Occurrence of hydatid cysts in *Camelus dromedarius* at the slaughterhouse of Tindouf, Southern Algeria

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Abstract

Cystic echinococcosis is a neglected zoonotic parasitic disease of worldwide occurrence, caused by the metacestodes of *Echinococcus granulosus* sensu lato. In Algeria, cystic echinococcosis has a highest impact on public health and livestock production. Sheep-dog cycle has been described as the main cause of human contamination, but the role of other intermediate hosts such as infested camels is poorly studied. The present survey was conducted to estimate the infection rate of hydatid cyst in dromedary camels at the slaughterhouse of Tindouf, Southern Algeria. From January 2017 to January 2020, a total of 15772 carcasses were examined for cysts detection through gross examination, palpation, and incision of internal organs. Overall, 31 camels (0.20%) were found to be infested. Infection rate was 0.13% in males (19/14660) and 0.27% in females (3/1103). Regarding the age of camels, 10/5047 aged of 5 to 7 years and 12/10725 over 7 years showed an infection rate of 0.20% and 0.11% respectively. Sex and age of 9 camels were not recorded during the present study. The most frequent localization of cystic lesions was in liver (26/31; 87.10%), lung (3/31; 9.69%), and finally in both lung and liver (mixed infection) (2/31; 6.45%). Microscopic examination of the liquid of all hydatid cysts showed a fertility rate of 6.38% (3/47). All fertile cysts were recorded in liver (3/38; 7.89%). This epidemiological study provide data on the importance of cystic echinococcosis in dromedary camels from Algeria, and the role of camels in the epidemiological cycle of *E. granulosus* sensu lato.

Keywords: Algeria, dromedary camel, fertility, hydatid cyst, prevalence.

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Introduction

Cystic echinococcosis (CE) is one of the most common parasitic anthropozoonoses especially in developing countries, and considered as a major public health and economic concern (Thompson and Lymbery, 1990; Budke et al., 2006; Deplazes et al., 2017). This disease is caused by the larval stage of the tapeworm *Echinococcus granulosus* (EG), which has many different genotypes worldwide in relationship with the parasite's tolerance to a variety of domestic or wild intermediate hosts (Nakao et al., 2007; Endalew and Nurradis, 2013). The definitive hosts are carnivores like dogs that carry the adult worm in their small intestine, while the intermediate hosts are herbivores and omnivores including sheep and cattle where the larval stage or cyst develops in the liver, lungs and other internal organs (Kaplan and Baspinar, 2009; Ould Ahmed Salem et al., 2010). Several mammalian species (including humans) become infected via oral routes and/or through canines contact by ingesting tapeworm eggs from dog feces (Deplazes et al., 2017).

In North Africa, both cystic and alveolar echinococcosis have been reported, however, cystic echinococcosis is more common and is a serious public health problem (Sadjjadi, 2006; Fikire et al., 2012; Lahmar et al., 2013) particularly in rural communities where dogs live closely with humans and herbivores (Tilahun and Terefe, 2013).

CE has been linked to considerable economic losses in livestock worldwide (Torgerson and Deplazes, 2009; Youssefi et al., 2016), that result in condemnation of livers and lungs rendered inappropriate for human consumption, as well as reduced meat and milk productivity (Torgerson, 2003: Tembo and Emmanue Nonga, 2015; Jemal and Kebede, 2016). In addition, Echinococcosis results in death of roughly 19,300 people every year, according to the World Health Organization (WHO) (World Health Organization, 2020).

Several prior investigations (Battelli et al., 2002; Capuano et al., 2006; Grosso et al., 2012; El-Dakhly et al., 2019; Borhani et al., 2020) revealed that the disease is endemic in Algeria and nearby Mediterranean nations. Infection incidence rates varied widely across intermediate hosts of various species and were impacted by many environmental factors and sanitary conditions (Omar et al., 2013), that is exacerbated by the presence of infected stray dogs (El-Dakhly et al., 2019).

Some intermediate hosts (cattle, camels) are mainly reported infected and it may recognize these species as reservoirs of dog infection in Algeria, but sheep/dog cycle is commonly assumed as the cycle primarily implicated in human contamination (Pandey et al., 1988; Bahia, 1997; Bardonnet et al., 2003). The maintenance of the *Echinococcus granulosus* life cycle is linked to the feeding of stray dogs on offal from slaughtered animals (Daryani et al., 2009). In Algeria, up to 78 percent of sheep, 91 percent of cattle, and 26 percent of camels were found infected with CE (Bardonnet et al., 2003; Hamrat et al., 2011; Kouidri et al., 2012; Ouchene et al., 2014), and dog infection with *Echinococcus spp.* ranged from 16 to 51 percent (Benchikh-Elfegoun et al., 2008; Bentounsi et al., 2009). One of the most crucial aspects in the epidemiology of *Echinococcosis granulosus* is the fertility of hydatid cysts. It changes based on the intermediate hosts species and geographical locations (Kose and Kirakli-Sevilmi, 2008; Scala and Mazette, 2009).

To our knowledge, very little information about cyst fertility in camels from Algeria has been published. This lack of knowledge could result in misunderstanding of the real importance of intermediary host's contribution in the parasite life cycle (Gusbi et al., 1990).

The goal of this research is to assess the prevalence of hydatidosis, fertility of hydatid cysts in the liver and lungs of camels slaughtered in Tindouf slaughterhouse (Southwest Algeria). These findings are

significant because they provide solid markers of camels' importance as a possible source of infection for dogs and humans.

Materials and Methods

Study design

The present study was conducted to determine the occurrence of CE in *camelus dromedarius* (*N* = 15772) slaughtered in the municipal slaughterhouse of Tindouf province (southern of Algeria) during the period of January 2017 to January 2020. This region is located in the extreme west of Algeria, in the natural region of Saoura, on the border with Morocco (to the west), Western Sahara (to the south-west), and Mauritania (to the south). Tindouf province is characterized by a hot desert climate typical of the hyper-arid Saharan zone with relatively long and extremely hot summers, and short and moderately warm winters. The climate is largely hyper-arid and extremely dry throughout the year since the average annual rainfall is around 27 mm.

During this study, the slaughterhouse was visited periodically to examine the liver and lungs of slaughtered animals. It comprises both sexes and all age groups. Age was determined based on the dentition and owner's information.

The liver and lungs of camels were examined for the detection of hydatid cysts through visual inspection, palpation, and systematic incision of each internal organ. For each animal, liver and lungs were examined macroscopically to note the presence or absence of cysts, to determine the number of cysts, and to assess consistency of each one.

All hydatid cysts obtained from the lungs and liver of each animal were collected during the postmortem examination; extracted, counted, and carefully removed during evisceration by dissection; and finally placed into sterile boxes with the animal identification (age, gender, organ), and transported to the laboratory of parasitology at the Higher National Veterinary School, Algiers, Algeria.

Data management and analysis were carried out using Stata version 12 (StataCorp, College Station, TX, USA).

Examination of Cysts

47 cysts from one hundred slaughtered camels were excised and the contents (hydrated liquid) were transferred into sterile container and examined microscopically (X10) to determine their fertility that depends on the presence of protoscoleces. The cysts were classified into three categories, as follows: fertile hydatid cysts, containing protoscoleces and/or daughter cysts, sterile hydatid cysts, full of fluid but without protoscoleces, and calcified hydatid cysts with a degenerative modifications (calcification or caseation) and absence of protoscoleces or fluid (Kamenetzky et al., 2000; Dyab et al., 2005). Cysts which contained no protoscoleces as well as heavily suppurative or calcified were considered unfertile (Laatamna et al., 2019).

Results

Out of 15772 examined carcasses during the study period, 31 (0.20%) animals were found to be infested by hydatid cysts (Figures 1, 2). Note that gender and age of 9 infected camels were not recorded during sampling, and they were not included in the statistical analysis of these variables. The infection rate according to gender was 0.13% in males (19/14660) and 0.27% in females (3/1103). Camels aged 5-7 years and those over 7 years showed an infection rate of 0.20% (10/5047) and 0.11% (12/10725) respectively. The statistical analysis showed that gender and age did not enhance the risk of exposure to this disease with no significant difference (Table 1).

Table 1. Categorical data for the risk of exposure of camelids to echinococcosis in Tindouf, Algeria.

Factor	Result			Prevalence (%)	X^2	OR (95% CI)	P-value
		Positive (n)	Negative (n)				
Age	5-7	10	5037	0.20	1.8328	1.77 (0.76-4.1)	0.175*
	>7	12	10713	0.11			
	Total	22	15772	-			
Sex	Male	19	14641	0.13	1.4921	0.48 (0.14-1.62)	0.221*
	Female	3	1100	0.27			
	Total	22	15741	-			
Localisation	Liver	26	5	87.10	34.271	48.53 (10.53-223.6)	< 0.00001**
	Lungs	3	28	9.69			
	Mixed	2	29	6.45		Ref	

X^2; Chi-square Test; OR–Odds Ratio; CI–Confidence Interval at 95 %; *: Not significant, P > 0.05; **: Very Significant, P ≤ 0.01; Ref; Reference.

The liver showed the most frequent localization of hydatid cysts (Figure 1, 26/31; 87.10%), followed by the lungs (Figure 2, 3/31; 9.69%), and finally in both organs (2/31; 6.45%).

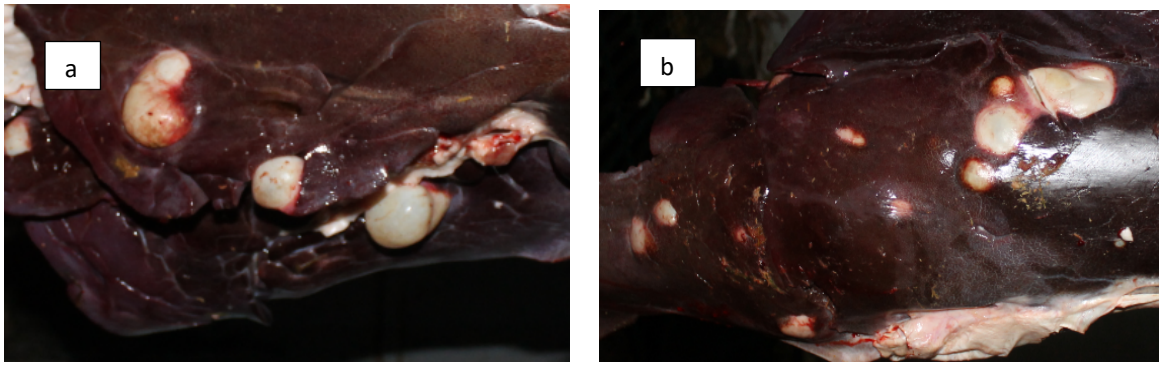

Figure 1. Hydatid cyst in the liver of slaughtered camels in Tindouf, Algeria.

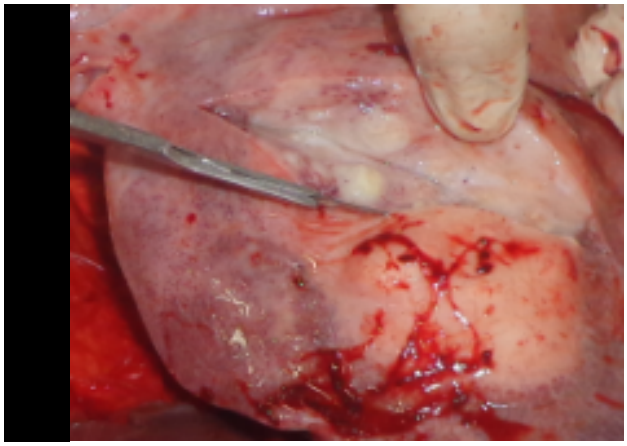

Figure 2. Hydatid cyst in the lung of slaughtered camels in Tindouf, Algeria.

Microscopic examination of the hydatid cyst fluid showed a fertility rate of 6.38% (3/47). 91.48% (43/47) of the investigated cysts were sterile and only one (1/47) was calcified (2.12%). All fertile cysts were recorded in the liver (3/38; 7.89%) (Table 2).

Table 2. Data analysis of fertility of hydatid cysts removed from slaughtered camels in Tindouf, Algeria.

Type	Infested Organ		Total
	Liver	Lungs	
Fertile	3/38 (7,89%)	0/9 (0%)	3/47 (6,38%)
Sterile	35/38 (92.11%)	9/9 (100%)	44/47 (93,62%)

Discussion

Interesting findings are presented in the current study about the occurrence of CE and various possible individual factors connected to the presence of hydatid cysts in camels from slaughterhouses in Tindouf district, Algeria. Given the lack of information on CE in southern Algeria, our work adds new knowledge regarding its prevalence and the actual role of camels in the upkeep of epidemiological statute of this zoonotic disease in this region.

Despite the efforts to control slaughtering procedures and increase health education that has mostly been designed to disrupt the typical sheep/dog cycle of the *Echinococcus* spp, CE remains a significant public health issue in Algeria.

In various nations, inspection records of slaughtered animals have served as important sources for assessing the epidemiological aspect of some diseases such as echinococcosis with their spatiotemporal spread (Blaise, 2001; Lotfi et al., 2010).

The current results highlight the crucial phases of *Echinococcus granulosus*' life cycle. The most typical transmission pattern and primary source of infection for humans is the synanthropic cycle comprising domesticated dogs and animals (such as sheep and cattle) (Zhenghuan et al., 2008).

In the current study, a very low infestation rate of 0.20% (31/15772) for camels slaughtered at Tindouf abattoir was recorded. Additionally, greater CE rates in camels were reported in other studies (Bardonnet et al., 2003; Ouchen et al., 2014); these rates were 8.35% and 24.8% at the Ouargla and Touggourt slaughterhouses from Algeria's northern Sahara, respectively. In camels from the Adrar region in southern Algeria, another study found a very significant frequency of hydatid cysts (16.62–24.88%) (Hamrat et al., 2011). Ould Ahmed Salem et al. (2010) and Azlaf and Dakkak (2006) reported disappointing results from Mauritania (5.9%) and the Rif Mountains of Morocco (7.37%), respectively. Similarly, camels from Beni Suef and Upper Egypt had been documented to have lower levels of 2.35% and 5%, respectively (Gab-Allah and Saba, 2010; Omar et al., 2013). In comparison to earlier investigations made by Dyab et al. (2005) in Egypt (7.67%) and Lahmar et al. (2013) in Tunisia, the frequency of CE identified in camels in the current study (0.20%) was significantly lower. Similarly, according to other studies (El-Dakhly et al., 2019; Tashani et al., 2002; Omondi et al., 2020), camels in various municipal slaughterhouses from different regions of Egypt, Libya, and Kenya had higher incidence rates of CE of 10.82%, 13.6%, and 29.1%, respectively. Gareh et al. (2021) showed that hydatid cysts were detected in 6% of examined camel lungs in Egypt.

In certain Algerian abattoir investigations, a significantly greater prevalence has been recorded in other animal

species (Laatamna et al., 2019), and the prevalence of 0.20% in camels is extremely low compared to other rates across worldwide endemicity parts (Deplazes et al., 2017).

Many authors suggested that a number of factors, including gender and age of the slaughtered animals, sample size, identification and screening methods, the geographic location, and various climate variables, may contribute to the substantially varying CE incidences (Sanli et al., 2011; Omar et al., 2013; Otero-Abad and Torgerson, 2013; Romig et al., 2015; Omondi et al., 2016).

In addition, the affinity and responsiveness of the parasite to the species of *Camelidae* is related to the hot, dry climate with low pluviometry which favors the propagation of the *Echinococcus granulosus* by jackals and stray dogs and extension of parasite in space by the transhumance and consumption of the eggs which are worn on the pastures (Christy, 1989; Jiao et al., 2005).

Moreover, the unhygienic disposal of condemned carcasses and infected organs, the ease of access stray dogs to slaughterhouses, and the unauthorized slaughter are also relevant factors in the transmission and spread of CE (Otero-Abad and Torgerson, 2013; El-Dakhly et al., 2019).

Considering age as a variable element, our study shows that older male camels (over 7 years) had a hydatid cyst frequency rate of 0.11% (12 out of 10725 investigated camels), but younger male camels (aged 5 to 7 years) had a hydatid cyst occurrence rate of 0.20% (10 out of 5047 studied camels), so there are hydatid cysts in both age categories with no significant difference. The current results concur with a number of other investigations conducted internationally (Tashani et al., 2002; Zewdu et al., 2010; Mulatu et al., 2013; Abo-Aziza et al., 2019).

According to Azlaf and Dakkak (2006) and Lahmar et al. (2013), a substantial significant difference between age groups in the rates of infection was recorded, and the most infected animals were older than 3 years.

This finding may be explained by the fact that older animals are exposed to *E. granulosus* eggs for longer periods of time, and that older animals are slaughtered more than younger ones because they have fewer productivity and less working ability (Ibrahim et al., 2011; Adinehbeigi et al., 2013). Since older animals have weakened immune systems that make them less able to fight off infections, immunity may also play a role in this discrepancy (Adinehbeigi et al., 2013). Because cysts tend to be larger in older animals, the likelihood of finding them during meat inspection is increased (Baswaid, 2007).

In our research, we observed that males (19/14660) had an infection rate of 0.13%, whereas females (3/1103) had an infection rate of 0.27%. The observed hydatid cysts in camels were found equally in both males and females when taking gender into account as a possible risk factor (P=0.2222). The fact that fewer females than males were examined in our study may result in this disparity.

Among other investigation, Kouidri et al. (2013) found that females were more likely than males to have CE infection (P=0.005) in small ruminant from western Algeria (Tiaret). Males are less likely than females to contract the metacestode of *E. granulosus*, and the parasite has been linked to persistent hormonal imbalances in chronic stages, particularly in the levels of testosterone and oestrogen (Blancas et al., 2007).

Other studies (Haleem et al., 2018; Abo-Aziza et al., 2019; Guduro and Desta, 2019) reported that management practices and age at slaughter were thought to be potential risk factors. In extensive and semi-extensive management of farms, animals are more likely exposed to dogs' feces that may contain eggs of *Echinococcus* spp. According to Iqbal et al. (2012), the stress of pregnancy, delivery, and nursing might increase a host's vulnerability to parasite infection.

The particularities of blood circulation may explain why hydatid cysts preferred the liver and lung more than other viscera. Lungs contain massive capillary networks. The liver receives a lot of blood from both portal veins and hepatic arteries; 25% of the blood flow into the liver originates from the hepatic arteries, which serve as the liver's main source of oxygen. The remaining 75% comes from the portal veins, which move different nutrients and dangerous compounds from the digestive tract to the liver (jointly from the veins of the stomach, intestine, spleen, and pancreas) (Qingling et al. 2014). Before reaching other peripheral organs, the oncosphere of *Echinococcus granulosus* is retained by the vast capillary networks in these organs. (Kebede et al., 2009a; Qingling et al., 2014).

The greater frequency of liver cysts may possibly be related to the younger age at which camels are killed. Few cysts might go via the bloodstream to the lungs at this time because the liver's capillaries are not dilated. The difference in organ distribution of cysts might be referred to strains and genetic diversity of the parasite. In addition, the hexacanth embryo may penetrate the lymphatic system and travel down the thoracic duct to the heart and lung, in this situation, the lung would get infected before the liver (Taylor et al., 2007).

The current investigation showed that camel livers were the most prevalent site of CE (26/31; 87.10%), whereas only three lung cysts (3/31; 9.69%) occurred. Similar outcomes have been documented by Omondi et al. (2020) in Kenya, but our findings contradict those numbers of earlier studies that suggested lung was the organ with the greatest infestation (Mahdy, 2014; Abbas et al., 2016; Abo-Aziza et al., 2019). However, according to Hamrat et al. (2011), additionally to camels, the lung seems to being the most badly afflicted organ in small ruminants, and these results were confirmed in other studies conducted by Tashani et al. (2002), Azlaf and Dakkak (2006), and Kebede et al. (2009b).

In a comparable result, Dakkak (2010) found that 85% of infested camels had cysts in their lungs. According to a recent echinococcosis examination in Egypt, CE was only found in camels' lungs (Gareh et al., 2021). Only two camels in the current study had a cyst infestation in both liver and lungs. The outcome was consistent with earlier research findings from Azzlaf and Dakkak (2006), Kouidri et al. (2012), and Getachew et al. (2012).

Fortunately, the involvement of only one organ has been documented, previous surveys indicated that the parasite showed double-organ involvement, and this finding is likely due to the parasite's strain and the studied geographic locations (Gottstein, 2000; El-Majdoub and Drah, 2008; Omar et al., 2013; Gareh et al., 2021).

Protoscoleces connected to the germinal layer and free protoscoleces in the hydatid fluid are further indicators of cyst fertility (Galindo et al., 2002). To understand the significance of fertile cysts in the disease's spread and to determine the likely role of each animal species in the dissemination of infection, the fertility rate of cysts is a key element in epidemiological investigations (Jarjees and Al-Bakri, 2012). In small ruminants from Algeria, sheep cysts were found to be more fertile than goat cysts, as also reported by Jarjees and Albakri (2012) in Iraq.

In the current study, almost all examined hydatid cysts were sterile (91.84%). In Sudan, Elmahdi et al. (2004) indicated that majority of the collected cysts were calcified (60%). Our findings were in contradiction with those reported by Gareh et al. (2021) which revealed that the major of collected hydatid cysts were fertile (66.7%) and only one was sterile (16.65%).

In addition, three camels had a single hydatid cyst, and three other animals had numerous hydatid cysts. The distinctive tissue resistance between the organs might be the cause of the variation in the fertility rates (Getachew et al., 2012). In contrast to

pulmonary cysts (0/11; 0.00%), the current study found that the fertility of hepatic cysts was highest (3/38; 7.89%). These findings conflicted with those published in Egypt by Gareh et al. (2021) and Kenya by Omondi et al. (2020), which demonstrated that fertile cysts were only found in the lungs of studied camels. It was reported that the considerably softer nature of lung tissue permits simpler formation of the cysts and favors their fertility (Himonas et al., 1987; Getaw et al., 2010), moreover, this may be connected to the small number of parasites that transfer to lungs via blood circulation. Since older animals have weakened immune system to fight infections, immunity may also play a role in this discrepancy (Himonas et al., 1987).

In both the liver and the lungs, there were a significant number of sterile cysts. This might be related to the development of a strong immune response against the parasite particularly in the liver. Meanwhile the relatively higher levels of reticuloendothelial cells and connective tissue reaction may enclose the cyst in a fibrous wall and render it sterile, limiting its ability to grow in the tissues (Regassa et al., 2010). According to McManus (2006) and Samari et al. (2022), the genotype of the parasite and variations in host immune responses may be responsible for fertility differences. Samari et al. (2022) revealed presence of *E. granulosus* G1, G3 and G6 genotypes with high haplotype variability that might be responsible for the difference in organ distribution and fertility rate of cysts.

Furthermore, the relevance of the liver as a possible source of infection for dogs is demonstrated by the increased incidence and fertility rate of hepatic cysts compared to pulmonary cysts removed from camels.

Conclusion

The findings of this investigation showed that cystic echinococcosis had been occurred in camels in the Tindouf district of southwest Algeria. Furthermore, due to its low infection rate along with low fertility of cysts, dromedary camels do not appear to be of great significance in the patterns of infection transmission in the studied area, as most of the cysts removed from them were sterile. These findings suggest that camels have a limited role in the maintenance of the zoonotic foci and the spread of the disease, but our results also suggest the possible spreading of this zoonotic disease to other provinces with animal movements.

However, a number of other variables, including the climate, socioeconomic status, management of agricultural and animal husbandry, cultural and religious practices, and transnational commercial exchanges, all have a role in the spread of CE in Algeria. The identification of the species of *Echinococcus spp.* that are circulating nationwide and further investigation into the participation of other intermediate hosts in the same study regions are advised.

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The author declares that there is no conflict of interest.

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