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Hydatidosis in camels (*Camelus dromedarius*) and their potential role in the epidemiology of *Echinococcus granulosus* in Iran

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Abstract

Hydatid cysts were recovered from 35.2% (233/661) of camels (*Camelus dromedarius*) slaughtered in five different regions of Iran. The degree of prevalence between males (34.4%) and females (36.6%) was not statistically significant. The highest rate of infection (59.3%) was found in the Isfahan region (in the central part of Iran) while the lowest (25.7%) was found in Kerman province. The organ distribution of cysts was 49.4% in lungs alone, 30.0% in both liver and lungs, 14.6% in liver only and 6.0% in other organs. Therefore, the lungs were the predominant sites of the hydatid cyst. The range in the number of cysts was 1–48 in infected animals. The majority of the camels had 1–5 cysts, with 21.9%, 11.6% and 5.6% of infected camels having 6–10, 11–20 and 21 or more cysts respectively. There was a direct relationship between the rate and intensity of infection and host age. The fertility rate of lung cysts (69.7%) was higher than that of liver cysts (58.7%) and other organs (50.0%) whilst the viability rate of protoscoleces of liver fertile cysts (80.3%) was significantly higher than that of lung cysts (55.8%) and other organs (57.1%). The role of camels in the epidemiology of *Echinococcus granulosus* in Iran is discussed.

Introduction

Cystic echinococcosis (CE) caused by *Echinococcus granulosus* has a worldwide distribution (Craig *et al.*, 1996) and occurs in many domestic animal intermediate hosts. Hydatidosis is one of the major infectious zoonotic diseases in Iran, especially where livestock animals are still slaughtered traditionally and carcass wastes are easily accessible to scavenging dogs and other wild carnivores (Fallah *et al.*, 1995; Eslami & Hosseini, 1998). In Iran, CE is known to occur in humans and many livestock animals including camels. The domestic sheep form, however, appears to be the most important for zoonotic potential. Developmental and molecular evidence also suggests that a separate camel strain of *E. granulosus* occurs in Iran, but it infects humans at a very low level (Hosseini & Eslami, 1998; Ahmadi, 2000; Ahmadi & Dalimi, 2002; Harandi *et al.*, 2002). Camel hydatidosis has been investigated in a number of countries in the Middle East and northern Africa with reported prevalence rates of 11.3–70% in Iran (Mobedi *et al.*, 1970; Afshar *et al.*, 1971; Motakef *et al.*, 1976; Moghaddar *et al.*, 1992), 77.5% in Pakistan (Anwar & Khan, 1998), 39.6% in Kuwait (Abdul-Salam & Farah, 1988), 8.8% in north Jordan (Al-Yaman *et al.*, 1985), 31% in Egypt (Rahman *et al.*, 1992), 80% in Morocco (Pandey *et al.*, 1986) and 48% in Libya (Ibrahem & Craig, 1998).

In Iran, the camel is still an important animal used for carriage purposes, in addition to being a good source of meat and sometimes for milk production especially in desert and semi-desert areas. A large number of camels (approx 143,000) are raised in Iran, particularly in the eastern half of the country (Anon., 1997). Cystic hydatidosis can be a major problem in that it affects the productivity and working efficiency of camels, and is also a potential danger for public health. The main aims of the present study were to determine: (i) the frequency and intensity of infection; (ii) the variety of internal organs involved; (iii) the proportion of fertile cysts; (iv) the

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viability of protoscoleces of fertile cysts in the liver, lungs and other sites; and (v) the effect of host age, sex and the geographical region on infections in slaughtered camels.

Materials and methods

The study was performed in five main regions where camels are mainly harboured (fig. 1). From each region, an abattoir where camels were slaughtered was selected. These abattoirs were visited between 2001 and 2002. At each visit, the lungs, liver, heart, spleen and kidneys of each animal recently slaughtered were grossly but carefully checked for the presence of hydatid cysts. Host age, sex and the number of cysts on each organ were also recorded. Each carcass was inspected individually by a veterinarian together with the author. The cyst fluid was aspirated using a sterile syringe from each infected organ, and a drop of each sample of cyst fluid was placed on a microscope slide and examined for the presence of protoscoleces or brood capsules. If protoscoleces were present, the corresponding cyst was considered fertile and the viability of the protoscoleces was assessed using a 0.1% eosin in a dye-exclusion test (Smyth & Barrett, 1980). Live protoscoleces did not take the dye up, whereas dead ones did. The viability rate was then calculated as the percentage of viable protoscoleces present. Cysts with fluid only and without protoscoleces were considered sterile, and all hard cysts were classified as calcified. Student's t-tests were applied for means of the viability of protoscoleces, and two proportions were compared by calculating the Z statistic. Correlation coefficients (r) were calculated to determine the relationship between host age and the mean number of hydatid cysts, and also with prevalence and fertility rates. In all tests, a *P*-value of <0.05 was considered statistically significant.

Results

Prevalence of infection

Of 661 camels examined from five regions, 233 (35.2%) were found to be infected with hydatid cysts (table 1). The prevalence of hydatidosis in Isfahan (in the central part of Iran) was significantly higher than in other regions ($P < 0.005$). The overall and regional infection rates for male and female camels are shown in table 1. Host age and prevalence were correlated in the camels as shown in fig. 2 ($r = 0.986$). Age-prevalence profiles showed that

Fig. 1. Map of Iran, showing the geographical locations (●) where *Echinococcus granulosus* samples were collected from camels.

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Table 1. The prevalence (%) of cystic echinococcosis in male and female camels in five regions of Iran in 2001–2002.

	Males		Females		Total	
Regions	No. examined	Prevalence (%)	No. examined	Prevalence (%)	No. examined	Prevalence (%)
Yazd	130	26.1	32	28.1	162	26.5
Kerman	65	24.6	79	26.6	144	25.7
Zahedan	66	31.8	50	34.0	116	32.7
Mashhad	74	37.8	47	36.2	121	37.2
Isfahan	69	58.0	49	61.2	118	59.3
All	404	34.4	257	36.6	661	35.2

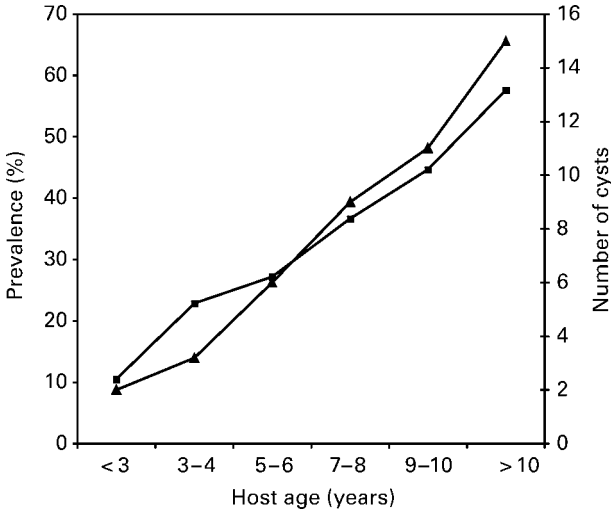

Fig. 2. Age prevalence (■) and intensity of infection (▲) profiles of hydatid cysts in camels in Iran.

10.5% of camels less than 3 years old had CE, which rose to 57.6% in camels aged 11 years or older (table 2).

Cyst location

Lungs were the most commonly infected organs. Overall, 49.4% of infected camels harboured cysts in the lungs alone, with only 14.6% having cysts in the liver and 30.0% having cysts in both liver and lungs. Infections in other locations represented 6.0% of all camels examined (table 3). Lung infections were significantly more common than those in the liver or other organs ($P < 0.001$). The prevalence of hydatid cysts in different organs of male and female camels in different areas is shown in table 3. Proportions of infections pertaining to different organs in infected camels were similar in the various age-groups. Table 2 shows the location of cysts relative to age groups.

Intensity of infection

The majority of infected camels (60.9%) harboured 1–5 cysts each, 21.9% had 6–10 cysts, 11.6% had 11–20 and 5.6% had >20 cysts each. The intensity of infection (cysts per animal) showed a direct relationship with host age (fig. 2) ($r = 0.991$). Distribution of number of cysts in different areas is listed in table 4.

Cyst fertility and viability

A total of 197 (65.0%) of the 303 examined cysts were fertile. Of the remaining cysts, 59 (19.5%) were sterile and 47 (15.5%) were calcified.

The fertility rates of cysts in different organs varied considerably (table 5). The proportion of fertile cysts in the lungs was higher (69.7%) than in the liver (58.7%). Only 15.7% of the lung infections were sterile and 14.6% were calcified; meanwhile, 22.1% of liver infections were sterile and the remainder (19.2%) calcified. In the other organs, 50.0% of the infections were fertile and the remainder (50.0%) sterile (table 5). Age-fertility profiles showed that 41.7% of camels less than 3 years old harboured protoscoleces, which rose to 75.4% in camels of 7–8 years old, and then decreased to 57.4% in camels over the age of 10 (table 2).

Table 5 shows the relative viability of cysts in the lungs, livers and other organs of the camels relative to sex. The viability ranged from 4% to 100%, so that the percentage of viable protoscoleces in the liver fertile cysts (80.3%) was significantly higher than that of lung cysts (55.8%) and other organs ($P < 0.005$).

Table 2. The prevalence (%), site, fertility and intensity of infection of Iranian camels with cystic echinococcosis, relative to host age.

Host age (years)	No. examined	Prevalence (%)	Lungs (%)	Liver (%)	Lungs + liver (%)	Other organs (no.)	Fertility (%)	Mean no. of cysts (range)
<3	86	10.5	66.7	0	33.3	0	41.7	2 (1–4)
3–4	91	24.2	54.6	13.6	27.3	1	67.9	3.2 (1–5)
5–6	108	25.9	50.0	14.3	28.6	2	75.0	6 (2–13)
7–8	128	36.7	48.9	14.9	29.8	3	75.4	9 (2–17)
9–10	123	44.7	47.3	16.4	30.9	3	63.9	11 (3–29)
≥11	125	57.6	47.2	14.9	30.6	5	57.4	15 (3–48)

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Table 3. Prevalence (%) of hydatid cysts in different organs of male and female camels from five regions of Iran in 2001–2002.

Regions	Males					Females					Total				
	No. infected	Lungs (%)	Liver (%)	Lungs + liver (%)	Other organs (%)	No. infected	Lungs (%)	Liver (%)	Lungs + liver (%)	Other organs (%)	No. infected	Lungs (%)	Liver (%)	Lungs + liver (%)	Other organs (%)
Yazd	34	52.9	8.8	32.3	5.9	9	44.4	11.1	33.3	11.1	43	51.2	9.3	32.6	7.0
Kerman	16	37.5	6.2	43.7	12.5	21	52.4	28.6	14.3	4.8	37	45.9	18.9	27.0	8.1
Zahedan	21	42.8	23.8	28.6	4.8	17	41.2	17.6	35.3	5.9	38	42.1	21.0	31.6	5.3
Mashhad	28	57.1	14.3	25.0	3.6	17	52.9	11.8	29.4	5.9	45	55.6	13.3	26.7	4.4
Isfahan	40	50.0	12.5	32.5	5.0	30	50.0	13.3	30.0	6.7	70	50.0	12.9	31.4	5.7
Total	139	49.6	12.9	31.7	5.8	94	48.9	17.0	27.7	6.4	233	49.4	14.6	30.0	6.0

Table 4. The intensity of infection of camels with hydatid cysts in five regions of Iran in 2001–2002.

Regions	% of camels with			
	1–5 cysts	6–10 cysts	11–20 cysts	≥20 cysts
Yazd	67.4	18.6	11.6	2.3
Kerman	64.9	21.6	8.1	5.4
Zahedan	60.5	23.7	10.5	5.3
Mashhad	60.0	22.2	11.1	6.7
Isfahan	55.7	22.9	14.3	7.1
Total	60.9	21.9	11.6	5.6

Discussion

Hydatidosis is an important zoonotic disease in Mediterranean and Middle East countries (Craig *et al.*, 1996; Schantz *et al.*, 1995). Studies in various parts of Iran confirm the fact that Iran is an endemic or hyperendemic area for *E. granulosus* and CE (Mobedi *et al.*, 1970, 1973; Hoghoughi, 1971; Dalimi & Mobedi, 1992; Moghaddar *et al.*, 1992; Mehrabani *et al.*, 1999; Dalimi *et al.*, 2002). The population of camels in Iran was more than 143,000 in 1997 and they were distributed in 19 of the 27 provinces (Anon., 1997). Of the total camel population, 77.6% (111,000) is distributed in the eastern half of Iran including Khorassan, Kerman, Sistan-Baluchestan and Yazd (Anon., 1997), which is mainly hot and arid or semi-arid, and climatically represents a less favourable environment for the long term survival of *Echinococcus* eggs.

Data on the prevalence of hydatidosis in camels and other intermediate hosts provide a reliable indicator of the extent of local environmental contamination with eggs from carnivores (Schwabe, 1968). In Iran, according to a few previous studies, the prevalence of CE of camels has previously been reported to be 64%, 42.8%, 11.4% and 70% in Tehran, south of Iran, Khorassan and Shiraz respectively (Mobedi *et al.*, 1970; Afshar *et al.*, 1971; Motakef *et al.*, 1976; Moghaddar *et al.*, 1992). In the present study, 35.2% of slaughtered camels in different regions of Iran were found to be infected with hydatid cysts. The infection rate in camels from Isfahan province in central Iran was significantly higher than in those from other regions. In a recent study of echinococcosis in dogs, the highest prevalence of *E. granulosus* was also reported from Isfahan province (Eslami & Hosseini, 1998). In addition, large parts of Isfahan climatically represent a more favourable environment for the survival of *Echinococcus* eggs. Therefore, a positive correlation is more likely to be found in the prevalence of infection in camels and dogs in Isfahan province. This variation in the prevalence rate of CE in camels in different areas of the country may be due to a number of factors, including the chance of exposure to *E. granulosus* eggs from dogs (Gusbi, 1987), climate conditions, education about the disease and performance of control and prevention programmes. In Mashhad (Khorassan province) in the north-east region of Iran, the infection rate of CE was higher than previously reported (Motakef *et al.*, 1976). It is possible that some camels may have come to Iran from neighbouring countries such as Pakistan and

Afghanistan, where CE has been reported, e.g. 77.5% in camels in Pakistan (Anwar & Khan, 1998), and also 39.6% in Kuwait camels (Abdul-Salam & Farah, 1988). Whether imported camels were sent directly to the abattoirs for slaughtering or reared for several months (or even years) in Iran prior to slaughter is not known due to the absence of accurate records. The prevalence of CE in camels relative to host sex did not significantly vary in each region.

Another important factor to be considered is the age of the camel. The prevalence rate in infected camels over 10 years of age during this survey was almost 5.5 times more that observed in camels aged under 3 years. An increase in the infection rate of camels with age (fig. 2) had already been noted in south Iran (Afshar *et al.*, 1971). Ibrahem & Craig (1998), observed an age-correlated increase in Libya in the overall prevalence of *E. granulosus* in camels, from 9% of recognizable hydatid cysts in camels of under 2 years old to 55% in camels aged over 8 years. In the Iranian camels, the lungs were the most commonly infected organs (79.4%), either alone (49.4%) or jointly with the liver (30.0%) (table 3). This agrees with data from Tehran (Iran), Jordan, Libya and Pakistan (Mobedi *et al.*, 1970; Al-Yaman *et al.*, 1985; Ibrahem & Craig, 1998; Anwar & Khan, 1998).

In the present study, while the majority of camels (60.9%) were lightly infected (1–5 cysts per animal), only 5.6% of them harboured heavy infections (>20 cysts per animal). The number of cysts found in infected camels did vary from region to region in Iran (table 4) but these differences were not significant, neither was the difference in the intensity of infection relative to host sex (data not shown). In addition, the number of cysts (which ranged between 3 and 48 per infected camel) was also higher in camels over 10 years of age. In contrast, young camels (<3 years old) harboured up to 4 cysts per animal and these occurred only in the lungs or jointly with the liver. This result agrees with that of Ibrahem & Craig (1998) who also reported a positive correlation between the intensity of infections of CE and the age of camels.

The fertility of cysts is an important factor that can influence the transmission of *E. granulosus*. Depending on the geographical situation, the nature of infected hosts and the sites of infection, cysts may have different fertility rates. The present work shows that the majority of infections (65.0%) in camels were fertile, and data on cyst fertility were similar to those recorded by other workers elsewhere (Gomez *et al.*, 1980; Al-Yaman *et al.*, 1985; Abdul-Salam & Farah, 1988; Gusbi & Awan, 1990). On an organ basis, the highest fertility rates were seen in the lungs, rather than the liver, these being the two most commonly infected organs. These results are supported by findings in Libya by Gusbi & Awan (1990). Sex-related differences in fertility rates were not statistically significant in the present study. Age-fertility profiles showed that the fertility rate increases with the age of camels; 41.7% of camels less than 3 years old had protoscoleces, which rose to 75.4% in camels of 7–8 years, and then decreased to 57.4% in camels over 10 years of age (table 2).

Results presented here indicate that viability ranged from 4% to 100%. The percentage of viable protoscoleces in the liver fertile cysts was significantly higher than that

Table 5. Fertility rates (%) of hydatid cysts and the viability of protoscoleces of fertile cysts in Iranian camels, relative to internal organs and host sex.

Internal organs	Males: Number of cysts examined	Males: Fertile (%)	Males: Sterile (%)	Males: Calcified (%)	Males: Viability (%)	Females: Number of cysts examined	Females: Fertile (%)	Females: Sterile (%)	Females: Calcified (%)	Females: Viability (%)	Total: Number of cysts examined	Total: Fertile (%)	Total: Sterile (%)	Total: Calcified (%)	Total: Viability (%)
Lungs	113	68.1	17.7	14.2	57.1	72	72.2	12.5	15.3	53.8	185	69.7	15.7	14.6	55.8
Liver	62	58.1	24.2	17.7	80.6	42	59.5	19.0	21.4	80.0	104	58.7	22.1	19.2	80.3*
Others	8	50.0	50.0	0.0	50.0	6	50.0	50.0	0.0	66.7	14	50.0	50.0	0.0	57.1
Total[a]	183	63.9	21.3	14.8	64.1	120	66.7	16.7	16.7	62.5	303	65.0	19.5	15.5	63.4

[a] Total infected organs: 303 (183 from male and 120 from female) because of multiple infections.
*Statistically significant between lungs and other internal organs.

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of lung cysts and other organs. Similar findings were reported in a study from Libya (Tashani *et al*., 2002).

Preliminary studies, based on DNA analysis (Ahmadi, 2000; Ahmadi & Dalimi, 2002; Harandi *et al*., 2002), morphometry of the larval rostellar hooks (Ahmadi, 2004), and/or the speed of development in the definitive host (Hosseini & Eslami, 1998), have already indicated that there are at least two distinct strains of *E. granulosus* (namely the sheep and camel strains) in Iran. Hosseini & Eslami (1998) suggested that protoscoleces of camel origin were readily infective to dogs, and a high proportion of them developed into adult worms. However, as Ahmadi (2000) and Harandi *et al.* (2002) reported, humans, sheep, cattle and camels can be infected with either strain. Moreover, the typing of *E. granulosus* strains was performed using a comparison of polymerase chain reaction (PCR)-amplified DNA sequences with one nuclear (BG 1/3) and two mitochondrial (CO1, ND1) targets by Bardonnet *et al.* (2002) in Mauritania, showing that the 'camel' strain is infectious to humans and transmission occurs between intermediate hosts including camels and cattle. Although previous studies have indicated that humans are refractory or poorly susceptible to infection with the camel strain of *E. granulosus* (Thompson & Lymbery, 1988; Washira *et al*., 1993; Rosenzvit *et al*., 1999), human infections with this strain can be found in Iran, and camels can act as reservoirs of human CE (Ahmadi, 2000; Ahmadi & Dalimi, 2002). In Iran, as in Kenya (Washira *et al*., 1993) and Argentina (Rosenzvit *et al*., 1999), the life-cycles of the sheep and camel strains probably overlap, both in the intermediate and definitive hosts.

As humans do not normally consume the lungs and liver of slaughtered camels in Iran, these organs are used for feeding dogs or other carnivores. Moreover, a full inspection of the lungs and other organs of slaughtered camels is not always carried out during routine rapid meat inspection. Therefore, the high rates of prevalence, fertility, viability and intensity of infections in camels and also the infectivity of the camel strain in humans indicate much potential for the transmission of *E. granulosus* in Iran. This is not only a threat to the health of camels but is also a potential danger for the human population, particularly those inhabiting rural areas where diagnostic facilities are rarely available and offal is incorrectly disposed of or where slaughtering is practiced on farms. Thus camels could play a major role in the transmission of *Echinococcus granulosus* in Iran, and the camel–dog cycle should be targeted in any control programmes.

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