Sero-epidemiology and risk factors for *Toxoplasma gondii* among pregnant women in Arab and African countries

Mohamed Alkhatim Alsammani

Received: 1 June 2014 / Accepted: 31 August 2014 / Published online: 20 September 2014
© Indian Society for Parasitology 2014

Abstract The epidemiology of toxoplasmosis in pregnancy is a major issue for public health. Primary infection in pregnant women can lead to serious sequelae. This review examined current sero-epidemiology and risks factor data for *Toxoplasma gondii* in pregnant women in Arab and African countries. A systematic electronic search of published literature was conducted. Data were extracted from relevant studies. Seropositivity is high in both regions. African countries have higher seropositivity than Arab countries due to differences in risk factors. Data on *T. gondii* infection in pregnancy are scant in many countries, especially where there is lack of political stability. Identified risk factors included eating raw meat, proximity with cats, undercooked food, and increasing maternal age. Toxoplasmosis in pregnancy in Arab and African countries is an underestimated health problem. Further research is needed. This report is a foundation for strategies and policies for intervention needed to combat the consequences of congenital toxoplasmosis.

Keywords *Toxoplasma gondii* · Sero-epidemiology · Congenital · Risk factors · African · Arab

Introduction

Toxoplasma gondii is an obligate single-celled intracellular protozoan parasite that infects all warm-blooded animals. It

causes toxoplasmosis, which is one of the most common human infections. It has been estimated that about one-third of the world's population is infected with *T. gondii* (Tenter et al. 2000).

Humans are infected through ingestion of sporulated oocysts in raw or undercooked meat, contact with cat feces, from soil, and from ingesting contaminated food or water (Hill and Dubey 2002). Other rare causes of transmission included transplacental transmission to the fetus, and through organ transplant from infected donors (Montoya and Liesenfeld 2004).

Immune status plays important role in the course of the parasite. In immunocompetent subjects, the disease is asymptomatic or there may be mild and transient symptoms such as fever, malaise, and lymphadenopathy. Fatal complications including encephalitis and disseminated toxoplasmosis have been reported in subjects with immunodeficiency, such as in patients with AIDS, transplant recipients, and people on immunosuppressive therapy (Luft and Remington 1992; Dubey et al. 2012; Weiss and Dubey 2009).

Mothers who acquired *T. gondii* at a distant time before pregnancy have a limited risk of congenital infection. On the other hand, women who become infected shortly before conception or during the first trimester are capable of transmitting the infection to their fetuses (Vogel et al. 1996; Cook et al. 2000). The degree of severity of congenital toxoplasmosis is inversely related to gestational age at the time of infection. During the first trimester, the transmission rate is low but the infection will result in severe congenital toxoplasmosis. Late infection is characterized by high transmission but less fetal morbidity (Lopez et al. 2000; Martin 2001; Dunn et al. 1999).

A wide range of adverse pregnancy outcomes has been described including spontaneous miscarriage or stillbirth. Congenital toxoplasmosis in an infant following

---

M. A. Alsammani (✉)
Department of Obstetrics and Gynecology, College of Medicine,
Qassim University, P.O. Box 665, Buraidah 51452, Kingdom of
Saudi Arabia
e-mail: m_sammani@yahoo.com

M. A. Alsammani
College of Medicine, Bahri University, Khartoum, Sudan

transplacental transmission can lead to a wide range of morbidity and mortality including neurologic and neuro-cognitive deficits and chorioretinitis (Jones et al. 2001). Complications can include failure to thrive, hydrocephalus or microcephalus, cerebral calcifications, or symptoms of CNS involvement later in life (Weiss and Dubey 2009; Tammam et al. 2013; Hide et al. 2009). Severe postpartum myonecrosis can result from co-infection with *Toxoplasma gondii* and *Clostridium perfringens* (Alsammani et al. 2012).

There is a wide disparity in the incidence of congenital toxoplasmosis in the developed countries, ranging between 1 and 10 per 10,000 live births. A rate of 0.8/10,000 was reported in the United States (Guerina 1994). Higher rates were reported in the United Kingdom (3.4/10,000) (Gilbert et al. 2006) and Denmark (4/10,000) (Lebech et al. 1999).

Serological testing for anti-toxoplasma antibodies is widely used for the diagnosis of toxoplasmosis (Remington et al. 2001). Yet, the diagnosis remains a challenge to health care providers. In pregnancy, it is essential to perform conclusive tests that must include PCR, IgA, IgG avidity test, and IgE, on individuals with both positive IgG and IgM (Pereira et al. 2010; Wilson et al. 2003), because toxoplasma-specific IgM antibodies may persist as long as 18 months after acute acquired infection (Pereira et al. 2010). However, biopsy, which is very specific, should be reserved for selective cases, especially in pregnancy, as it is an invasive procedure.

In Arab and African countries, data on *T. gondii* infection during pregnancy is scant. Moreover, most studies are regional. Pregnant women are not routinely investigated for *T. gondii* during pregnancy, and follow-up does not exist. Thus, the current review examined the current knowledge state on sero-epidemiology and possible risk factors of *T. gondii* in pregnant women in Arab and African countries.

Methodology

A systematic electronic search of published data was conducted. The search was performed using the Qassim University academic digital library which encompasses many global data base for both books and electronic journals including PubMed, Medline, EBSCO, Elsevier, ProQuest Central, Ovid e-Journal, Oxford Journals, Oxford Scholarship Online, Science Direct, Wiley-Blackwell e-Journals, and Springer Online Journals. In addition, search engines Google (<http://www.google.com>) and Google scholar (<http://www.scholar.google.com/>) were used. There are 59 Arab and African countries (see Tables 1, 2). The following search terms were used: *Toxoplasma gondii*, pregnancy, risk factors, seroprevalence, Arab, Middle East, Africa, and individual country names. Relevant data were extracted from studies. There was no search restriction. We also expanded the search for country-specific data on

seropositivity to toxoplasma among women of reproductive age and in the general population in some cases.

The Arab world comprises 22 culturally diverse member states with variable levels of economic development and a combined population of about 340 million people. In the Gulf region, there is a tendency towards decentralization of health care delivery management, autonomy of health facilities, and adoption of advanced methods of health services. In contrast, in African and African Arab countries there is a lack of distribution of facilities for economic and political reasons, bureaucracy and hierarchy, lack of knowledge, and lack of basic skills among health systems (Elsheikha et al. 2009).

For geographical and social similarity, and simplicity for this report, we divided the Arab countries into 4 regions: Arabian Peninsula, Bilad Alsham, North African, and Nile River regions. The data are shown in Table 1.

In Africa, many studies were performed in early 1990s to assess the prevalence of *Toxoplasma gondii* in pregnant women, but there was no follow-up even for the general population. Most of the African countries suffer from drought, political conflicts, and famine, causing massive population displacement. This displacement may perhaps lead to lack of studies and lack of follow-up data on *T. gondii* in these countries. Generally, the disease is thought to be endemic; a seroprevalence as high as 92.5 % has been reported in the general population (Ayi et al. 2009), and fortunately, few pregnant women acquire the infection during pregnancy (Nowakowska et al. 2006). In these countries, the burden of *T. gondii* infection in pregnant women is an under-estimated public health concern.

For the purpose of cultural and geographical similarity, we have divided Africa into five geographical regions: the Northern, Southern, Eastern, Western, and Central Regions. The Northern region is entirely occupied by the Arab states, shown in Table 1. The rest of the data are shown in Table 2.

Results

Toxoplasma gondii in pregnant women in the Arabian peninsula region

The Arabian Peninsula region is the most distinct geographical area, comprising about 35 % of the Arab world, and the world's largest single source of crude oil.

Previous studies have shown a seropositivity rate in this region ranging from 22.9 to 58.2 % (Shawky and Soliman 2001; Dar et al. 1997; Al-Nakib et al. 1983). More detailed study taking into consideration rate from previous data

Table 1 Seroprevalence of *Toxoplasma gondii* infection among pregnant women in Arab countries

Country	Sample size	Region	Assay	IgG (%)	Reference
Arabian Peninsula region					
Saudi Arabia	2,176	Al Ahsa	ELISA	51.4	Al-Mohammad et al. (2010)
Qatar		Doha	ELISA	29.8	Abu-Madi et al. (2008)
Qatar	1,857	Doha	ELISA	35.1	Abu-Madi et al. (2010)
UAE	2,343		IFA	24.2	Singh (1998)
Kuwait	573	Kuwait	PHAT	58.2	Al-Nakib et al. (1983)
Oman	NA	Oman	ELISA	42.3	Elbualy et al. (1996)
Yemen	NA	Taiz	ELISA	32.5	Saleh et al. (2010)
Bilad Sham region					
Iraq	254	Ramadi	ELISA	38.4	Mohammad et al. (2012)
Syria	260	Damascus	ELISA	23.48	Al-Mendalawi and Barah (2011)
Lebanon	232		ELISA	62	Szenasi et al. (1997)
Jordan	280	Amman	IFA	31.7	Jumaian (2005)
Gaza strip	1,954	Gaza	ELISA	7.9	Al-Hindi et al. (2010)
Nile River region					
Egypt	323	Menoufia	ELFA,	67.5	El Deeb et al. (2012)
Sudan	487	Khartoum	ELISA	34.1	Elnahas et al. (2003)
North African region					
Libya	143	Tripoli	ELISA	45	Mousa et al. (2011)
Tunis	2,351	Tunisia	ELISA	47.7	Fakhfakh et al. (2013)
Algeria	1,028	Annaba	ELISA	47.8	Messerer et al. (2014)
Morocco	2,456	Morocco	ELISA	50.6	El Mansouri et al. (2007)

demonstrated a similar range of seroprevalence among pregnant women ranging from 25 % in 1989 to 51.4 % in 2010 (Pappas et al. 2009; al-Meshari et al. 1989). In Saudi Arabia, there is a great regional variation in the seropositivity rate, in Aseer (Al-Mohammad et al. 2010), Riyadh (Bin Dajem and Almushait 2012), Al Ahsa (al-Meshari et al. 1989), Jeddah (Almogren 2011) and in the Eastern Province (Al-Mulhim and Al-Qurashi 2001) were 41, 38, 54.4, 61.4 and 39.4 %, respectively.

UAE (Shawky and Soliman 2001) showed the lowest seropositivity in the Arabian Peninsula (22.9 %), despite the fact that there is a high density of *Felis margarita* with high seropositivity rate. In Qatar, a study that examined seropositivity in the general population demonstrated a rate of 29.8 % (Abu-Madi et al. 2010). In the other Arabs peninsula countries, seropositivity rates were lower, except for Kuwait (45.7 %) (Jones et al. 2007; Mosti et al. 2013; Flatt and Shetty 2013; Lopes et al. 2012).

Bilad Sham region

This is the most publically unstable part of the Arab world. Countries in this region have a lower prevalence of

Toxoplasma gondii ranging from 23.48 to 38.4 % with the exception of Lebanon which showed a 62 % seropositivity rate among pregnant women (Barah 2011; Bouhamdan et al. 2010). There was no follow-up data.

North African (Maghreb) region

The seroprevalence of *Toxoplasma gondii* in this region is high compared to other Arab countries and is comparable to seropositivity in African countries, ranging from 45 to 50.6 %. Follow-up data is available from Tunisia which showed many regional studies with different seropositivity rates. In one study the prevalence rate in Tunisia was 47.7 % (Bouratbine et al. 2001). In another study 10 years later a higher rate of 58.4 % was reported (Fakhfakh et al. 2013), indicating that *T. gondii* may be on the rise whereas in other countries there is no follow-up data. The rate in Algeria, Morocco and Libya were 47.8, 50.6, 63.3 %, respectively (Kassem and Morsy 1991).

Arabian Nile River region

Toxoplasma gondii infection among pregnant women has been extensively studied in Egypt, and results showed a

Table 2 Seroprevalence of *Toxoplasma gondii* infection among pregnant women in African countries

Country	Sample size	Region	Assay	Seroprevalence IgG (%)	Reference
Eastern					
Ethiopia	201	Jimma	ELISA	83.6	Zemene et al. (2012)
Madagascar	599	Antananarivo	ELISA	83.5	Lelong et al. (1995)
Tanzania	350	Mwanza	ELISA	30.9	Mwambe et al. (2013)
Eritrea, Burundi, Djibouti, Kenya, Mozambique, Rwanda, Malawi, Somalia, South Sudan, Uganda, Zimbabwe Zambia, the Seychelles—no data found					
Southern					
Botswana			ELISA	11	Jacobs and Mason (1978)
South Africa	2,308	Cape town	ELISA	22.3	Capretti et al. (2014)
Angola, Lesotho, Malawi, Namibia, Swaziland—no data found					
Central					
Congo	2,897	Congo	ELISA	60	Makuwa et al. (1992)
Rwanda	NA	Rwanda (rural)	ELISA	50	Gascon et al. (1989)
Central Africa Republic	1,953	Bangui	ELISA	50.6	Morvan et al. (1999)
Burundi, Chad, Equatorial Guinea, Gabonese Republic, and São Tomé and Príncipe—no data found					
Western					
Gabon	767	Gabon	ELISA	71	Nabias et al. (1998)
Mali	760	Mali	HAT	27	Ouologuem et al. (2013)
Benin	113	Benin	ELISA	53.6	Rodier et al. (1995)
Senegal	70	Guediawaye	ELISA	40	Ndir et al. (2004)
Nigeria	352	Lagos	ELISA	78	Onadeko et al. (1992)
Côte d'Ivoire	1,025	Abidjan	IFT	60	
Guinea	197	Port Moresby	ELISA	18	Klufio et al. (1993)
Uganda	130	Uganda	ELISA	54	Lindstrom et al. (2006)
Cameroon	192	Yaounde	ELISA	77.1	Ndumbe et al. (1992)
Kenya	94	Nairobi	ELISA	54	Brindle et al. (1991)
Angola	707	Angola	ELISA	71.43	Lopez et al. (1992)
Sao Tome and Principe	499	DRSTP	ELISA	75.2	Hung et al. (2007)
Somalia	NA	Mogadishu.	ELISA	56	Ahmed et al. (1988)
Zambia				54	Watts et al. (1984)
Zimbabwe	NA			18.7	Watts et al. (1984)
Burkina Faso, Cape Verde, Gambia, Ghana, Guinea-Bissau, Togo, Liberia, Mauritania, Niger, Sierra Leone—no data found					

high prevalence among the general population and pregnant women. We found a seropositivity rate of 46.1 % among women with first trimester miscarriage (Tammam et al. 2013). Another study evaluating prevalence among pregnant women in Egypt showed rate of 72.61 % (El Deeb et al. 2012). In Sudan, where the disease is not well studied, Elnahas et al. (2003) in 2003 reported a rate of 34.1 % among pregnant women, which is comparatively lower than reports from Egypt. Generally, the prevalence of *T. gondii* in Egypt is similar to rates from central Africa. This high seropositivity rate in Egypt may be due to high environmental contamination with *T. gondii* oocytes from rats (97.4 %) (Remington et al. 2001), in addition to inadequate hygiene, and suitable climatic factors for survival of oocytes.

Seroepidemiology of *Toxoplasma gondii* among pregnant women in African countries

Eastern region

For many years, this region has been one of the most unstable areas with racial conflicts. Prevalence of *Toxoplasma gondii* in pregnant women in the region is similar to seroprevalence among the general population. Most countries fall in high endemic zone ranges from 44 to 85 % (Ahmed et al. 1988; Gebremedhin et al. 2013; Lelong et al. 1995).

The highest seropositivity rate in this region in was reported from Madagascar (Lelong et al. 1995) followed by Ethiopia (Gebremedhin et al. 2013), Zambia (Watts et al. 1984), Zimbabwe (Watts et al. 1984), 85, 81.4, 54, and

18.7 %, respectively. There is little information on toxoplasma in both pregnancy and the general population in this region.

Southern region

The southernmost region of the African sub-continent is famous for the export of diamonds and platinum; it is the most political stable part of Africa. The seroprevalence of *Toxoplasma gondii* in this part of Africa is one of the lowest reported rates worldwide. The rate among pregnant women is similar to the rate in general population, ranging from 15 to 23 % (Capretti et al. 2014; Zumla et al. 1991; Nabias et al. 1998; Lindstrom et al. 2006) with an overall seropositivity of 20 % (Lindstrom et al. 2006). Another important medical problem in this region is the high prevalence of HIV/AIDS patients including pregnant women; nevertheless, co-infection with both HIV and toxoplasma is low with seropositivity of 8 % (Nabias et al. 1998). Additional studies are needed to clarify the relationship between these diseases. There are few studies on *T. gondii* prevalence in this region and in sub-Saharan Africa in general (Lindstrom et al. 2006; Shimelis et al. 2009).

Central Africa

Central Africa has the highest reported prevalence rates of infectious diseases. The Democratic Republic of Congo has the highest rate among these countries (80.3 %) (Gascon et al. 1989) and the lowest prevalence was reported in Rwanda (31 %) (Doudou et al. 2014). Most countries in this region lack current information on *Toxoplasma gondii* for pregnant women and the general population.

Western Africa

In this region, the seroprevalence rate ranged from 53.5 % in the Republic of Benin (Rodier et al. 1995) to 92.5 % in Ghana (Ayi et al. 2009). A lower prevalence rate was reported from Benin (30.0 %) (De Paschale et al. 2014) and Burkina Faso (20.3 %) (Linguissi et al. 2012).

Risk factors associated with transmission of *Toxoplasma gondii* among pregnant women in Arab and African countries

Consumption of raw or undercooked meat

Toxoplasma gondii seropositivity among pregnant African women was found to be strongly associated with eating undercooked or raw meat (adjusted OR 5.73, 95 % CI 1.35–24.39; $p = 0.02$) (Walle et al. 2013). This finding is

in consistent with findings from other African and Arab countries (Cook et al. 2000; Jones et al. 2009). Similar results were obtained from Sudan where authors concluded that, eating raw meat, undercooked meat, and living in the Southern region are predictors of seropositivity of *T. gondii* infections in pregnancy (Elnahas et al. 2003). Daily consumption of raw meat in many part of Africa is very common. This may explain the high seropositivity rate seen in many parts of Africa.

Many studies on food animals as potentials source of infection have been performed. In Sudan, a study on food cattle showed that the seropositivity was 44.8 % (Elfahal et al. 2013), and a similar study in the same country showed a rate 53.71 % (Diakoua et al. 2013). Studies from Arab countries revealed similar findings (Almushait et al. 2014, Tammam et al. 2013, Alsammani et al. 2012). In Saudi Arabia, sheep and goats as potentials source of infections were examined for IgG antibodies. Results showed high seropositivity rates 52.2 and 51.7 % respectively indicating potential sources of infection (Sanad and Al-Ghabban 2007). In the Riyadh region, results showed less infection among these animals: 36.4 % for sheep, 35.3 % for goats, and 23.6 % for camels (Alanazi 2013). A large study carried in different Egyptians governorates showed that there was high zoonotic chicken toxoplasmosis seropositivity (68.8 %) which indicates additional source of infection (Barakat et al. 2012). High rate of seropositivity was reported in goats (70.48 %) in an Ethiopian study (Gebremedhin et al. 2013). A recent study, showing high prevalence of infection in dairy goats, suggests a potential risk of the transmission route of toxoplasma via unpasteurized milk (Zhao et al. 2012). This high seropositivity in animals observed in both Arab and African countries may be potential sources of infection for pregnant women by either consumption of raw or undercooked meat or unpasteurized milk from these animals. These results are consistent with studies from other countries showing meat as a source of infection in China, Norway, and the United States (Li and Wu 2002; Jones et al. 2009; Cook et al. 2000).

Consumption of unwashed raw vegetables or fruits and farming as an occupation

Consumption of unwashed raw vegetables or fruits was reported as a significant factor for *T. gondii* infection. There many infectious oocysts shed from cats in vegetables which are capable of producing infection to human. Seropositivity for toxoplasmosis in Arabs countries was significantly associated with eating miswashed vegetables. A study in Côte d'Ivoire evaluating risk factors for toxoplasmosis showed that contact with soil and uncooked food were the only sources of contamination (Adou-Bryn et al. 2004).

This is consistent with results from a study in China that found that consumption of unwashed raw vegetables and fruits was associated with increased toxoplasmosis infection during pregnancy (Liu et al. 2009). Similarly, other studies proved that farming contact with soil were strong predictors of infectivity with *T. gondii* infection (Cook et al. 2000). The association between *T. gondii* infection and food as a potential source of infection is understudied in both Arab and African countries.

Proximity of cats (cleaning the cat litter box) and other animals

Contact with animals and in particular cats, or cleaning the cat litter box was found to be significantly associated with seropositivity for toxoplasmosis (Fakhfakh et al. 2013). In one study in Ethiopia it was found that living with domestic cats increase the rate infection by *T. gondii* by fivefold (OR 5.82, 95 % CI 1.61–20.99; $p < 0.05$) (Zemene et al. 2012). Cats can infect other domestic animals leading to an increased chance of infectivity and creating another potential source of infection. The risk of contracting toxoplasma is higher when there is frequent exposure to feline feces or neglect of preventive measures like washing hands.

Living in rural areas

Residency in rural areas has a great influence on toxoplasma seropositivity for both Arab and African populations. In Egypt we found that living in a rural area was an independent predictor of toxoplasmosis seropositivity (OR 3.800, CI 1.100–10.813, $p = 0.034$) (Tammam et al. 2013). This finding is supported by studies from Saudi Arabia (Al-Qurashi et al. 2001, Al-Mohammad et al. 2010). African countries showed similar results indicating that rural living significantly increases seropositivity of *T. gondii* in pregnancy. Living in a rural area in Tanzania increased the risk for *T. gondii* by twofold (OR 2.2, 95 % CI 1.4–3.7, $p = 0.001$) (Mwambe et al. 2013). This was supported by studies in Mali (Ouologuem et al. 2013) and Sudan (Elnahas et al. 2003). In Italy, higher associations were reported for living in rural areas (Thaller et al. 2011). Living in a rural area and high chance of developing *T. gondii* in pregnancy is also consistent with global literature by Pappas et al. (2009). High prevalence in rural areas is an accepted finding in settings where there is poor sanitary facilities, contact with soil or animals, and drinking of unpasteurized or unboiled water and milk.

Maternal age

Some studies in Arab and African countries have shown that seroprevalence of *Toxoplasma gondii* is significantly associated with maternal age. Mwambe (Mwambe et al.

2013) reported that the risk of contracting infection with *T. gondii* increases by 7 % for each year increase in a woman's age (OR 1.07, 95 % CI 1.02–1.11, $p = 0.002$). Similar results from Mali showed that the risk of infection increases with the increase in maternal age (Ouologuem et al. 2013). This is supported by studies from Arabs countries (Mohammad et al. 2012; Al-Qurashi et al. 2001) and a large study from Egypt which showed that the prevalence of Toxoplasma infection increases with age (Elsheikha et al. 2009). On the other hand, age is not found to be associated with toxoplasma infection among Chinese pregnant women (Sun et al. 2006).

Pregnancy outcomes

Congenital Toxoplasma gondii and premature birth

In Saudi Arabia IgM was reported in 23.1 % of premature infants (Martin 2001). Long-term effects are only available from retrospective diagnosis from case reports following reporting to specialized units such as for vision (Luft and Remington 1992) and hearing problem (Montoya and Liesenfeld 2004).

Congenital toxoplasma and risk of miscarriage

Data on the rate of miscarriage and congenital disease caused by *Toxoplasma gondii* is very limited and scarce. Recently, we demonstrated tachyzoites from conceptus material in 76 women with first trimester miscarriage screened for toxoplasma-specific IgG and IgM antibodies, giving a miscarriage rate of 1.3 % (Tammam et al. 2013). A similar study was conducted in Dakar; authors demonstrated a 22.8 % seroconversion rate among women who miscarried compared to 10 % for pregnant women ($p = 0.041$) (Ndir et al. 2004). An Egyptian study of women with miscarriage demonstrated histological characteristics of toxoplasmic placentitis with detection of the organism in the placenta (el-Ridi et al. 1991).

In the Gulf area two studies were performed to examine the relation between *T. gondii* and miscarriages. The *T. gondii* seroconversion rate among mothers with spontaneous and recurrent pregnancy loss was 24.2 and 30.6 % (el-Sebai 1991, Singh 1998) respectively.

This high seropositivity of *T. gondii* among pregnant women may be responsible for a significant number of miscarriages, although we cannot guarantee that this is due to *T. gondii* infection since additional confirmatory tests such as PCR, Avidity tests, IgA and IgE, and/or histopathologic studies were not performed. Because anti-toxoplasma IgM antibodies may persist as long as 18 months after acute infection (Wilson et al. 2003), serologic tests alone often have ambiguous results.

Conclusions

Little is known about seroprevalence and the disease burden of congenital toxoplasmosis in both Arab and African countries although it is the most important form of the disease. The seroprevalence of *T. gondii* among pregnant women in Africa ranges from 25 to 92.5 % (Torgerson and Mastroiacovo 2013), which is very high compared to the seroprevalence in Arab countries and much higher compared to the U.K. (6–17 %), France (50–60 %), North America (10–25 %), and Asia (10–60 %), but comparable to countries in South America (45–80 %) (Al-Nakib et al. 1983; Jones et al. 2007; Dromigny et al. 1996; Pal et al. 1996; Baril et al. 1999; Nash et al. 2005; Dubey and Jones 2008; Rosso et al. 2008; Fernandes et al. 2009; Sroka et al. 2010; Xiao et al. 2010). Worldwide, about 1,90,100 cases of congenital toxoplasmosis are reported every year. High burdens are reported from South American, Middle Eastern, and low-income countries (Torgerson and Mastroiacovo 2013). Reports indicated a considerable variation in the incidence of *Toxoplasma gondii* in pregnancy between different geographical regions and within the same region. These variations can be ascribed to exposure to *T. gondii* from different types of food and environmental sources. Additionally, seropositivity may be influenced by type of test used, sample size, and cat density, and there may be other risk factors depending on geographical area. In addition, lower positivity rates may be explained by community awareness and health education.

Risk factors identified by multivariate analysis in Arab and African countries for *T. gondii* infection included consumption of raw meat and milk, unwashed raw vegetables or fruit, proximity of cats (cleaning the cat litter box) and other animals, living in rural areas, low educational level, and increased age.

From the few available studies, risk factors for *Toxoplasma gondii* among pregnant women in Arab countries does not differ from those in other developed countries. Some factors in the Arab countries that may influence the prevalence of *T. gondii* are socio-economics, lack of health education, and migration from highly endemic regions. Migration will increase the apparent seropositivity in recipient countries, and presents a challenge for recipient health care systems.

A new concept of congenital human toxoplasmosis

Previously we believed there are only three major genotypes of *Toxoplasma gondii* that are responsible for congenital infections and remaining isolates are harmless (Ndir et al. 2004). This belief is changing because of greater genetic diversity as a result of sexual recombination of the parasite (Su et al. 2010; Khan et al. 2011). A recent study indicated that congenital *T. gondii* can occur in immune

mothers (seropositive) when an atypical genotype overcomes the acquired resistance from the original infecting genotype (Elbez-Rubinstein et al. 2009). Moreover, a study recently demonstrated a severe form of congenital *T. gondii* in children of non-immune mothers in the third trimester (Delhaes et al. 2010), which is rarely caused by the typical genotypes. Such information may change our concepts about the mechanism of congenital toxoplasmosis. Testing of the parasite should include atypical species since they proved to be capable of producing severe infection, contrary to our previous beliefs. The current tests used for the diagnosis of *T. gondii* lack the ability to differentiate between typical and atypical genotypes, therefore adding new challenges to the concept of seroprevalence of the disease.

Strategies and preventive measures to control *Toxoplasma gondii* infection among pregnant women in Arabs and African countries

The status of *Toxoplasma gondii* infection in pregnant women in Arab and African countries is a major health issue for practitioners and those involved in health care strategies. Limited data are available in these countries to assist in estimating the portion of the disease burden of toxoplasmosis in pregnant women. Only regional studies are available which do not reflect the depth of the problem nationally. Another issue is that there is a great regional variation in the seroprevalence of *T. gondii* among pregnant women even in the same district. The phenomenon of mixed cultural populations may explain some of the observed differences seen in African countries. These differences are harder to explain in Arab countries, as communities are more similar. Preventive measures are available for pet owners, work hazards in gardening and farming (i.e. wearing gloves and washing hands frequently). Kitchen hygiene should be improved, including avoiding drinking contaminated liquids or consuming inadequately washed vegetables and fruits. Health education about preventive measures is the most accessible and cost-effective method (Elsheikha et al. 2009).

Health education of women of child-bearing age about food hygiene and prevention of exposure to cat feces is an integral part of prevention of toxoplasmosis. At first antenatal visit, health providers of women of childbearing age should deliver information's about meat-related and soil-borne toxoplasmosis prevention with a focus on specific habits. Prenatal screening could identify women requiring prenatal therapy.

Additionally, researchers should give proper estimates of the burden of toxoplasmosis in both pregnant women and newborn infants. It is essential to improve screening and diagnostics tests for toxoplasma

We conclude that there is a high seropositivity rate of *T. gondii* infection among pregnant women in African and Arab countries and that the disease is on the rise. On the other hand, there are many gaps in the literatures on this topic in both regions. Most of studies indentified prevalence by using IgG only; IgM, which indicated recent infection, was only seen in few of these studies. More importantly, congenital toxoplasma and miscarriage, which are the most important consequences of the disease, are an under-estimated public health issue. Most of the previous work on toxoplasma in these countries used smaller sample sizes, which could definitively affect the apparent seropositivity rates. A larger sample size is needed for a better estimate of the true prevalence of the disease.

Acknowledgments The authors would like to acknowledge the editorial assistance of Dr. Belinda Peace.

Conflict of interest We declare that we have no conflicts of interest.

References

- Abu-Madi MA, Al-Molawi N, Behnke JM (2008) Seroprevalence and epidemiological correlates of *Toxoplasma gondii* infections among patients referred for hospital-based serological testing in Doha, Qatar. *Parasit Vectors* 1:39
- Abu-Madi MA, Behnke JM, Dabritz HA (2010) *Toxoplasma gondii* seropositivity and co-infection with TORCH pathogens in high-risk patients from Qatar. *Am J Trop Med Hyg* 82:626–633
- Adou-Bryn KD, Ouhon J, Nemer J, Yapo CG, Assoumou A (2004) Serological survey of acquired toxoplasmosis in women of child-bearing age in Yopougon (Abidjan, Cote d'Ivoire). *Bull Soc Pathol Exot* 97:345–348
- Ahmed HJ, Mohammed HH, Yusuf MW, Ahmed SF, Hult G (1988) Human toxoplasmosis in Somalia. Prevalence of toxoplasma antibodies in a village in the lower Scebelli region and in Mogadishu. *Trans R Soc Trop Med Hyg* 82:330–332
- Alanazi AD (2013) Determination of seropositivity for *Toxoplasma gondii* in sheep, goats and camels slaughtered for food and human consumptions in Riyadh municipal abattoirs, Saudi Arabia. *J Egypt Soc Parasitol* 43:569–576
- Al-Hindi A, Al-Helou T, Al-Helou Y (2010) Seroprevalence of *Toxoplasma gondii*, cytomegalovirus, rubella virus and *Chlamydia trachomatis* among infertile women attending in vitro fertilization center, Gaza strip, Palestine. *J Egypt Soc Parasitol* 40:451–458
- Al-Mendalawi MD, Barah F (2011) Prevalence of IgG antibodies against *Toxoplasma gondii* among Syrian females of childbearing age. *Saudi Med J* 32:1210
- al-Meshari AA, Chowdhury MN, Chattopadhyay SK, De Silva SK (1989) Screening for toxoplasmosis in pregnancy. *Int J Gynecol Obstet* 29:39–45
- Almogren A (2011) Antenatal screening for *Toxoplasma gondii* infection at a tertiary care hospital in Riyadh, Saudi Arabia. *Ann Saudi Med* 31:569–572
- Al-Mohammad HI, Amin TT, Balaha MH, Al-Moghannum MS (2010) Toxoplasmosis among the pregnant women attending a Saudi maternity hospital: seroprevalence and possible risk factors. *Ann Trop Med Parasitol* 104:493–504
- Al-Mulhim AA, Al-Qurashi AM (2001) Sero-prevalence of toxoplasmosis in pregnant mothers and new born infants in Eastern province, Saudi Arabia. *J Family Community Med* 8:45–48
- Almushait MA, Dajem SM, Elsherbiny NM, Eskandar MA, Al Azraqi TA, Makhoul LM (2014) Seroprevalence and risk factors of *Toxoplasma gondii* infection among pregnant women in South Western, Saudi Arabia. *J Parasit Dis* 38:4–10
- Al-Nakib W, Ibrahim ME, Hathout H, Moussa MA, Deverajan LV, Thorburn H, Yousof AM (1983) Seroepidemiology of viral and toxoplasma infections during pregnancy among Arab women of child-bearing age in Kuwait. *Int J Epidemiol* 12:220–223
- Al-Qurashi AR, Ghandour AM, Obeid OE, Al-Mulhim A, Makki SM (2001) Seroepidemiological study of *Toxoplasma gondii* infection in the human population in the Eastern region. *Saudi Med J* 22:13–18
- Alsammani MA, Ahmed SR, Alsheeha MA, Saadia Z, Khairi SA (2012) Co-infection with *Toxoplasma gondii* and *Clostridium perfringens* in a postpartum woman with uterine gas gangrene: a case report. *J Obstet Gynaecol Res* 38:1024–1027
- Ayi I, Edu SA, Apea-Kubi KA, Boamah D, Bosompem KM, Edoh D (2009) Sero-epidemiology of toxoplasmosis amongst pregnant women in the greater accra region of Ghana. *Ghana Med J* 43:107–114
- Barah FA (2011) Prevalence of IgG antibodies against *Toxoplasma gondii* among Syrian females of childbearing age. *Saudi Med J* 32:531–533
- Barakat AM, Salem LM, El-Newishy AM, Shaapan RM, El-Mahllawy EK (2012) Zoonotic chicken toxoplasmosis in some Egyptians governorates. *Pak J Biol Sci* 15:821–826
- Baril L, Ancelle T, Goulet V, Thulliez P, Tirard-Fleury V, Carme B (1999) Risk factors for toxoplasma infection in pregnancy: a case-control study in France. *Scand J Infect Dis* 31:305–309
- Bin Dajem SM, Almushait MA (2012) Detection of *Toxoplasma gondii* DNA by PCR in blood samples collected from pregnant Saudi women from the Aseer region, Saudi Arabia. *Ann Saudi Med* 32:507–512
- Bouhamdan SF, Bitar LK, Saghir HJ, Bayan A, Araj GF (2010) Seroprevalence of toxoplasma antibodies among individuals tested at hospitals and private laboratories in Beirut. *J Med Liban* 58:8–11
- Bouratbine A, Siala E, Chahed MK, Aoun K, Ben Ismail R (2001) Sero-epidemiologic profile of toxoplasmosis in Northern Tunisia. *Parasite* 8:61–66
- Brindle R, Holliman R, Gilks C, Waiyaki P (1991) Toxoplasma antibodies in HIV-positive patients from Nairobi. *Trans R Soc Trop Med Hyg* 85:750–751
- Capretti MG, De Angelis M, Tridapalli E, Orlandi A, Marangoni A, Moroni A, Guerra B, Arcuri S, Marsico C, Faldella G (2014) Toxoplasmosis in pregnancy in an area with low seroprevalence: is prenatal screening still worthwhile? *Pediatr Infect Dis J* 33:5–10
- Cook AJ, Gilbert RE, Buffolano W, Zufferey J, Petersen E, Jenum PA, Foulon W, Semprini AE, Dunn DT (2000) Sources of toxoplasma infection in pregnant women: European multicentre case-control study. European research network on congenital toxoplasmosis. *BMJ* 321:142–147
- Dar FK, Alkarmi T, Uduman S, Abdulrazzaq Y, Grundsell H, Hughes P (1997) Gestational and neonatal toxoplasmosis: regional seroprevalence in the United Arab Emirates. *Eur J Epidemiol* 13:567–571
- De Paschale M, Ceriani C, Cerulli T, Cagnin D, Cavallari S, Cianflone A, Diombo K, Ndayake J, Aouanou G, Zaongo D, Priuli G, Vigano P, Clerici P (2014) Antenatal screening for *Toxoplasma gondii*, Cytomegalovirus, rubella and *Treponema pallidum* infections in Northern Benin. *Trop Med Int Health* 19(6):743

- Delhaes L, Ajzenberg D, Sicot B, Bourgeot P, Darde ML, Dei-Cas E, Houfflin-Debarge V (2010) Severe congenital toxoplasmosis due to a *Toxoplasma gondii* strain with an atypical genotype: case report and review. *Prenat Diagn* 30:902–905
- Diakoua A, Papadopoulos E, Panousis N, Karatzias C, Giadinis N (2013) *Toxoplasma gondii* and *Neospora caninum* seroprevalence in dairy sheep and goats mixed stock farming. *Vet Parasitol* 198:387–390
- Doudou Y, Renaud P, Coralie L, Jacqueline F, Hypolite S, Hypolite M, Patrick M, Andreia Ida L, Van Sprundel M, Marleen B, Van Geertruyden JP, Pascal L (2014) Toxoplasmosis among pregnant women: high seroprevalence and risk factors in Kinshasa, Democratic Republic of Congo. *Asian Pac J Trop Biomed* 4:69–74
- Dromigny JA, Pecarrere JL, Leroy F, Ollivier G, Boisier P (1996) Prevalence of toxoplasmosis in Tananarive. Study conducted at the Pasteur Institute of Madagascar (PIM) on a sample of 2354 subjects. *Bull Soc Pathol Exot* 89:212–216
- Dubey JP, Jones JL (2008) *Toxoplasma gondii* infection in humans and animals in the United States. *Int J Parasitol* 38:1257–1278
- Dubey JP, Lago EG, Gennari SM, Su C, Jones JL (2012) Toxoplasmosis in humans and animals in Brazil: high prevalence, high burden of disease, and epidemiology. *Parasitology* 139:1375–1424
- Dunn D, Wallon M, Peyron F, Petersen E, Peckham C, Gilbert R (1999) Mother-to-child transmission of toxoplasmosis: risk estimates for clinical counselling. *Lancet* 353:1829–1833
- El Deeb HK, Salah-Eldin H, Khodeer S, Allah AA (2012) Prevalence of *Toxoplasma gondii* infection in antenatal population in Menoufia governorate, Egypt. *Acta Trop* 124:185–191
- El Mansouri B, Rhajaoui M, Sebti F, Amarir F, Laboudi M, Bchitou R, Hamad M, Lyagoubi M (2007) Seroprevalence of toxoplasmosis in pregnant women in Rabat, Morocco. *Bull Soc Pathol Exot* 100:289–290
- Elbez-Rubinstein A, Ajzenberg D, Darde ML, Cohen R, Dumetre A, Yera H, Gondon E, Janaud JC, Thulliez P (2009) Congenital toxoplasmosis and reinfection during pregnancy: case report, strain characterization, experimental model of reinfection, and review. *J Infect Dis* 199:280–285
- Elbualy MS, Kolhatkar A, Al-Dharhy SHS (1996) Seroprevalence of rubella, cytomegalovirus, measles and toxoplasmosis among pregnant women in Oman. *Oman Med J* 12:6–10
- Elfahal AM, Elhassan AM, Hussien MO, Enan KA, Musa AB, El Hussein AM (2013) Seroprevalence of *Toxoplasma gondii* in dairy cattle with reproductive problems in Sudan. *ISRN Vet Sci* 2013:895165
- Elnahas A, Gerais AS, Elbashir MI, Eldien ES, Adam I (2003) Toxoplasmosis in pregnant Sudanese women. *Saudi Med J* 24:868–870
- el-Ridi AM, Nada SM, Aly AS, Ramadan ME, Hagar EG, Taha TA (1991) Toxoplasmosis and pregnancy: an analytical study in Zagazig, Egypt. *J Egypt Soc Parasitol* 21:81–85
- el-Sebai MM (1991) Study on toxoplasmosis in Quasseem, Saudi Arabia. *J Egypt Soc Parasitol* 21:273–275
- Elsheikha HM, Aboul-Dahab MA, Abdel Maboud AI, El-Sherbini ET (2009) Prevalence and risk factors of *Toxoplasma gondii* antibodies in asymptomatic Egyptian blood donors. *J Egypt Soc Parasitol* 39:351–361
- Fakhfakh N, Kallel K, Ennigro S, Kaouech E, Belhadj S, Chaker E (2013) Risk factors for *Toxoplasma gondii* and immune status of pregnant women: cause and effect? *Tunis Med* 91:188–190
- Fernandes GC, Azevedo RS, Amaku M, Yu AL, Massad E (2009) Seroepidemiology of toxoplasma infection in a metropolitan region of Brazil. *Epidemiol Infect* 137:1809–1815
- Flatt A, Shetty N (2013) Seroprevalence and risk factors for toxoplasmosis among antenatal women in London: a re-examination of risk in an ethnically diverse population. *Eur J Public Health* 23:648–652
- Gascon J, Torres-Rodriguez JM, Soldevila M, Merlos AM (1989) Seroepidemiology of toxoplasmosis in 2 communities of Rwanda (Central Africa). *Rev Inst Med Trop Sao Paulo* 31:399–402
- Gebremedhin EZ, Abebe AH, Tessema TS, Tullu KD, Medhin G, Vitale M, Di Marco V, Cox E, Dorny P (2013) Seroepidemiology of *Toxoplasma gondii* infection in women of child-bearing age in central Ethiopia. *BMC Infect Dis* 13:101
- Gilbert R, Tan HK, Cliffe S, Guy E, Stanford M (2006) Symptomatic toxoplasma infection due to congenital and postnatally acquired infection. *Arch Dis Child* 91:495–498
- Guerina NG (1994) Congenital infection with *Toxoplasma gondii*. *Pediatr Ann* 23(138–42):147–151
- Hide G, Morley EK, Hughes JM, Gerwash O, Elmahaishi MS, Elmahaishi KH, Thomasson D, Wright EA, Williams RH, Murphy RG, Smith JE (2009) Evidence for high levels of vertical transmission in *Toxoplasma gondii*. *Parasitology* 136:1877–1885
- Hill D, Dubey JP (2002) *Toxoplasma gondii*: transmission, diagnosis and prevention. *Clin Microbiol Infect* 8:634–640
- Hung CC, Fan CK, Su KE, Sung FC, Chiou HY, Gil V, Reis da Conceicao dos, Ferreira M, de Carvalho JM, Cruz C, Lin YK, Tseng LF, Sao KY, Chang WC, Lan HS, Chou SH (2007) Serological screening and toxoplasmosis exposure factors among pregnant women in the Democratic Republic of Sao Tome and Principe. *Trans R Soc Trop Med Hyg* 101:134–139
- Jacobs MR, Mason PR (1978) Prevalence of toxoplasma antibodies in Southern Africa. *S Afr Med J* 53:619–621
- Jones JL, Kruszon-Moran D, Wilson M, McQuillan G, Navin T, McAuley JB (2001) *Toxoplasma gondii* infection in the United States: seroprevalence and risk factors. *Am J Epidemiol* 154:357–365
- Jones JL, Kruszon-Moran D, Sanders-Lewis K, Wilson M (2007) *Toxoplasma gondii* infection in the United States, 1999–2004, decline from the prior decade. *Am J Trop Med Hyg* 77:405–410
- Jones JL, Dargelas V, Roberts J, Press C, Remington JS, Montoya JG (2009) Risk factors for *Toxoplasma gondii* infection in the United States. *Clin Infect Dis* 49:878–884
- Jumaian NF (2005) Seroprevalence and risk factors for toxoplasma infection in pregnant women in Jordan. *East Mediterr Health J* 11:45–51
- Kassem HH, Morsy TA (1991) The prevalence of anti-toxoplasma antibodies among pregnant women in Benghazi, (S.P.L.A.J.) Libya. *J Egypt Soc Parasitol* 21:69–74
- Khan A, Dubey JP, Su C, Ajioka JW, Rosenthal BM, Sibley LD (2011) Genetic analyses of atypical *Toxoplasma gondii* strains reveal a fourth clonal lineage in North America. *Int J Parasitol* 41:645–655
- Klufio CA, Delamare O, Amoa AB, Kariwiga G (1993) The prevalence of toxoplasma antibodies in pregnant patients attending the Port Moresby General Hospital antenatal clinic: a seroepidemiological survey. *P N G Med J* 36:4–9
- Lebech M, Andersen O, Christensen NC, Hertel J, Nielsen HE, Peitersen B, Rechnitzer C, Larsen SO, Norgaard-Pedersen B, Petersen E (1999) Feasibility of neonatal screening for toxoplasma infection in the absence of prenatal treatment. Danish Congenital Toxoplasmosis Study Group. *Lancet* 353:1834–1837
- Lelong B, Rahelimino B, Candolfi E, Ravelojaona BJ, Villard O, Rasamindrakotroka AJ, Kien T (1995) Prevalence of toxoplasmosis in a population of pregnant women in Antananarivo (Madagascar). *Bull Soc Pathol Exot* 88:46–49
- Li M, Wu JH (2002) Toxoplasma infection among pregnant women in Zhoushan city, Zhejiang Province. *Chin J Health Educ* 18:734–735

- Lindstrom I, Kaddu-Mulindwa DH, Kironde F, Lindh J (2006) Prevalence of latent and reactivated *Toxoplasma gondii* parasites in HIV-patients from Uganda. *Acta Trop* 100:218–222
- Linguissi LS, Nagalo BM, Bisseye C, Kagone TS, Sanou M, Tao I, Benao V, Simporé J, Kone B (2012) Seroprevalence of toxoplasmosis and rubella in pregnant women attending antenatal private clinic at Ouagadougou, Burkina Faso. *Asian Pac J Trop Med* 5:810–813
- Liu Q, Wei F, Gao S, Jiang L, Lian H, Yuan B, Yuan Z, Xia Z, Liu B, Xu X, Zhu XQ (2009) *Toxoplasma gondii* infection in pregnant women in China. *Trans R Soc Trop Med Hyg* 103:162–166
- Lopes AP, Dubey JP, Moutinho O, Gargate MJ, Vilarés A, Rodrigues M, Cardoso L (2012) Seroepidemiology of *Toxoplasma gondii* infection in women from the North of Portugal in their childbearing years. *Epidemiol Infect* 140:872–877
- Lopez R, Contreras R, Font L, Vega O (1992) Presence of antibodies against *Toxoplasma gondii* in adolescents from the African continent. *Rev Latinoam Microbiol* 34:49–52
- Lopez A, Dietz VJ, Wilson M, Navin TR, Jones JL (2000) Preventing congenital toxoplasmosis. *MMWR Recomm Rep* 49:59–68
- Luft BJ, Remington JS (1992) Toxoplasmic encephalitis in AIDS. *Clin Infect Dis* 15:211–222
- Makuwa M, Lecko M, Nsimba B, Bakoue-Tela J, Lounana-Kouta J- (1992) Toxoplasmosis et la femme enceinte au Congo. Bilan de 5 ans de dépistage (1986–1990). *Méd Afr Noire* 39:493–495
- Martin S (2001) Congenital toxoplasmosis. *Neonatal Netw* 20:23–30
- Messerer L, Bouzbid S, Gourbdji E, Mansouri R, Bachi F (2014) Seroprevalence of toxoplasmosis in pregnant women in Annaba, Algeria. *Rev Epidemiol Sante Publique* 62:160–165
- Mohammad M, Ahmed S, Hussain A (2012) Seroprevalence of *Toxoplasma gondii* in couples in Ramadi City using enzyme linked immunosorbent assay (ELISA). *Int J Med Med Sci* 4:55–59
- Montoya JG, Liesenfeld O (2004) Toxoplasmosis. *Lancet* 363:1965–1976
- Morvan JM, Mambely R, Selekon B, Coumanzi-Malo MF (1999) Toxoplasmosis at the Pasteur Institute of Bangui, Central African Republic (1996–1998): serological data. *Bull Soc Pathol Exot* 92:157–160
- Mosti M, Pinto B, Giromella A, Fabiani S, Cristofani R, Panichi M, Bruschi F (2013) A 4-year evaluation of toxoplasmosis seroprevalence in the general population and in women of reproductive age in central Italy. *Epidemiol Infect* 141:2192–2195
- Mousa DA, Mohammad MA, Toboli AB (2011) *Toxoplasma gondii* infection in pregnant women with previous adverse pregnancy outcome. *Med J Islam World Acad Sci* 19:95–102
- Mwambe B, Mshana SE, Kidenya BR, Massinde AN, Mazigo HD, Michael D, Majinge C, Gross U (2013) Sero-prevalence and factors associated with *Toxoplasma gondii* infection among pregnant women attending antenatal care in Mwanza, Tanzania. *Parasit Vectors* 6:222
- Nabias R, Ngouamizokou A, Migot-Nabias F, Mbou-Moutsimbi RA, Lansoud-Soukate J (1998) Serological investigation of toxoplasmosis in patients of the M.I.P. center of Franceville (Gabon). *Bull Soc Pathol Exot* 91:318–320
- Nash JQ, Chissel S, Jones J, Warburton F, Verlander NQ (2005) Risk factors for toxoplasmosis in pregnant women in Kent, United Kingdom. *Epidemiol Infect* 133:475–483
- Ndir I, Gaye A, Faye B, Gaye O, Ndir O (2004) Seroprevalence of toxoplasmosis among women having spontaneous abortion and pregnant women following in a center of health up-town in Dakar. *Dakar Med* 49:5–9
- Ndumbe PM, Andela A, Nkemkeng-Asong J, Watonsi E, Nyambi P (1992) Prevalence of infections affecting the child among pregnant women in Yaounde, Cameroon. *Med Microbiol Immunol* 181:127–130
- Nowakowska D, Stray-Pedersen B, Spiewak E, Sobala W, Malafiej E, Wilczynski J (2006) Prevalence and estimated incidence of toxoplasma infection among pregnant women in Poland: a decreasing trend in the younger population. *Clin Microbiol Infect* 12:913–917
- Onadeko MO, Joynson DH, Payne RA (1992) The prevalence of toxoplasma infection among pregnant women in Ibadan, Nigeria. *J Trop Med Hyg* 95:143–145
- Ouologuem DT, Djimde AA, Diallo N, Doumbo OK, Roos DS (2013) *Toxoplasma gondii* seroprevalence in Mali. *J Parasitol* 99:371–374
- Pal RA, Qayyum M, Yaseen M (1996) Seroprevalence of antibodies to *Toxoplasma gondii*, with particular reference to obstetric history of patients in Rawalpindi-Islamabad, Pakistan. *J Pak Med Assoc* 46:56–58
- Pappas G, Roussos N, Falagas ME (2009) Toxoplasmosis snapshots: global status of *Toxoplasma gondii* seroprevalence and implications for pregnancy and congenital toxoplasmosis. *Int J Parasitol* 39:1385–1394
- Pereira KS, Franco RM, Leal DA (2010) Transmission of toxoplasmosis (*Toxoplasma gondii*) by foods. *Adv Food Nutr Res* 60:1–19
- Remington JS, McLeod R, Thulliez P, Desmonts G (2001) Toxoplasmosis. In: Remington JS, Klein JO (eds) *Infectious diseases of the fetus and newborn infant*. The WB Saunders Co., Philadelphia, pp 205–346
- Rodier MH, Berthonneau J, Bourgoin A, Giraudeau G, Agius G, Burucoa C, Hekpazo A, Jacquemin JL (1995) Seroprevalences of toxoplasma, malaria, rubella, cytomegalovirus, HIV and treponemal infections among pregnant women in Cotonou, Republic of Benin. *Acta Trop* 59:271–277
- Rosso F, Les JT, Agudelo A, Villalobos C, Chaves JA, Tunubala GA, Messa A, Remington JS, Montoya JG (2008) Prevalence of infection with *Toxoplasma gondii* among pregnant women in Cali, Colombia, South America. *Am J Trop Med Hyg* 78:504–508
- Saleh MM, AL-Shamiri AH, Qaed AA (2010) Seroprevalence and incidence of *Toxoplasma gondii* among apparently healthy and visually or hearing disabled children in Taiz City, Yemen. *Kor J Parasitol* 48:71–73
- Sanad MM, Al-Ghabban AJ (2007) Serological survey on toxoplasmosis among slaughtered sheep and goats in Tabouk, Saudi Arabia. *J Egypt Soc Parasitol* 37:329–340
- Shawky S, Soliman NK (2001) Going beyond the curriculum to promote medical education and practice in Saudi Arabia. *Saudi Med J* 22:477–480
- Shimelis T, Tebeje M, Tadesse E, Tegbaru B, Terefe A (2009) Seroprevalence of latent *Toxoplasma gondii* infection among HIV-infected and HIV-uninfected people in Addis Ababa, Ethiopia: a comparative cross-sectional study. *BMC Res Notes* 2:213
- Singh N (1998) Status of toxoplasma antibodies in recurrent fetal loss in U.A.E. women. *Indian J Pediatr* 65:891–897
- Sroka S, Bartelheimer N, Winter A, Heukelbach J, Ariza L, Ribeiro H, Oliveira FA, Queiroz AJ, Alencar C Jr, Liesenfeld O (2010) Prevalence and risk factors of toxoplasmosis among pregnant women in Fortaleza, Northeastern Brazil. *Am J Trop Med Hyg* 83:528–533
- Su C, Shwab EK, Zhou P, Zhu XQ, Dubey JP (2010) Moving towards an integrated approach to molecular detection and identification of *Toxoplasma gondii*. *Parasitology* 137:1–11
- Sun X, Liu P, Song Y, Zhang S, Ren J (2006) Preventive medicine tribune. *Br Med J* 1:675–676
- Szenasi Z, Ozsvar Z, Nagy E, Jeszenszky M, Szabo J, Gellen J, Vegh M, Verhofstede C (1997) Prevention of congenital toxoplasmosis in Szeged, Hungary. *Int J Epidemiol* 26:428–435
- Tammam AE, Haridy MA, Abdellah AH, Ahmed SR, Fayed HM, Alsammani MA (2013) Seroepidemiology of *Toxoplasma gondii*

- infection in women with first trimester spontaneous miscarriage in Qena governorate, Egypt. *J Clin Diagn Res* 7:2870–2873
- Tenter AM, Heckeroth AR, Weiss LM (2000) *Toxoplasma gondii*: from animals to humans. *Int J Parasitol* 30:1217–1258
- Thaller R, Tammaro F, Pentimalli H (2011) Risk factors for toxoplasmosis in pregnant women in central Italy. *Infez Med* 19:241–247
- Torgerson PR, Mastroiacovo P (2013) The global burden of congenital toxoplasmosis: a systematic review. *Bull World Health Organ* 91:501–508
- Vogel N, Kirisits M, Michael E, Bach H, Hostetter M, Boyer K, Simpson R, Holfels E, Hopkins J, Mack D, Mets MB, Swisher CN, Patel D, Roizen N, Stein L, Stein M, Withers S, Mui E, Egwuagu C, Remington J, Dorfman R, McLeod R (1996) Congenital toxoplasmosis transmitted from an immunologically competent mother infected before conception. *Clin Infect Dis* 23:1055–1060
- Walle F, Kebede N, Tsegaye A, Kassa T (2013) Seroprevalence and risk factors for toxoplasmosis in HIV infected and non-infected individuals in Bahir Dar, Northwest Ethiopia. *Parasit Vectors* 6:15
- Watts TE, Larsen SA, Brown ST (1984) A case-control study of stillbirths at a teaching hospital in Zambia, 1979–1980: serological investigations for selected infectious agents. *Bull World Health Organ* 62:803–808
- Weiss LM, Dubey JP (2009) Toxoplasmosis: a history of clinical observations. *Int J Parasitol* 39:895–901
- Wilson M, Jones JL, McAuley JM (2003) *Toxoplasma*. In: Murray PR, Baron EJ, Pfaller MA, Jorgensen JH, Tenover FC (eds) *Manual of clinical microbiology*. American Society for Microbiology, Washington, pp 1970–1980
- Xiao Y, Yin J, Jiang N, Xiang M, Hao L, Lu H, Sang H, Liu X, Xu H, Ankarklev J, Lindh J, Chen Q (2010) Seroepidemiology of human *Toxoplasma gondii* infection in China. *BMC Infect Dis* 10:4
- Zemene E, Yewhalaw D, Abera S, Belay T, Samuel A, Zeynudin A (2012) Seroprevalence of *Toxoplasma gondii* and associated risk factors among pregnant women in Jimma town, Southwestern Ethiopia. *BMC Infect Dis* 12:337
- Zhao G, Shen B, Xie Q, Xu LX, Yan RF, Song XK, Hassan IA, Li XR (2012) Detection of *Toxoplasma gondii* in free-range chickens in China based on circulating antigens and antibodies. *Vet Parasitol* 185:72–77
- Zumla A, Savva D, Wheeler RB, Hira SK, Luo NP, Kaleebu P, Sempala SK, Johnson JD, Holliman R (1991) *Toxoplasma* serology in Zambian and Ugandan patients infected with the human immunodeficiency virus. *Trans R Soc Trop Med Hyg* 85:227–229