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Review

Status of Cystic-echinococcosis caused by *Echinococcus granulosus* in Sudan

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Abstract

Cystic Echinococcosis (CE) represents the most common neglected parasitic zoonotic food-borne infection worldwide with serious pathological effects on human and his domesticated animals. The disease caused by *Echinococcus granulosus*, a heteroxenous helminthes, which has developed several potential routes of transmission within and between different host species including humans and their livestock. CE is maintained by a cycle involves dog and ruminants association. In this review, we aim to provide a general idea on research progress in the epidemiology and molecular epidemiological data of CE in animals and humans in Sudan. The current review also intended to update the available information on the aspects of epidemiology, and diagnostic techniques elaborated for diagnosis of *Echinococcus granulosus* infection in man and animals in Sudan. Data obtained from different sources including journals, books, annual reports, conferences proceedings, veterinary hospitals, abattoirs records, medical centers and hospitals websites visited as well as other internet search up to the year 2015 also reviewed. The results showed that morphological, serological and molecular techniques used for detection *Echinococcus granulosus* infection. The socio-economic consequences in livestock and human associated with CE also discussed. Data presented in this review are probably improve our current understanding of the distribution, transmission, host specificity, immunogenicity, pathogenesis, and genotyping of *E. granulosus* in order to design and for implementation of efficient control strategies against cystic echinococcosis in Sudan.

Keywords: Echinococcus granulosus, Epidemiology, Molecular diagnosis, Transmission, Sudan

INTRODUCTION

The Cestodal *Echinococcus granulosus* (*E. granulosus*) is the agent of hydatid disease, one of the major zoonoses affecting man as well as domestic and wild animals (Dopchiz, *et al*., 2009). The parasite has a global distribution but is particularly prevalent in rural areas (Torgerson and Budke, 2003 and Mirzanejad-Asl, *et al*., 2010). Cystic echinococcosis is endemic in sub-Saharan Africa including Ethiopia, Kenya, Mauritania, Sudan, and Tanzania (Romig *et al*., 2011 and Magambo *et al*., 2006). In Sudan, cystic echinococcosis or hydatidosis is an important parasitic disease caused by a specific tapeworm, *E. granulosus*. Thus, the review and summarize of epidemiological, molecular and socioeconomics impact data published on cystic echinococcosis in production animals and human improve the understanding of the distribution, transmission, host specificity, immunogenicity, pathogenesis, and genotyping of *E. granulosus* in order to design and implementation of efficient control strategies against cystic echinococcosis in Sudan. cystic echinococcosis represents the most common neglected parasitic zoonotic food borne infection worldwide.

Table 1. Prevalence (%) of cystic echinococcosis in production animals reported in different areas of the Sudan

Area	Camels (%)	Cattle (%)	Sheep (%)	Goats (%)	Reference
Western Sudan	-	24.8	12.2	10.0	Elkhawad *et al*. (1978)
Western Sudan	-	25	12	10	Elkhawad *et al*. (1979b)
Central region	35.3	4.28	8.16	3.17	Elkhawad *et al*. (1979a)
Tamboul area	45.4	-	-	-	Saad *et al*. (1983)
Central-Eastern Sudan	56.4	2.1	2.0	-	Tola (1987)
The Sudan area accept the South	48.69	3.84	12.9	4.4	Saad and Magzoub (1989a and 1989b)
El Obied	67.74	-	-	-	Saad *et al*. (1989)
Eldamer Province	37	-	-	-	Elhussien and Ali (1990)
Omdurman	-	-	8.9	4.21	El Sawi (1994)
Omdurman	43.9	-	-	-	El Sawi and Saad (1995)
Kassala	-	-	30.5	-	Elansary and Hamad (1997)
Nyala	79.51	6.42	-	-	Mohammed and Elmalik (2000)
Central Sudan	44.6	3.0	6.9	-	Elmahdi *et al*. (2004)
Central Sudan	55.6	20.0	2.5	-	Omer *et al*. (2010)
Western Sudan	61.4	5.2	11.9	1.9	Omer *et al*. (2010)
Khartoum	-	2.8	1.4	-	Sahar and Atif (2010)
Sinnar area	29.7	2.7	0.6	-	Ibrahim *et al* (2011)
North Darfur	35	2.5	0.8	0.4	Osman (2012)
North Darfur	55	-	-	-	Mohammed (2012)
Tamboul	16.1	-	-	-	Elmahdi *et al*. (2013)
Nyala	29.1	-	-	-	Elmahdi *et al*. (2013)
Central Sudan	21.8	4.8	1.8	-	Ali, *et al*., 2013
White Nile area	50	1.7	-	-	Makky, *et al*., 2013
Central Sudan	22	0.05	0.01	0.0	Shadia and Abdel Rahim, 2015

Echinococcus granulosus, heteroxenous, helminthes that has developed several potential routes of transmission within and between different host species including humans and their livestock. In Sudan, there is a little information about cystic echinococcosis and detailed recent demographic data of groups at risk are badly in need for updating. The present review is aim to give full account on *Echinococcus granulosus* infection among human and his domestic and wild animals in Sudan. The scarcity of information available on prevalence, distribution, epidemiology and magnitude of the disease among both human and animals in Sudan, the current review is intended to update the available information on the aspects of epidemiology, and diagnostic techniques elaborated for diagnosis of *Echinococcus granulosus* infection in man and animals in Sudan

Cystic echinococcosis affecting production of animals in Sudan

The total number of livestock in Sudan was estimated to be about 127.1 million animals. Out of these 33.1 million cattle, 47.2 million sheep, 43.8 million goats and 3 million camels (AOAD, 1998). Ruminants represent an important source of animal protein, which are often the main supply of daily meat and milk in Sudan. Moreover, Ruminants are used in ceremonial festivities, providing important trade between the different parts of Sudan and contribute significantly in the improvement of individual income in most areas.

A number of studies have shown that echinococcosis/hydatidosis is an increasing public health and socio-economic concern. In Sudan the first detection of the disease reported in a camel slaughtered in Khartoum province in 1908 (Annual Report of Sudan Veterinary Service, 1908). Also previously, Abdelmalek (1959) reported in his checklist of the parasites in Sudan a single case of bovine liver hydatidosis in Kosti, 3 cases of lung, liver and spleen cysts in camels in Khartoum and Omdurman. Accordingly, several studies documented the endemicity of cystic echinococcosis in different parts of the country (Table. 1). As shown in Table (1), camel hydatidosis is highly endemic in Sudan with high estimated average prevalence rate of 43.9% (range from 16.1% to 79.51%), where the areas of Western Sudan had high prevalence rate 54.6% (29.1% - 79.51%) followed by the areas of Central-Eastern Sudan 38.3% (16.1% - 56.4%) and Northern Sudan (37%). Also, Lower prevalence of bovine hydatidosis 7.3% (ranging from 0.05% to 25%) documented in Sudan, for as much as Western Sudan had higher prevalence rate 12.8% (2.5% - 25%) than the areas of Central-Eastern Sudan 4.6% (1.7% - 20.0%). Although ovine hydatidosis broadly

identified through the country, the infection is apparently less prevalent in sheep 7.5% (0.01% - 30.5%), where the prevalence rate of 30.5% was only observed in Kassala, Eastern Sudan. Similar situation found with cystic echinococcosis infection in goats 4.3% (0.0% - 10.0%), where the prevalence rate of 10.0% observed in Western Sudan.

Morphological studies demonstrated that cyst fertilities varied, significantly between both livestock host populations and areas studied. Average rates of 55.3% (range: 22.0 – 85.4%) was reported among camel (Saad and Magzoub, 1989a and 1989b). Other authors stated that in cattle, the infection rate ranges from23.0 to 87.5 %(Mohammed and Elmalik, 2000; Elmahdi *et al*., 2004). On the other hand, Sheep and goats, recorded average infection rates of 18.3% (range: 0.0 – 50.0%) and 11.0% (range: 0.0 – 33.0%) respectively (Elansary and Hamad, 1997;; Omer *et al*., 2010; Ibrahim *et al*., 2011; Osman, 2012; Mohammed, 2012; Ali, *et al*., 2013; Makky, *et al*., 2013; Elmahdi *et al*., 2013 and Shadia and Abdel Rahim, 2015). Mohammed, (2004) induced experimental transmission in sheep, goats and wild gazelles (*Gazella dorcas*) by eggs of *E.canadensis* (G6). His result indicated that there is no fertile cyst found. The infectivity rates in sheep were 75% and in goats was 25%. Thus, the broad variation observed in prevalence rates and cyst fertility among livestock host populations may be due to host immune responses or to the involvement of different strains/genotypes, beside that most of the small ruminants slaughtered in young ages, where age of animal is very important factors in most of that studies. However, all these studies demonstrated the main role of camel and secondary role of cattle in life cycle of *Echinococcus granulosus* and as reservoirs of human infection. These observations experimentally confirmed by Saad and Magzoub, (1988), Mohammed, (1997, 2004) and Abakar, *et al*., (2013).

Cystic echinococcosis in human

In humans, since the first record of human hydatidosis in 6 cases (2 Egyptians and 4 Sudanese patients) by Christopherson in 1909, Tola (1987) observed a prevalence rate of 1.2% in Khartoum Province. Whilst, Elmahdi (2003) found a single case of human hydatidosis in Central Sudan. Moreover, an ultrasound survey in 2005 (unpublished data) by Elamin *et al* in Tamboul area, central eastern Sudan, revealed a prevalence rate of 0.92% of hydatid cysts in humans (Ahmed *et al*, 2011). In addition to that, a hospital based-study in three large centers in Khartoum demonstrated that 44.7% of the Sudanese patients with hydatid disease affected in lung (Ahmed *et al*., 2007). Recently, abdominal Ultrasonography in Tamboul area, central eastern Sudan demonstrated prevalence rate of 1.04% of liver cystic echinococcosis (Ahmed, 2010). Currently, Ahmed et al. (2013), reported 38 cystic echinococcosis surgery in Khartoum (1998-2003) and 20 patients presented to Elshaab teaching hospital with suspected pulmonary hydatid cysts in the past 7 years, beside two extra patients diagnosed post operatively.

Echinococcosis in definitive host

Since, Abdelmalek (1959) reported in his check list of the parasites in Sudan 4 cases of *Echinococcus granulosus* in the small intestine of dogs in Khartoum and Kosti, dogs are not only become important animals in transmission of *E. granulosus* but also in many zoonotic parasites in Sudan. Therefore, many workers have reported echinococcosis and others parasitic infections in dogs in Sudan (Table. 2). Recently, experimental transmission in Darfur region proved that foxes (*Vulpes pallida*) can serve as definitive host for camel strain (G6) of *Echinococcus granulosus* (Worm recovery rate range: 15.43%-67.73%), although there is no prevalence rate was recorded in survey of 116 foxes (Mohammed, 2004). In more recent study, Hiwytalla, *et al*. (2013) identified *E.canadensis* (G6) from 40 of the 73 (55.0%) taeniid egg-positive samples of lions (*Panthera leo*) and 27(43.0%) of hyenas (*Hyaena hyaena*) from the Dinder National Park.

Molecular genotyping of cystic echinococcosis in production animals and human

In Sudan, in recent years hydatid cysts, eggs and worms of *Echinococcus granulosus* samples were identified to the species/strain level by a set of PCRs, mitochondrial cytochrome oxidase submit1 (Cox1) and NADH dehydrogenase subunit 1 (nad1) sequencing techniques. Molecular evidence shows that *E. canadensis* 'camel strain' (G6) is predominant strain among livestock in Sudan (Osman, *et al*., 2007; Ibrahim *et al*., 2011 and Elmahdi *et al*., 2013a). Moreover, some studies demonstrated that *E. canadensis* 'camel strain' (G6) co-exits with *E. ortleppi* 'cattle strain' (G5) are circulating in production animals, where *E. ortleppi* was found in cattle only in Central, Eastern and western Sudan (Dinkel *et al,.* 2004; Omer *et al*., 2010; Elmahdi 2012; Elmahdi *et al*., 2013b and Makky, *et al*., 2013). On the other hand, some molecular studies in Central Sudan and Sinnar, Blue Nile states proved that *E. canadensis* 'camel strain' (G6) is circulating in dogs (Elmahdi *et al*., 2006 and Ibrahim *et al*. 2013). However, one study conducted in Tamboul and Rofaa indicated to camel strain' (G6) in dogs, whereas *E. granulosus* sensu stricto (sheep strain) identified in a single case in Rofaa and deposited in GeneBankTM Accession nr HQ 012553 (Omer *et al*., 2013). In addition to that, Hiwytalla, *et al*. (2013) reported *E.canadensis* (G6) in lions (*Panthera leo*) and hyenas (*Hyaena hyaena*) of the Dinder National Park. On the

Table 2. Prevalence (%) of *Echinococcosis granulosus* infections in dog in different areas of the Sudan

Area	No. of dogs examined	Prevalence (%)	Worm Burden/animal	Reference
Khartoum	33	6.06	34-3200	Eisa *et al*. (1977)
Omdurman	-	3.03	-	Elkhawad *et al*. (1979a)
Khartoum	-	17.51	-	Idris (1985)
Tamboul	50	51	24800	Saad and Magzoub (1986)
Nyala	26	26.92	-	Mohammed and Elmalik (2000)
Tamboul	66	53	22-80	Omer, *et al*. (2013)
Rofaa	18	44	103	Omer, *et al*. (2013)
Nyala	117	6.8	1-403	Abd Almalaik, *et al*. (2013)

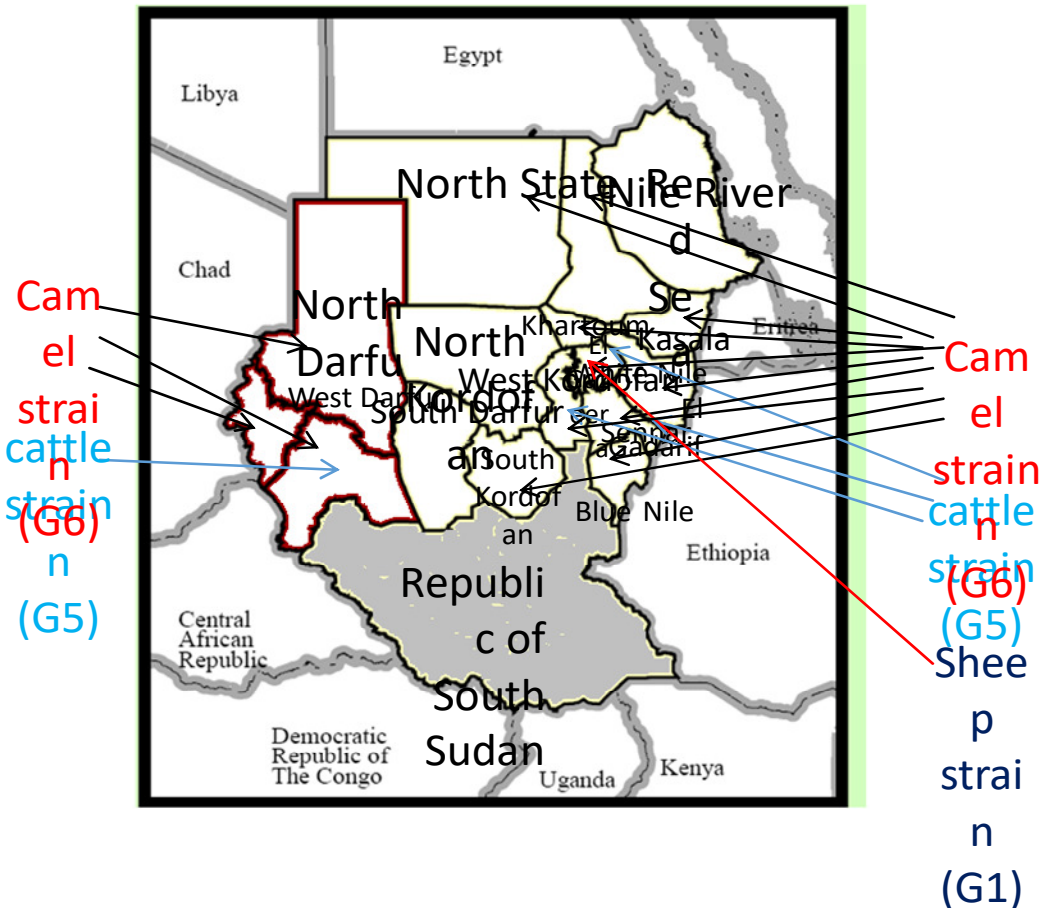

Figure 1. Molecular epidemiology of the *Echinococcus granulosus* complex in domestic and wild animals and humans based on published literature in the Sudan.

other side, Omer, *et al*. (2004), Ahmed and Aradaib (2006) and Omer *et al*. (2010) documented the predominance of *E. canadensis* 'camel strain' (G6) in humans in Sudan. However, genotyping of 22 patients isolates from Elshaab Teaching Hospital, Khartoum showed the G6 (Camel strain) in all except one patient showed G1 strain (sheep strain) (Ahmed, *et al*., 2013). Figure 1. Shows the distribution of *Echinococcus granulosus* genotypes in Sudan.

Socio-economic impact of cystic echinococcosis in production animals and human:

Dakkak (2010) stated that, assessing the socio-economic impact of hydatidosis is difficult. So, it is necessary to consider not only human and animal health, but agriculture, trade, and market factors as well. Hence, in traditional lifestyles such as nomadic or semi-nomadic pastoralism all other factors necessary for CE

transmission like home slaughter without meat inspection, inappropriately managed abattoirs, lack of knowledge about the disease and its transmission, sharing of water sources with dogs and low levels of hygiene are usually present. Previously, Ibrahim, (1999) indicated to some human behavior that increase human hazards created by diseases of wild animals, where Rates, Squirrels and Foxes are consumed by certain communities and Foxes hides are used for making shoes and their fats as medicine. Recently, economic impact study conducted by Mohammed (2012) estimated that, the cost of condemned organs due to hydatid cyst infection was 12020 SDP (4451.9 USD) at El Fashir abattoir, while the total annual economic loss due to condemned organs, decreased carcass weight and decreased milk production at North Darfur was 36060 SDP (13355.6 USD). In more recent study, Ahmed, *et al*. (2013) stated that 73.7% of the respondents in Tambool area, central of Sudan never heard about the Echinococcosis, where only 26% heard about it, beside that in terms of attitude, half of the participants who heard about the disease believe Hydatid cyst patients should be isolated. In addition to that, participants practice showed some behavioral risk as 81.7% slaughter animals inside home without veterinary supervision and 70 % throw the offal outside home where stray dogs eat it. Recently, Socio-economic impacts of cystic echinococcosis (CE) conducted by Abd Almalaik (2015). The author did identify key factors associated with development and persistence of CE in South Darfur State, Western Sudan. This main finding showed that the annual financial loss in animals due to edible organs condemnation and cost of control by chemotherapy for the study period estimated to be 38682492.3, 6713390.5, 7213173.9 and 175180.9 USD per annum for cattle, sheep, goats and camel respectively. The total financial loss was 52784237.2 USD per annum. In human, the cost of computed tomography (CT) was estimated to be 85.5 USD and for Ultrasonography (US) was 12 USD per case, whereas the cost per surgical patient vary from 2906 to 9059.8 USD per surgical case (unpublished data).

CONCLUSION

Cystic echinococcosis is endemic in Western and Central Sudan. The dog-camel cycle seems to maintain the cystic echinococcosis in the investigated areas of Sudan. Cattle play secondary role in maintaining life cycle of *Echinococcus granulosus* and as reservoirs of human infection. However, sheep and goats only play a marginal role in the *Echinococcus granulosus* transmission cycle. *E. canadensis* 'camel strain' (G6) is predominant strain among domestic and wild animals and humans in Sudan, whereas *E. ortleppi* (cattle strain) and *E. granulosus* sensu stricto (sheep strain) are rare.

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