Seroprevalence and correlates of Toxoplasma gondii infection in Yoremes (Mayos) in Mexico: a cross-sectional study

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ABSTRACT

Objectives: We sought to determine the prevalence of anti-Toxoplasma gondii antibodies in Yoremes and to identify associations of T. gondii exposure with sociodemographic, clinical and behavioural characteristics of Yoremes.

Design: A cross-sectional survey.

Setting: Yoremes were enrolled in the locality of Tierra Blanca in the municipality of Navojoa in Sonora State, Mexico.

Participants: We studied 200 Yoremes (Mayos); they are an indigenous ethnic group living in a coastal region in northwestern Mexico.

Primary and secondary outcome measures: We assessed the prevalence of anti-Toxoplasma IgG and IgM antibodies in participants using enzyme-linked immunosassays. We used a standardised questionnaire to obtain the characteristics of Yoremes. The association of T. gondii exposure and Yoremes’ characteristics was assessed by bivariate and multivariate analyses.

Results: Of the 200 Yoremes studied (mean age: 31.50±18.43 years), 26 (13.0%) were positive for anti-T. gondii IgG antibodies and 19 (73.1%) of them were also positive for anti-T. gondii IgM antibodies. Seroprevalence of T. gondii infection did not vary with sex, educational level, occupation or socioeconomic status. In contrast, multivariate analysis of sociodemographic and behavioural characteristics showed that T. gondii exposure was associated with increasing age (OR=1.02; 95% CI 1.00 to 1.04; p=0.03) and consumption of squirrel meat (OR=4.99; 95% CI 1.07 to 23.31; p=0.04). Furthermore, seroprevalence of T. gondii infection was significantly higher in Yoremes with a history of lymphadenopathy (p=0.03) and those suffering from frequent abdominal pain (p=0.03). In women, T. gondii exposure was associated with a history of caesarean sections (p=0.03) and miscarriages (p=0.02).

Conclusions: We demonstrate, for the first time, serological evidence of T. gondii exposure among Yoremes in Mexico. Results suggest that infection with T. gondii might be affecting the health of Yoremes.

INTRODUCTION

Toxoplasma gondii is a ubiquitous intracellular parasite. This parasite is currently infecting about one-third of humanity. Infection with T. gondii is usually asymptomatic. However, T. gondii disseminates after infection to many organs and may lead to disease in the eyes, lymph nodes and central nervous system. Furthermore, primary infection in T. gondii pregnant women is a threat for congenital toxoplasmosis. The main routes of T. gondii infection are ingestion of food or water contaminated with oocysts shed by cats and eating undercooked or raw meat containing tissue cysts.

The epidemiology of T. gondii infection in ethnic groups in Mexico has been poorly studied. Serological evidence of T. gondii infection has been demonstrated in

Strengths and limitations of this study

- This is the first cross-sectional study of Toxoplasma gondii infection in the Mexican ethnic group of Yoremes (Mayos).
- The seroprevalence of T. gondii infection was determined in Yoremes.
- Prevalence association with sociodemographic, clinical and behavioural characteristics of Yoremes was determined.
- The sample size was small and the seropositivity rate was low to perform a wider analysis of the association of T. gondii exposure and characteristics of Yoremes.

Results may be useful for an optimal design of preventive measures against T. gondii infection.
Mennonites, Tepehuano and Huicholes in the northern Mexican State of Durango. However, there is a lack of knowledge about the seroepidemiology of T. gondii infection in Yoremes or Mayos (an indigenous ethnic group living in a coastal region in the northwestern Mexican states of Sonora and Sinaloa). Yoremes live in rural communities and work mainly in agriculture and fishing. They live in a region with a climate that is different from those in other regions where other population groups in Mexico were studied for the seroepidemiology of T. gondii infection. The climate in the Yoremes’ region is desert-like or subtropical, and it is unclear whether this climate (or the food habits among Yoremes) may influence the seroprevalence of T. gondii. Indigenous people in Mexico, including the Yoremes, usually live in rural areas with a limited coverage of health services. The aims of the present study were to determine the seroprevalence of T. gondii in Yoremes and the association of T. gondii prevalence with the sociodemographic, clinical and behavioural characteristics of Yoremes.

**MATERIALS AND METHODS**

**Study design and Yoremes’ population studied**

Through a cross-sectional survey, we studied Yoremes in Sonora, Mexico, from January to June 2015. Yoremes were enrolled in the locality of Tierra Blanca in the municipality of Navojoa in Sonora State, Mexico. Tierra Blanca (27°19′N 109°34′W) is situated at an altitude of 25 m above sea level and has a desert-like climate and a mean annual temperature of 25.4°C. It Blanca has a mean annual rainfall of 266 mm. Inclusion criteria for the study participants were: (1) Yoremes’ ethnicity (people who speak the Yoremes’ language and identify themselves as Yoremes); (2) aged 12 years and older and (3) that they voluntarily accepted to participate.

**Sample size and sampling method**

We calculated the sample size using a two-sided confidence level of 95%, a power of 80%, a ratio of unexposed: exposed=1, a reference T. gondii seroprevalence of 22.4% in unexposed participants, and an OR of 2.6. The result of the calculation was 182 participants. We added a 5% for refusals and the final sample size was 198 participants. Sampling of Yoremes was performed by a convenience method. First, the authors met the Yoremes leaders to provide information about the study. After obtaining permission from the leaders, they invited the people they lead. Yoremes who accepted to participate in the study were gathered in two public places (a health centre and a high school) to provide a blood sample and submit a questionnaire. Since this strategy was not enough to reach the sample size, the authors visited homes in the community to enrol participants until the sample size was reached. This new strategy is not likely to influence the results since a minority of cases was obtained by this type of sampling. In total, 200 Yoremes were included in the study.

**Serological tests for anti-T. gondii antibodies**

We obtained a blood sample from each participant. Blood samples were centrifuged and serum samples were obtained. Sera were stored at −20°C until analysed. Serum samples were tested for anti-T. gondii IgG antibodies with the commercially available ‘Toxoplasma IgG’ (Diagnostic Automation Inc, Calabasas, California, USA) enzyme immunoassay (EIA). Anti-T. gondii IgG antibody levels were expressed as IU/mL, and a value ≥8 IU/mL was used as a cut-off for seropositivity. Sera positive for anti-T. gondii IgG antibodies were further analysed for anti-T. gondii IgM antibodies by the commercially available ‘Toxoplasma IgM’ (Diagnostic Automation Inc) EIA. The cut-off for anti-T. gondii IgM seropositivity for each assay was obtained by multiplying the mean cut-off calibrator optical density by a correction factor (f=0.35–0.40) printed on the label of the calibrator. All assays were performed following the manufacturer’s instructions, and positive and negative controls were included in each run.

**Statistical analysis**

Data were analysed with the aid of the software Epi Info V.3.5.4 and SPSS V.15.0. To avoid bias in the measure of associations, care was taken in obtaining all data about the characteristics of participants, and there were no missing data. We used Pearson’s $\chi^2$ test and Fisher’s exact test (when values were small) for initial comparison of the frequencies among groups. Multivariate analysis was used to assess the association between the sociodemographic and behavioural characteristics of Yoremes and the seropositivity to T. gondii. Only variables with a p value ≤0.10 obtained in the bivariate analysis were included in the multivariate analysis. This strategy allowed us to substantially reduce the number of variables in the analysis. OR and 95% CI were calculated by logistic regression using the stepwise backward method.
We used the Hosmer-Lemeshow goodness of fit test to assess the fitness of the regression model. Statistical significance was set at a p value <0.05.

RESULTS

Yoremes participating in the study had a mean age of 31.50 ± 18.43 years (range 12–83 years). Of the 200 Yoremes studied, 26 (13.0%) were positive for anti-T. gondii IgG antibodies. Of these 26 IgG-seropositive patients, 19 (73.1%) were also positive for anti-T. gondii IgM antibodies. Of the 26 anti-T. gondii IgG-positive Yoremes, 16 (61.5%) had IgG levels higher than 150 IU/mL and 10 (38.5%) between 24 and 45 IU/mL. A correlation of the sociodemographic characteristics of Yoresmes and T. gondii seroprevalence is shown in Table 1. Seroprevalence of T. gondii infection did not vary with sex, birthplace, residence, educational level, occupation or socioeconomic status of Yoremes (Table 1). In contrast, seroprevalence increased significantly with age (p = 0.005). With respect to anti-T. gondii IgM seropositivity among the 26 IgG-seropositive Yoremes, seroprevalence did not vary with age (p = 0.54), and seropositivity was found in 6 of 10 males and 13 of 16 females (p = 0.36).

With respect to clinical characteristics (Table 2), seroprevalence of T. gondii infection was significantly higher in Yoremes with a history of lymphadenopathy (p = 0.03) and those suffering from frequent abdominal pain (p = 0.03). In women, T. gondii exposure was associated with a history of caesarean sections (p = 0.03) and miscarriages (p = 0.02). Some clinical variables associated with T. gondii exposure may interact with each other, and no further regression analysis with these clinical variables was performed. The frequencies of other clinical characteristics including the presence of underlying diseases, suffering from frequent headaches, impairments in reflexes, hearing and vision, and a history of surgery, blood transfusion or transplant were similar among T. gondii-positive and T. gondii-negative Yoremes.

Concerning behavioural characteristics, a number of variables showed p values ≤0.10 in the bivariate analysis including consumption of goat and squirrel meat, raw dried meat, beef intestines and beef brains, and alcoholism. Other behavioural characteristics of Yoremes including contact with animals, travelling, consumption of meat other than that of goat and squirrel, frequency of meat consumption, degree of meat cooking, consumption of untreated water, unpasteurised milk, processed meat, unwashed raw vegetables or fruits, frequency of eating out of home, contact with soil, and type of flooring at home showed p values higher than 0.10 in the bivariate analysis. Multivariate analysis of sociodemographic and behavioural variables showed that T. gondii exposure was associated only with increasing age (OR = 1.02; 95% CI 1.00 to 1.04; p = 0.03) and consumption of squirrel meat (OR = 4.99; 95% CI 1.07 to 23.31; p = 0.04). An acceptable fit (p = 0.37) of our regression model was obtained in the Hosmer-Lemeshow test.

DISCUSSION

The epidemiology of T. gondii infection among ethnic groups in Mexico has been scantily studied. This work aimed to determine the seroprevalence and correlates of T. gondii infection in an indigenous ethnic group (Yoremes) in northwestern Mexico. We found a 13.0% seroprevalence of T. gondii infection in Yoremes. To the best of our knowledge, there are no previous reports of T. gondii exposure in this ethnic group. The seroprevalence found in Yoremes is lower than seroprevalences of T. gondii infection reported in other ethnic groups in the northern Mexican state of Durango: seroprevalences of 22.4%, 30.3% and 33.2% have been reported in Tepelahuanos, Mennonites and Huicholes, respectively. The lower prevalence of T. gondii exposure in Yoremes than in Tepelahuanos, Mennonites and Huicholes might be explained by differences in their environment or behavioural difference. Seroprevalence of T. gondii infection may be influenced by environment conditions with a high seroprevalence in humid regions and a low seroprevalence in dry and hot regions. Tepelahuanos and Huicholes live in remote communities in a mountainous region (Sierra Madre Occidental) and Mennonites in a Valley region, whereas Yoremes live in a desert region at low altitude. Very little is known about the seroprevalence of T. gondii infection in population groups living in a desert climate. In a study in Niamey, Niger researchers showed that prevalence of toxoplasmosis was higher in humid coastal regions than in dry desert areas. Seroprevalence of T. gondii infection increased with age. This finding might be related to differences in sanitation and hygiene among generations. Poor sanitation and hygiene have been linked to T. gondii infection in the indigenous population in Brazil. Improvement of these epidemiological factors may result in the lowering of seroprevalence of T. gondii exposure in younger generations. We did not include minor (younger than 12 years) participants in this study because the frequency of T. gondii infection in young people is usually very low. We also analysed associations with factors other than the environment. Seroprevalence was found to increase with age, consistent with previous reports in rural and urban populations in northern Mexico. The mean age (31.50 years) in Yoremes was similar to that in Tepelahuanos (31.03 years). However, the mean age in Yoremes was lower than the one (37.98 years) in Huicholes and that (38.4 years) in Mennonites.

Multivariate analysis also showed an association of T. gondii exposure with consumption of squirrel meat. In two previous studies in the general population in rural and urban Durango, consumption of squirrel meat was also associated with T. gondii exposure. These findings show the importance of consumption of squirrel meat in the transmission of T. gondii infection in the region. Although squirrel meat is usually cooked before eating, failure to obtain a thorough cooking may occur specially for thick pieces of meat. Yoremes usually grill the
squirrel meat, and this process may result in an uneven cooking. In addition, tasting of raw or undercooked meat while grilling might occur. Tasting of fresh raw meat was linked to toxoplasmosis in Italy.\textsuperscript{18} Serological evidence of \textit{T. gondii} infection has been demonstrated in squirrels.\textsuperscript{19} In addition, \textit{T. gondii} has been detected in organs of Korean squirrels (\textit{Tanius sibericus})\textsuperscript{20} and grey squirrels (\textit{Sciurus carolensis})\textsuperscript{21} with fatal toxoplasmosis. We previously investigated the presence of \textit{T. gondii} in animals in Durango but were unable to detect anti-\textit{T. gondii} antibodies in 69 squirrels (\textit{Spermophilus variegatus})\textsuperscript{22} collected. However, we cannot rule out \textit{T. gondii} infection in squirrels in the region because the sample size was small and infection might occur in other squirrel species than the one studied. Further research about the epidemiological link of \textit{T. gondii} infection and consumption of squirrel meat including the search for \textit{T. gondii} in squirrels should therefore be conducted.

Intriguingly, in this study, we found an association of \textit{T. gondii} exposure with abdominal pain, history of lymphadenopathy, caesarean sections and miscarriages. It is well known that \textit{T. gondii} infection is a cause of lymph node enlargement and miscarriages.\textsuperscript{2} 4 In contrast, \textit{T. gondii} infection is not typically associated with abdominal pain, but abdominal pain has been reported in gastric toxoplasmosis in patients with AIDS.\textsuperscript{23} 24 We also found an association of \textit{T. gondii} infection with a history of caesarean section. It is not clear why women with caesarean sections had a higher seroprevalence of \textit{T. gondii} infection than those without this history. Interestingly, in a study of women with stillbirths in Durango, Mexico, \textit{T. gondii} exposure was associated with a history of surgery.\textsuperscript{25} It raises the question whether a specific type of surgery as caesarean section or a specific population group as women might have a higher risk of \textit{T. gondii} exposure than others. We did not investigate the indications for the caesarean sections or the health status of the children born by this surgical procedure, and this was a limitation of the study. Several factors could be considered to explain \textit{T. gondii} infections in women with caesarean sections. Congenital toxoplasmosis may precipitate not just early delivery or induction of delivery, but it may also prompt caesarean section.\textsuperscript{26}–\textsuperscript{28} In addition, the use of contaminated surgical instruments or materials during caesarean sections cannot be ruled out. Blood transfusion is relatively common in surgical patients, and infection with \textit{T. gondii} by blood transfusion may also occur.\textsuperscript{29} Further research about the association of \textit{T. gondii} infection and caesarean section and other surgical procedures should be conducted.

In this work, anti-\textit{T. gondii} IgM antibodies were present in a relatively high number of anti-\textit{T. gondii} IgG-positive

| Characteristic                        | Participants tested | Prevalence of \textit{T. gondii} infection |
|--------------------------------------|---------------------|------------------------------------------|
|                                      | Number              | Number | Percentage | p Value |
| Age groups (years)                   |                     |        |            |         |
| 30 or less                           | 124                 | 9      | 7.3        | 0.005   |
| 31–50                                | 38                  | 7      | 18.4       |         |
| >50                                  | 38                  | 10     | 26.3       |         |
| Sex                                   |                     |        |            |         |
| Male                                 | 77                  | 10     | 13.0       | 0.99    |
| Female                               | 123                 | 16     | 13.0       |         |
| Birthplace                           |                     |        |            |         |
| Sonora state                         | 198                 | 26     | 13.1       | 1       |
| Other Mexican state or abroad        | 2                   | 0      | 0.0        |         |
| Residence area                       |                     |        |            |         |
| Rural                                | 184                 | 22     | 12.0       | 0.13    |
| Urban                                | 16                  | 4      | 25.0       |         |
| Educational level                    |                     |        |            |         |
| No education                         | 6                   | 1      | 16.7       | 0.33    |
| 1–6 years                            | 32                  | 7      | 21.9       |         |
| 7–12 years                           | 144                 | 15     | 10.4       |         |
| >12 years                            | 18                  | 3      | 16.7       |         |
| Occupation                           |                     |        |            |         |
| Labourer*                            | 43                  | 8      | 18.6       | 0.21    |
| Non-labourer†                        | 157                 | 18     | 11.5       |         |
| Socioeconomic level                  |                     |        |            |         |
| Low                                  | 111                 | 19     | 17.1       | 0.15    |
| Medium                               | 88                  | 7      | 8.0        |         |
| High                                 | 1                   | 0      | 0.0        |         |

*Labourer: agriculture, business, construction, livestock raising, professional, other.
†Non-labourer: student or housekeeping.
Yoremes compared with previous studies. This finding should be interpreted with caution because positive results in IgM tests may indicate persistent IgM antibodies rather than acute infection.\textsuperscript{30} We did not test all participants for anti-\textit{T. gondii} IgM antibodies. Only IgG-positive patients were tested because a high number of false-positive results for IgM have been reported when using immunoassays.\textsuperscript{30} Therefore, a positive IgM test with a negative IgG test has a limited usefulness for drawing diagnostic and epidemiological conclusions.

The small sample size and the low rate of seropositivity were limitations of the study. These factors did not allow us to perform a wider analysis of the association of \textit{T. gondii} exposure and the characteristics of Yoremes. Reaching the sample size of Yoremes was challenging. However, the strategy to enrol participants by visiting

### Table 2: Bivariate analysis of clinical data and infection with \textit{Toxoplasma gondii} in Yoremes

| Characteristic                  | Participants tested | Prevalence of \textit{T. gondii} infection |
|--------------------------------|---------------------|-------------------------------------------|
|                                | Number              | Number | Percentage | p Value |
| Clinical status                |                     |        |            |         |
| Healthy                        | 170                 | 19     | 11.2       | 0.08    |
| Ill                            | 30                  | 7      | 23.3       |         |
| Lymphadenopathy ever           |                     |        |            |         |
| Yes                            | 57                  | 12     | 21.1       | 0.03    |
| No                             | 143                 | 14     | 9.8        |         |
| Abdominal pain frequently      |                     |        |            |         |
| Yes                            | 51                  | 11     | 21.6       | 0.03    |
| No                             | 149                 | 15     | 10.1       |         |
| Headache frequently            |                     |        |            |         |
| Yes                            | 54                  | 10     | 18.5       | 0.15    |
| No                             | 146                 | 16     | 11         |         |
| Memory impairment              |                     |        |            |         |
| Yes                            | 28                  | 5      | 17.9       | 0.37    |
| No                             | 172                 | 21     | 12.2       |         |
| Dizziness                      |                     |        |            |         |
| Yes                            | 46                  | 6      | 13         | 0.99    |
| No                             | 154                 | 20     | 13         |         |
| Reflexes impairment            |                     |        |            |         |
| Yes                            | 23                  | 5      | 21.7       | 0.19    |
| No                             | 177                 | 21     | 11.9       |         |
| Hearing impairment             |                     |        |            |         |
| Yes                            | 16                  | 1      | 6.3        | 0.70    |
| No                             | 184                 | 25     | 13.6       |         |
| Visual impairment              |                     |        |            |         |
| Yes                            | 45                  | 8      | 17.8       | 0.27    |
| No                             | 155                 | 18     | 11.6       |         |
| Surgery ever                   |                     |        |            |         |
| Yes                            | 55                  | 10     | 18.2       | 0.18    |
| No                             | 145                 | 16     | 11         |         |
| Blood transfusion              |                     |        |            |         |
| Yes                            | 15                  | 4      | 26.7       | 0.11    |
| No                             | 185                 | 22     | 11.9       |         |
| Pregnancies                    |                     |        |            |         |
| Yes                            | 71                  | 12     | 16.9       | 0.17    |
| No                             | 52                  | 4      | 7.7        |         |
| Deliveries                     |                     |        |            |         |
| Yes                            | 51                  | 8      | 15.7       | 0.45    |
| No                             | 72                  | 8      | 11.1       |         |
| Caesarean sections             |                     |        |            |         |
| Yes                            | 23                  | 6      | 26.1       | 0.03    |
| No                             | 100                 | 10     | 10         |         |
| Miscarriages                   |                     |        |            |         |
| Yes                            | 16                  | 5      | 31.3       | 0.02    |
| No                             | 107                 | 11     | 10.3       |         |
| Stillbirths                    |                     |        |            |         |
| Yes                            | 6                   | 1      | 16.7       | 0.57    |
| No                             | 117                 | 15     | 12.8       |         |
suggest that infection with T. gondii may be associated with specific food habits and health conditions. The optimal design of preventive measures against T. gondii infection should take our findings into consideration.

CONCLUSIONS

We demonstrate, for the first time, serological evidence of T. gondii exposure among Yoremes in Mexico. Results suggest that infection with T. gondii may be associated with specific food habits and health conditions. The optimal design of preventive measures against T. gondii infection should take our findings into consideration.

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Contributors CA-E, AR-C, MAGC-M and MLA-M designed the study protocol and participated in the coordination and management of the study. AR-C, MAGC-M, GJA-B and ADN-A obtained blood samples, submitted the samples for analysis and performed the data analysis. CA-E performed the laboratory tests. CA-E, JH-T, LFS-A, AR-C, MAGC-M, MLA-M and OL performed the data analysis and wrote the manuscript.

Funding Universidad Juárez del Estado de Durango.

Competing interests None declared.

Patient consent Obtained.

Ethics approval The Institutional Ethical Committee of the University of Sonora, Mexico approved this study. The purpose and procedures of the survey were explained to all Yoremes. Participation in the study was voluntary. Written informed consent was obtained from all participants and from the next of kin of minor participants.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

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REFERENCES

1. Smith JE. A ubiquitous intracellular parasite: the cellular biology of Toxoplasma gondii. Int J Parasitol 1995;25:1301–9.
2. Dubey JP. Toxoplasmosis of animals and humans. 2nd edn. Boca Raton, FL: CRC Press, 2010.
3. Hill DE, Chirukandoth S, Dubey JP. Biology and epidemiology of Toxoplasma gondii in man and animals. Anim Health Res Rev 2005;6:41–61.
4. Montoya JG, Liesenfeld O. Toxoplasmosis. Lancet 2004;363:1965–76.
5. Harker KS, Ueno N, Lodoen MB. Toxoplasma gondii dissemination: a parasite’s journey through the infected host. Parasite Immunol 2015;37:141–9.
6. Maenz M, Schlüter D, Liesenfeld O, et al. Ocular toxoplasmosis past, present and new aspects of an old disease. Prog Retin Eye Res 2014;39:77–106.
7. Oz HS. Maternal and congenital toxoplasmosis, currently available and novel therapies in horizon. Front Microbiol 2014;5:385.
8. Weiss LM, Dubey JP. Toxoplasmosis: a history of clinical observations. Int J Parasitol 2009;39:895–901.
9. Alvarado-Esquivel C, Rojas-Rivera A, Estrada-Martínez S, et al. Seroepidemiology of Toxoplasma gondii infection in a Mennonite community in Durango State, Mexico. J Parasitol 2010;96:941–5.
10. Alvarado-Esquivel C, Estrada-Martínez S, García-López CR, et al. Seroepidemiology of Toxoplasma gondii infection in Tepehuanos in Durango, Mexico. Vector Borne Zoonotic Dis 2012;12:138–42.
11. Alvarado-Esquivel C, Pacheco-Vega SJ, Hernández-Tinoco J, et al. Seroreplication of Toxoplasma gondii infection and associated risk factors in Huicholes in Mexico. Parasit Vectors 2014;7:301.
12. Juzel J, Magnaval JF, Meynard D, et al. Seroepidemiology of toxoplasmosis in Niamey, Niger. Med Trop (Mars) 1996;56:48–50.
13. Markovich MP, Shohat T, Ritkis I, et al. Seroepidemiology of Toxoplasma gondii infection in the Israeli population. Epidemiol Infect 2014;142:149–55.
14. Bóia MN, Carvalho-Costa FA, Sodré FC, et al. Seroreplication of Toxoplasma gondii infection among Indian people living in lauareté, São Gabriel da Cachoeira, Amazonas, Brazil. Rev Inst Med Trop Sao Paulo 2006;48:17–20.
15. Alvarado-Esquivel C, Cruz-Magallanes HM, Esquivel-Cruz R, et al. Seroepidemiology of Toxoplasma gondii infection in human adults from three rural communities in Durango State, Mexico. J Parasitol 2008;94:81–16.
16. Alvarado-Esquivel C, Estrada-Martínez S, Pizarro-Villabobos H, et al. Seroepidemiology of Toxoplasma gondii infection in general population in a northern Mexican city. J Parasitol 2011;97:40–3.
17. Alvarado-Esquivel C, Liesenfeld O, Burciaga-López BD, et al. Seroepidemiology of Toxoplasma gondii infection in elderly people in a northern Mexican city. Vector Borne Zoonotic Dis 2012;12:568–74.
18. Vitale M, Tumino G, Partanna S, et al. Impact of traditional practices on food safety: a case of acute toxoplasmosis related to the consumption of contaminated raw pork sausage in Italy. J Food Prot 2014;77:843–6.
19. Smith DD, Frenkel JK. Prevalence of antibodies to Toxoplasma gondii in wild mammals of Missouri and east central Kansas: biologic and ecologic considerations of transmission. J Wildl Dis 1995;31:15–21.
20. Carrasco L, Raya AI, Nuñez A, et al. Fatal toxoplasmosis and concurrent Caudium hepaticum infection in Korean squirrels (Tanias sibericus). Vet Parasitol 2006;137:180–3.
21. Dubey JP, Hodgkin EC, Hamir AN. Acute fatal toxoplasmosis in squirrels (Sorex cerei) with bradyzoites in visceral tissues. J Parasitol 2006;92:658–9.
22. Dubey JP, Velmurugan GV, Alvarado-Esquivel C, et al. Isolation of Toxoplasma gondii from animals in Durango, Mexico. J Parasitol 2009;95:319–22.
23. Alpert L, Miller M, Alpert E, et al. Gastric toxoplasmosis in acquired immunodeficiency syndrome: antemortem diagnosis with histopathologic characterization. Gastroenterology 1996;110:258–64.
24. Ganji M, Tan A, Maitar ML, et al. Gastric toxoplasmosis in a patient with acquired immunodeficiency syndrome. A case report and review of the literature. Arch Pathol Lab Med 2003;127:732–4.
25. Alvarado-Esquivel C, Pacheco-Vega SJ, Salcedo-Jaquez M, et al. Stillbirth history and Toxoplasma gondii infection in women attending public health centers in a northern Mexican City. Eur J Microbiol Immunol (Bp) 2015;5:164–71.
26. Freeman K, Oakley L, Pollak A, et al. European Multicentre Study on Congenital Toxoplasmosis. Association between congenital toxoplasmosis and preterm birth, low birthweight and small for gestational age birth. BJOG 2005;112:31–7.
27. Nishikawa A, Yamada H, Yamamoto T, et al. A case of congenital toxoplasmosis whose mother demonstrated serum low IgA avidity and positive tests for multiplex-nested PCR in the amniotic fluid. J Obstet Gynaecol Res 2009;35:372–8.
28. Sato S, Nishida M, Nasu K, et al. Congenital toxoplasmosis from a mother with type 2 diabetes mellitus: a case report. J Obstet Gynaecol Res 2014;40:2158–61.
29. Alvarado-Esquivel C, Liesenfeld O, Márquez-Conde JA, et al. Seroepidemiology of infection with Toxoplasma gondii in workers occupationally exposed to water, sewage, and soil in Durango, Mexico. J Parasitol 2010;96:847–50.
30. Liesenfeld O, Press C, Montoya JG, et al. False-positive results in immunoglobulin M (IgM) Toxoplasma antibody tests and importance of confirmatory testing: the Platelia Toxo IgM test. J Clin Microbiol 1997;35:174–8.