	8.50 (1.89–38.21)	9.04 (1.96–41.71)
≥ 20 years since completing residency	23 (52.3)	139 (48.4)	0.86 (0.46–1.61)	0.85 (0.44–1.62)
			1.17 (0.62–2.20)	0.91 (0.47–1.77)

CARN = Collaborative Ambulatory Research Network; CI = confidence interval; OR = odds ratio. Significant odds ratios are shown in bold.

*Missing responses excluded from denominator. Reference groups for the odds ratios are female gender, CARN member, and < 20 years since completing residency.

†Adjusted for gender, CARN status, and years since completing residency.

‡P < 0.05.

§P < 0.005.

¶Due to the effect modification of CARN status on gender with respect to the odds of correctly answering this question, ORs and Wald 95% CIs were calculated for the two levels of CARN membership. The SAS ODDS RATIO statement was used, which produces ORs and 95% confidence limits, but does not produce P values.

cysticercosis, persons living in the same household should be evaluated for taeniasis and cysticercosis (univariate OR = 1.71, $P < 0.05$), correctly identifying the combination of serologic testing and radiologic imaging as the best way to diagnose cysticercosis (multivariate OR = 1.78, $P < 0.05$), and, for non-CARN respondents only, correctly responding that medications used to treat taeniasis can be given after the first trimester (univariate OR = 8.50 [95% CI = 1.89, 38.21]; multivariate OR = 9.04 [95% CI = 1.96, 41.71]; P -values not calculated, see Table 3). Non-CARN membership was associated with correctly responding to the same questions described above in the comparison of response proportions (Table 3).

Practicing in a state in which cysticercosis is reportable was not significantly positively associated with answering any of the 12 knowledge questions correctly (data not shown). Practicing in a cysticercosis-reportable state was actually negatively associated with correctly answering eight of the 12 knowledge questions, although most of the associations were not significant. There was a significant inverse association between practicing in a cysticercosis-reportable state and knowing that taeniasis was caused by eating undercooked pork containing *T. solium* cysts (univariate OR = 0.53, $P < 0.05$) and knowing that the family members of someone found to have cysticercosis should be evaluated for taeniasis and cysticercosis (multivariate OR = 0.53, $P < 0.05$).

DISCUSSION

Overall, our study showed that knowledge of taeniasis and cysticercosis in practicing U.S. obstetrician-gynecologists is limited. The crude response data suggest some knowledge of taeniasis and cysticercosis, but also confusion about the life cycle and transmission of *T. solium* infection, and lack of knowledge of the diseases in the context of obstetrics. For example, a majority of respondents incorrectly indicated infected food handlers or household members with inadequate personal hygiene could be a source of both cysticercosis and taeniasis. Also, a majority of respondents incorrectly indicated that both taeniasis and cysticercosis could be caused by ingestion of eggs shed in human stools, ingestion of eggs shed in pig stools, or ingestion of undercooked pork. Overall, however, more responses were "not sure" rather than incorrect, which suggests a lack of information rather than misinformation.

Although there was confusion about the life cycle and transmission of *T. solium* infection, a majority of respondents recognized the role of household members in transmitting cysticercosis. Specifically, if someone in the household is found to have cysticercosis, all household members should be screened for taeniasis, and persons with compatible neurologic signs and symptoms should be evaluated for cysticercosis. Taeniasis is diagnosed via a stool ova and parasites test.^{4,32} Even with an experienced microscopist, the sensitivity of the ova and parasites test is low due to the variability in number of eggs excreted in the stool. A coproantigen enzyme-linked immunosorbent assay (ELISA) for *Taenia* spp. infection exists that is 2.6 times as sensitive as microscopy,^{4,32} but is not available in U.S. commercial and clinical laboratories. Similarly, a highly sensitive (95%) and specific (100%) serologic test specific to *T. solium*

was developed at the CDC, but is not approved for use in routine diagnostic testing.^{33,34} Neurocysticercosis is diagnosed with radiologic imaging with the assistance of a serologic test. The highly sensitive and specific enzyme-linked immunotransfer blot available at CDC is preferred to commercial ELISAs.⁶ Persons with taeniasis should be treated and follow-up testing of stool specimens should be performed to ensure the infection is cleared. Taeniasis and cysticercosis are preventable diseases. Not only pregnant women but all members of their households should consume only thoroughly cooked pork to prevent acquisition of taeniasis and practice good hand hygiene to prevent transmission of cysticercosis.

Four of the five questions with the highest percentage of "not sure" responses were those asking whether a pregnant woman can infect and cause taeniasis or cysticercosis in her infant, the drugs used to treat taeniasis, and whether those drugs are safe to use during pregnancy. Pregnant women with taeniasis can be treated with niclosamide or praziquantel after the first trimester to prevent the possibility of postpartum or intrapartum transmission of cysticercosis to newborn babies.^{19,35} Niclosamide and praziquantel kill the adult worms but not the eggs; therefore, a mild cathartic can be taken shortly after the anthelmintic to prevent continued release of infective eggs and proglottids from decaying adult worms left behind in the intestinal tract.³⁵ Niclosamide is not absorbed well and therefore may be safer to use during pregnancy than praziquantel, although both are U.S. Food and Drug Administration pregnancy category B drugs, which means they have shown no evidence of embryo toxicity in animal studies but for which there are insufficient data on their effect on human embryos.^{19,36} Niclosamide is generally not available for human use in the United States, although it may be available via select compounding pharmacies.³⁶ Praziquantel should only be administered if concurrent intracerebral neurocysticercosis has been ruled out via neuroimaging, since this drug also has cysticidal activity, which might lead to intracranial hypertension and seizures.^{37–39}

Our study did not assess physician knowledge about cysticercosis treatment during pregnancy, but treatment of pregnant symptomatic neurocysticercosis patients should be aimed at controlling the seizures and other symptoms of infection.^{23,24} Antiparasitic treatment with albendazole, a pregnancy category C drug, should be delayed until postpartum unless the clinical condition of the patient is severe enough to warrant its use.¹⁹ Praziquantel may also be used to treat cysticercosis, although it may not be as effective as albendazole.⁴⁰ Corticosteroids should be coadministered with albendazole and praziquantel to control the edema that can occur as a result of the immune response to the dying parasites.⁴¹ The decision about whether to treat symptomatic neurocysticercosis with antiparasitics is complex; an expert with experience managing this disease should be involved in the decision-making process.

The World Health Organization classifies albendazole, praziquantel, and niclosamide as compatible with breastfeeding, although the data on the use of anthelmintics during lactation are extremely limited.^{42,43} It is not known whether albendazole or niclosamide are excreted in breast-

milk, but small amounts of praziquantel are excreted in breastmilk and the Biltricide[®] package insert advises mothers to wait 72 hours after taking the dose before resuming breastfeeding.^{44,45}

Neurocysticercosis signs and symptoms can mimic those of eclampsia; therefore, a complete and continual evaluation of signs and symptoms should be conducted. Neuroimaging and risk factor analysis (e.g., country of origin of the patient) can differentiate neurocysticercosis from eclampsia.^{25,28,31}

We explored the response proportions by CARN membership to assess whether participating in periodic ACOG surveys about a variety of medical topics corresponded with having a wider breadth of knowledge about diseases and conditions that are not frequently encountered in daily OB/GYN clinical practice, like taeniasis and cysticercosis. CARN members did not correctly answer any of the knowledge questions significantly more frequently than non-CARN members, and the proportion of correct responses by CARN members was significantly less than that of non-CARN members for four questions. However, there were no significant differences by CARN status in knowing that a mother with taeniasis can be a source of cysticercosis in her infant, that is, via postpartum or intrapartum transmission. These data, along with a non-CARN response rate half that of the CARN rate, suggest a possible nonresponse bias toward more knowledgeable non-CARN respondents. That is, the non-CARN clinicians who responded to the survey, who were not obligated to participate in the survey like the CARN clinicians, may have included a higher proportion of respondents who were interested in or knowledgeable about taeniasis and cysticercosis.⁴⁶

Having 20 or more years since completing residency was significantly associated with answering three of the 12 questions correctly, including the best laboratory diagnostic method for taeniasis. However, having less than 20 years since completing residency was significantly associated with knowing the best laboratory diagnostic method for cysticercosis. This may reflect the status of cysticercosis as an emerging disease in the United States, with younger clinicians more likely to have learned about the disease in medical school and training. U.S. case reports of neurocysticercosis only began to increase with the development of radiologic imaging technologies beginning in the 1970s, and appear to be increasing as a result of more U.S. clinician encounters with patients who have immigrated from or have a recent history of travel to endemic countries.⁴⁷

Cysticercosis is not a nationally notifiable disease in the United States, but as of 2010, it was reportable in Arizona, California, New Mexico, Oregon, and Texas.‡ We examined the relationship between practicing medicine in one of these five states and correctly answering the knowledge questions. In our cohort, obstetrician-gynecologists

‡Despite the fact that taeniasis does not usually cause symptomatic disease, it is reportable in four of the six states in which cysticercosis is reportable as of 2016—Arizona, California, Oregon, and Texas—so that tapeworm carriers can be treated in order to prevent cysticercosis cases.

practicing in states where cysticercosis is not reportable were slightly more knowledgeable about taeniasis/cysticercosis than their counterparts in cysticercosis-reportable states. It is not necessarily surprising that practicing in a cysticercosis-reportable state did not correlate with having more knowledge about *T. solium* infection. Although physicians are provided with state reportable disease lists, they do not necessarily receive more education and training relating to diseases that are reportable in their states, particularly for diseases which are not commonly seen in their fields of practice.

Greater knowledge of taeniasis and cysticercosis among obstetrician-gynecologists is important as continued immigration of persons from endemic countries increase the chances that clinicians will encounter pregnant women with *T. solium* infection. Knowledge of the diseases and the parasite life cycle will be needed to offer safe and effective treatment and prevention messages to protect the health of mother and child, as well as to protect obstetrician-gynecologists and their staff from potential exposures to *T. solium* eggs.

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