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Review Article

A Partial Annotated Bibliography of Echinococcosis/ Hydatidosis in the One-Humped Camel

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Abstract

The one-humped camel is an important domestic animal in arid and semiarid areas of Mediterranean Africa, East Africa and West and South Asia where it contributes to human livelihoods and welfare. Little studied until recently infection with hydatid cysts of *Echinococcus granulosus* has now been recorded in the animal in more than 20 counties of its recorded natural range. In comparative studies, mostly on animals slaughtered for human consumption, that include other domestic ruminants the camel usually has higher rates of infection than sheep, cattle or goats. Highest rates of infection of internal organs are usually found in the lungs and secondarily in the liver whereas in other livestock the predilection site is usually the liver. Most studies have examined the epidemiology of the disease but more recent ones have attempted molecular characterization and descriptions of the G6 (camel) strain of *E. granulosus*. The camel is often regarded as an anachronism by national administrations and veterinary services but as an important domestic animal for often marginalized human groups and as a potential source of infection for human's identification and control of hydatid disease more attention to the problem is warranted.

INTRODUCTION

Studies on the adult stage of *Echinococcus granulosus* in the dog were first undertaken as early as 1685 and then again in 1808. Elucidation of the life cycle of this parasite was published in the 1850s when its connection with hydatid disease in man was recognized. By the end of the 19th century, many papers had appeared describing the geographical distribution of the disease which is most commonly associated with sheep-raising countries. Australia, New Zealand, Iceland, South America and parts of North and South Africa are usually identified as the areas of greatest prevalence [1].

The zoonotic parasitic infection known as echinococcosis is caused by the larval stage of several species of the genus *Echinococcus*. Echinococcosis in humans results from direct or indirect infection from canid hosts which are themselves infected by various domestic and wild mammals. Echinococcosis is a major public health concern particularly in developing regions with limited economic resources and constitutes a significant financial constraint derived from human health costs and livestock production losses [2]. Cystic echinococcosis is usually maintained by the domestic cycle (dog/domestic ungulate) and represents a persistent zoonosis in rural livestock-raising areas where humans cohabit with dogs fed on raw livestock offal [3].

Transmission of *E. granulosus* relies primarily on the cycle in which domestic livestock species act as intermediate hosts. Principal determinants of livestock infection found in literature studies encompass the animal species, level of environmental contamination with parasite eggs, age of the host, study location, different livestock origins, season, altitude, temperature, rainfall and sex [2]. Studies differ, however, on which livestock species presents the highest rates. Small ruminants have frequently shown high rates of infection with sheep registering higher risks compared to goats. Cattle have also been identified as bearing the highest prevalence of those observed in domestic animal species [2].

Although comparatively less studied than other domestic animals, camels have often been reported as the intermediate host most likely to be infected and to transfer the zoonose to humans. This paper presents comprehensive but by no means complete information on infection by *Echinococcus* species in the one-humped camel in more than 20 countries throughout its natural range from West Africa to India in terms of longitude and from Iran to Kenya in terms of latitude (Figure 1).

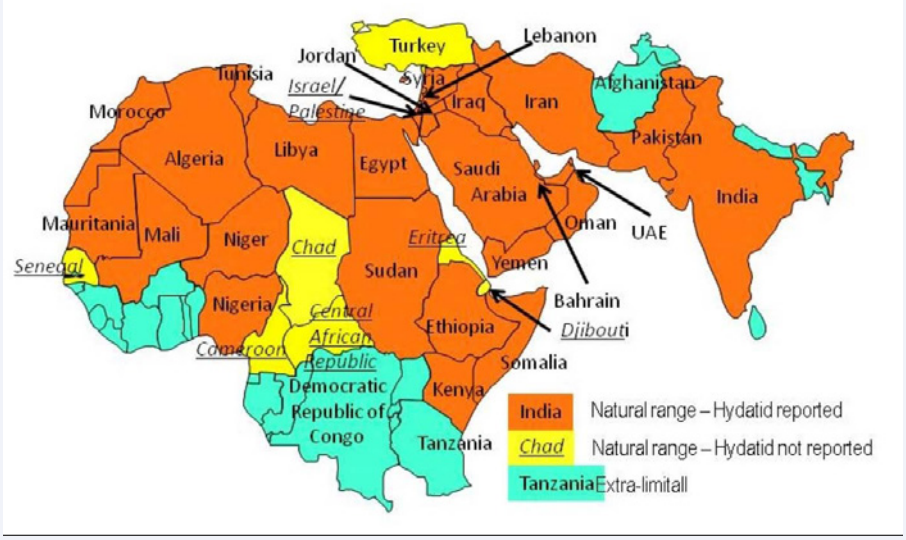

Figure 1 Presence of hydatid cysts in the one-humped camel across its normal range (source: compiled by author).

RESULTS

Algeria

Reports from as early as 1908 [4] and 1952 [5] provide information on echinococcosis in camels in Algeria. In one study it was found that 5.4 % percent of cattle were infected, 14.3 percent of sheep, 21.2 percent of goats and 42.1 percent of camels [6]. Molecular typing by PCR amplification and sequencing of mitochondrial genes of cytochrome oxidase 1 (CO1) and NADH dehydrogenase 1 (ND1) were used to characterize 42 isolates of *E. granulosus* from 28 animals (17 camels, 4 sheep, 4 cattle and 3 goats) collected in slaughterhouses and 14 collected on humans in surgical services in southern Algeria. Two distinct genotypes were demonstrated: G1 (sheep strain, 85.7 percent) and G6 (camel strain, 14.3 percent). G1 was found in 75 percent of sheep, 100 percent of goats, 100 percent of cattle and 82.3 percent of camels. G6 was identified in 17.6 percent of camels, 25 percent of sheep and 14.3 percent of humans. The high frequency of G1 in camels – an infecting strain for humans – suggests that camels, in which prevalence and fertility of hydatid cysts is high, could represent a source of indirect transmission to humans [7].

Bahrein

One case of a singular alveolar cyst and one of multiple cysts (Figure 2) in dead camels has been reported from Bahrain [8].

Egypt

Hydatid disease in the camel was first formally recorded in Egypt in 1920 [9]. Further reports of camel hydatidosis were published in 1943 and 1946 [10,11] and in 1956 [12]. Other sources that provide information on camel hydatidosis have also been published [13-15] as well as others on the serological detection of the disease [16-19]. The double diffusion test was used for detection of cross serological reactions between hydatid fluid antigens and sera of camel, sheep, buffalo and cattle and was able to show differences in hydatid fluid antigens from camel, sheep and cattle [20,21].

A review of the published literature on the presence and distribution of echinococcosis in Egypt provided a summary of the data [22]. This showed that the overall prevalence of hydatidosis in camels was 17.61 percent. Some 18.66 percent of males and 11.53 percent of females were infected. Peak prevalence of 23.23 percent was found in summer whereas the lowest rate of 11.85 percent occurred during winter. Apparently healthy camels showed an infection rate of 16.62 percent whereas weak animals had a 21.49 percent infection rate. The lungs were overwhelmingly the most infected with 94.62 percent of cysts being found at this site compared to only 5.37 percent of cysts being found in the liver. Most examined cysts (77.08 percent) were fertile, 65.60 percent were fertile and viable, 4.16 percent were calcified, 13.54 percent were casemated and 5.20 percent were sterile. Medium sized cysts were the most prevalent in the infected lung (45.5 percent) whereas hepatic cysts were mostly of small size (66.6 percent).

The foregoing review is based on a plethora of other publications mostly produced in local university in-house journals which often provide data on infection rates and risk factors [23-30]. In recent years more attention has been given to obtaining information on serology (to help diagnose the presence of hydatid cysts in live animals) and to molecular characterization of strains and species of *Echinococcus granulosus* [31-40].

Ethiopia

In a general study of internal parasites of camels at Jijiga abattoir in southwestern Ethiopia, 29.2 percent of 41 camels had hydatid cysts. Overall presence of eggs or oocysts of parasites was 95.6 percent in 180 faecal samples. Other parasites present were *T. evansi* in 21 of 321 camels, 85.3 percent larvae of *Cephalopina titillator*, 88.0 percent *Haemonchus*, 39.0 percent *Stilesia*, 44.0 percent *Avetillina*, 31.0 percent *Monezia* and 4.8 percent *Thysaneizia giardi*. It was concluded that integrated approach was required to achieve maximum benefits from camel herding [41].

Figure 2 Single and multiple alveolar cysts from dead camels in Bahrain (source: [8]).

A 2-year cross-sectional study on 770 camels slaughtered for human consumption showed 61.6 percent had hydatid cysts of varying numbers and sizes. Of 3,850 cysts, 53.51 percent were in the liver, 40.39 percent in the lungs, 0.13 percent in the heart, 0.90 percent in the gastrointestinal tract and 0.13 percent in the kidneys. Infection rates varied among age groups (higher in older animals), sex and body condition score. Fertility and viability did not differ by geographical origin with 41.5 percent of cysts fertile and viable [42]. Similar results to the foregoing were obtained in lowland eastern Ethiopia. Some 28.76 percent of slaughtered camels harbored hydatid cysts. Among infected animals 51.23 percent of cysts were in the lungs, 45.06 percent in the liver, 2.46 percent in the gastrointestinal tract and 0.6 percent in each of the kidney and heart. In this study age, sex, body condition and origin were not statistically significant risk factors. Fertile cysts were 68.75 percent in the liver and 70.50 percent in the lungs and 41.01 percent of cysts were fertile and viable [43].

A total of 22.6 percent of 460 camels from three areas of Ethiopia harbored hydatid cysts with in infection rates differing with area of origin. Prevalence in males (19.0 percent) was significantly lower than in females (49.1 percent). Infection rates were higher in older animals. Cysts in 67.3 percent of cases were in lungs alone, 25.0 percent in both liver and lungs, 6.7 percent in liver only and 0.96 percent in the heart. Most cysts were none calcified. Cyst fertility was 57.2 percent in the lungs and 40.0 percent in the liver: 66.6 percent of cysts from both lungs and liver were viable [44].

A recent "portmanteau" paper claimed to review and summarize data on the disease in Ethiopia: it included an extensive bibliography mostly comprising abattoir studies by veterinary students doing thesis work. Data cover the period 1985-1999 gathered in three agro ecological zones of Ethiopia. Work was undertaken in 21 abattoirs but camels were found at only five of these. The analysis showed the presence of hydatid cysts in 31.15 percent 22,863 cattle, 11.78 percent of 6518 sheep, 4.9 percent of 1753 goats, 16.79 percent of 417 camels and 0.00 percent of 150 pigs. Differences in the infection rate among species were statistically significant. In camels the lungs were more affected than the liver [45].

India

Among the very few reports of hydatid cysts in camels are India two do little more than indication of the present of the parasite [46, 47]. One other reports on *E. granulosus* genotypes isolated from 32 human patients and indicates that 30 of thee were G1 (sheep) and G3 (buffalo) types with one each being strain G5 (cattle) and G6 (camel). G5 was recorded for the first time in Asia and G6 or the first time in India [48].

A recent overview of parasitic zoonoses in India stresses the increasing importance of the disease in humans and animals but provides only 12 literature sources, only one of which refers to camels [49].

Iran

Early studies emphasised identification and epidemiology of hydatid cysts in camels in many areas of Iran [50-53]. In one such study hydatid cysts were found in the livers in 40 percent of 40 camels in the Shiraz area, in 30 percent of lungs with the remainder in both organs. Nodules of *Dipetalonema evansi* were found in 17.5 percent of lungs, an apparent first record of this parasite for Shiraz [54].

In other studies cysts were found in 35.2 percent of 661 camels in five areas with a range of 1-48 although most had less than 5 cysts. Prevalence in males was 34.4 percent and in females 36.6 percent. Geographically the highest infection (59.3 percent0 was in Isfahan region whereas the lowest (25.7 percent) was in Kerman province. Distribution of cysts was 49.4 percent in lungs alone, 30.0 percent in liver and lungs, 14.6 percent in liver alone and 6.0 percent in other organs. A direct relation was established between rate and intensity of infection and host age. Fertility of 69.7 percent in lung cysts was higher than liver cysts (58.7 percent) and other organs (50.0 percent) but liver cyst viability (80.3 percent) was higher than lung cysts (55.8 percent) and other organs (57.1 percent) [55]. Later studies in Kerman province [56] and over several regions [57] found similar results to those presented here. Recent studies have concentrated on genetic characterization [58-60].

A general review of echinococcosis/hydatidosis in Iran with a bibliography of 85 references mainly covers humans and dogs.

It points out, however an infection rate in camels of up to 70 percent and that the presence of camel strain G6 is confirmed along with the more cosmopolitan G1 strain [61].

Iraq

Early reports of hydatid disease in Iraq did not mention its presence in camels [62-64]. A somewhat later paper, however, noted that infection rates had been reduced over the years due to destruction of stray dogs, higher standards of meat inspection and an overall improvement in socio-economic conditions but then went on to say that infection rates were still high in camels and that fertility in camel cysts was higher than in sheep or goats [65].

The indirect haemagglutination test was sensitive in sheep (96 percent) and cattle (77 percent) with titres ≥ 1:256 but gave 16 and 20 percent non-specific false positive to non-infected animals in the two species, this probably being due to cross-reaction with other cestodes. The test was less sensitive for camels (35 percent). Most in sera from infected animals gave either negative or very low titres and 14 camels gave non-specific false negative reactions [66].

Israel and Palestine

There does not appear to be any publications on camel hydatidosis but there was a high prevalence in sheep and goats and in dogs in some areas [67]. Human echinococcosis was found more prevalent in Muslim than Jewish women in southern Israel [68]. The Muslim women were mainly Bedu who live in proximity – one might say in intimacy – with their camels. As neighbouring countries all report echinococcosis in camels it is reasonable to assume that Israeli camels are also infected.

Jordan

Cysts were present in 4.0 percent of 704 sheep, 3.6 percent of 391 goats, 11.4 percent of 280 cattle and 8.8 percent of 68 camels slaughtered at two abattoirs in North Jordan. In general, older animals had higher infection rates than younger ones. The percentage of infected animals with fertile cysts was 66.7 percent in camels, 34.3 percent in cattle, 28.6 percent in goats and 7.1 percent in sheep. The lung was the predominant location for cysts in camels [69]. An infection rate of 27.8 of 471 sheep, 1.7 percent of 118 goats, 5.8 percent of 157 cattle and 10.7 percent of 79 camels was found in a further study of animals slaughtered in North Jordan abattoirs during March-May 1984 [70].

Kenya

The high prevalence of hydatid disease in nomadic Turkana herders is due largely to the behaviour of the people. There is a very close relationship between people and heavily infected dogs and "nurse" dogs are used to clean and guard children. Dog faeces are used as medicaments or lubricants [71-73]. It was later confirmed that the camel strain of *E. granulosus* is confined geographically to the Turkana area where the disease is hyperendemic in humans [74]. Studies during the 1980s concentrated on strain differentiation within the parasite [75-78].

Kuwait

An early (1975) search for hydatid cysts in domestic livestock did not find any infection in camels [79]. Such infection in camels was not recorded for the first time until 1982. The overall rate in 293 slaughtered camels was 39.6 percent, 8.5 percent in animals < 6 years old and 40.1-45.2 in older animals. Infection in females (44.9 percent) was significantly higher than in males (24.7 percent). Females had more infections in multiple organs (22.7 percent) than males (10.5 percent). The lung was the predominant infected site (63.0 percent). Pulmonary cysts (71.7 percent) showed higher fertility than hepatic cysts (29.2 percent). The authors postulate the high infection rate is probably related to shifts in the production system from traditional free-grazing to enclosure in pens [80].

Lebanon

The earliest study on echinococcosis in camels in Lebanon appears to have been published in 1970 [81]. Somewhat later a taxonomic study of the parasite was undertaken with the aim of providing better information on speciation [82]. More recently it was found that up to 100 percent of camels in some areas of the country were infected [83].

Libya

According to hospital records there is an annual rate of 70-100 of confirmed human surgical cases in the northern cities of Libya [84]. These cases have been related to high infection rates in domestic stock. Most publications on hydatids in camels refer simply to infection rates in slaughtered animals. For example around Tripoli infection rates of 27 percent to as high as 60 percent have been recorded [85-90]. There appear to be two exceptions to the high rate of infection. One is from local bred camels slaughtered at Sirt abattoir (on the Mediterranean coast to the east of Tripoli) where hydatid cysts were found in only 3.62 percent and 2.7 percent of animals examined at two different periods [91-92]. The other is an infection rate of 12.54 percent from 7,496 camels slaughtered in government abattoirs in different (unspecified) parts of Libya [93]. The general finding of these studies was similar for various traits. For example, older animals had higher infection rates than younger ones. Most infections (75-85 percent) were confined to the lungs or in the lungs jointly with the liver. Lung cysts had higher fertility than liver ones. In one study more than 90 percent of camel cysts were fertile [88] and in another it was 84 percent with sterile and calcified cysts being present in similar proportion (Figure 3) [93]. Condemnations were estimated 0.2 percent of the economic value of the carcass [87]. In contrast to the high infection rates in camels, cattle, sheep and goats generally had much lower rates of infection.

Camel hydatid cyst fluid could be an important source of diagnostic antigens for human cystic echinococcosis. The 100 and 130 kDa antigens were strongly recognized by sera from echinococcosis patients when camel or horse hydatid cyst fluids was used in immunoblotting but were only weakly recognized if sheep or human hydatid cyst fluid was used [94]. Sequencing a portion of the cytochrome c-oxidase subunit I (cox1) gene from each of 30 protoscolex samples from Libya (12 from cattle, three

Figure 3 Fertile, sterile and calcified cysts from Libyan camels (source; [91]).

from humans, five from camels and 10 from sheep) showed that all were identical to that published for the common sheep strain of *E. granulosus* [95]. In another taxonomic study it was inferred that all cyst isolates from humans (n = 55) and a small number from cattle (13 percent of 38) belonged to the G1–G3 complex of *E. granulosus* (or *E. granulosus* sensu stricto) whereas most (87 percent) cysts from cattle and all (100 percent) of 83from camels were linked to the G6–G10 complex (or *E. canadensis*) [96].

A very recent paper purports to review hydatid disease in Libya [97]. The paper is, however, a much more general review of the disease with only 14 of the 98 papers cited pertaining directly to Libya. Of these seven are relevant to camels and all of these have already been covered in the present bibliography

Mali

In an abattoir survey of 11 animals in March/April 1987 *Haemonchus longistipes* was predominant with prevalence with a rate of 85.7 percent. *Impalaia*, *Trychostrongylus*, *Cooperia* and *Oesophagostomum* were also recovered and a fertile larval stage of *Echinococcus granulosus* was found in the lungs of one animal [98]. A recent study demonstrated genotype G6 in a dog in the Malian capital, Bamako, being the first report of hydatids in dogs for the country [99].

Mauritania

A doctoral study deplored the lack of information on hydatids in camels in Mauritania but was able to establish an infection rate of 8.44 percent of which 70.7 percent were in the lungs (60.6 percent in the lungs alone) with other localizations being the liver or both the lungs and the liver. In 1984-1986 about one-quarter of all organs condemned were due to hydatid cysts [100]. In contrasts to the low infection rate of the previous study, 53.7 percent of 1264 camels at Nouakchott abattoir were infected. Infestation in the lungs at 61 percent was higher than in the liver at 23 percent) and fertility in lung cysts was also higher (93 versus 60 percent) [101].

Differences in infection rates in a study in northern Mauritania revealed significant differences between Zoiarate (37 percent) and Nouadhibou (26 percent) but there were no differences of infection rates in sheep and goats in these two areas. There was a fertility rate of 69-73 percent in camel cysts which was much higher than the rates of 37-42 percent in the small ruminant species. It was concluded that differences between prevalence rates, cyst fertility and location in the internal organs (73 percent in lungs in camels) was possibly dependent on the strain(s) of *E. granulosus* [102]. In another study by the same research group hydatid cysts were found in 30.1 percent of camels, 5.5 percent of the cattle and 6.5 percent of sheep in the Nouakchott area. Cyst fertility rate in humans (75 percent) and camels (76 percent) was significantly higher than in sheep (24 percent) and cattle (23 percent). Differences in strains were again considered to be the reason for variations in infection rates [103].

Morocco

Official interest in hydatid disease in Morocco started as early as the beginning of the twentieth century [104]. The disease has also proved of interest as a field of study for higher degrees [105]. Towards the middle of the century an enquiry into echinococcosis in the Marrakesh region in central Morocco was based on a literature survey, hospital and abattoir records, interviews and some personal observations. It showed a high incidence of infection in stray dogs (up to 70 percent) with town dogs having a lower incidence than others. Marrakesh abattoir records over a 3-year period showed hepatic hydatid cysts as 15 percent in cattle, 5 in sheep, 6 in goats, 14 in pigs and 44 percent in camels [106]. An infection rate of 80 percent was found in 35 camels in Ouarzazate in south-central Morocco whereas infection rates were as low as 0.7 percent in sheep and 1.4 percent in goats. There was an increase in prevalence as animals aged; there were more cysts in the lungs than in other organs in all species and fertility was higher in camels (68 percent) than in sheep (50 percent) [107].

In a more recent study post mortem inspection of 2,948 sheep showed 10.58 percent infection with hydatid cysts, 1.58 percent of 2,337 goats were infected, 22.98 percent of 618 cattle harbored cysts, 12.03 percent of 482 camels were infected as were 17.80 percent of 455 equines. Highest rates of infection were in older animals and other than in cattle the liver was more infected than the lungs. *Echinococcus granulosus* is in an endemic steady state in Morocco with no evidence of protective immunity in the intermediate hosts [108]. Studies in five regions in Morocco showed considerable variations of hydatid infection rates among farm animals. High figures were 48.72 percent in cattle, 31.65 percent in sheep, 2.19 percent in goats, 10.87 percent in camels and 17.80 percent in horses. Prevalence rates were higher in older animals [109].

Niger

A total of 32 cases of hydatidosis were noted in two hospitals in Niger over a 5-year period with 81 percent of these having extra-hepatic localizations [110]. The report says studies in slaughtered animals from Niger show a high prevalence of hydatidosis in camels but no reference to these studies has been

found. In a paper published after the appearance of the previous one, however, abattoir data from 10,168 animals slaughtered in Tahoua and Niamey showed hydatid cysts in 1.96 percent of goats, 2.18 percent of cattle, 2.76 percent of sheep and 89.74 percent of camels [111].

Nigeria

In terms of numbers of animals the camel does not rate very highly in Nigeria where it is geographically confined to the northern parts of the country. More camels are slaughtered than the official population numbers and these imports have been implicated in the presence of hydatid cysts in slaughtered camels in northern abattoirs [112].

Small numbers have not, however, restricted the number of publications on camel hydatidosis, many of which are attributable to a single researcher and his associates [113-117]. A survey at Kano abattoir found hydatid cysts in sheep (11.4 percent), cattle (14.7 percent), goats (26.5 percent) and camels (55.5 percent) [113]. In another study *Echinococcus granulosus* infection was recorded for the first time in dogs in Kaduna State with an infection rate of 1.2 percent in 330 dogs. In slaughtered stock infection rates were 1.5 percent in cattle, 5.0 percent in pigs, 7.1 percent in sheep, 18.4 percent in goats and 70.9 percent in camels [114]. In a departure from abattoir studies the author showed that all of three serological tests (countercurrent immunoelectrophoresis, double diffusion and indirect haemagglutination) were always positive in camels with hydatid cyst infection affecting both the liver and the lung. A combination of indirect haemagglutination and Ouchterlony's double diffusion tests could be useful for diagnosing hydatidosis in camels and probably other animals [118]. Later studies have produced results similar to the foregoing [119-123].

A recent study of a different type was undertaken to evaluate the usefulness of Enzyme Linked-Immunosorbent Assay (ELISA) in determining the current status of hydatidosis in camels and cattle slaughtered in Sokoto metropolitan abattoir and to ascertain the sensitivity and specificity of the test. Serum samples from 189 camels and 285 cattle were examined. The prevalence of *Echinococcus granulosus* antibody response was 38.6 percent being 59.3 percent in camels and 24.3 percent in cattle. Sensitivity of ELISA in camels was 96.4 percent and in cattle was 70.5 percent with specificities of 80 percent and 76 percent. A non-significant higher prevalence was recorded for older than younger animals. The association between sex and disease prevalence was highly significant. The study concluded that hydatidosis is prevalent in camels and cattle in Sokoto and that ELISA is a sensitive and specific assay that could be employed in serodiagnosis of hydatidosis in camels, cattle and other domestic animals [124].

Oman

In southern Oman infection of 65 camels by hydatid cysts showed that older animals were infected than younger ones, difference between males and females were not significant and lungs were more infected (70.8 percent) than the liver (7.7 percent). Some 81.5 percent of cysts were fertile [125].

Pakistan

The prevalence of hydatidosis in animals slaughtered at Faisalabad abattoir was 5.9 percent in 81,441 goats, 14.8 percent in 27,777 sheep, 33.0 percent in 28,903 cattle, 49.0 percent in 30,302 buffalo and 53.8 percent in 175 camels. In all species hydatid cysts mainly developed in lungs (52-55 percent), livers (26-29 percent) or both (16-22 percent) [126]. In a similar study also at Islamabad between June 1987 and September 1988 hydatid cysts were found in 33 percent of 372 buffalo, 39 percent of 210 cattle and 59 percent of 34 camels. Most cysts were found in the lungs (68 percent in camels) and most (63 percent) were infertile. IHA (cattle and buffalo) and ELISA were not very sensitive, specific or efficient at detecting infection in sera [127]. No seasonal differences were detected in the infection rate [128].

Cyst prevalence and fertility in 39,738 animals in Punjab was highest in camels (prevalence 17.29 percent, proportion fertile 95 percent), followed by sheep (7.52 percent and 86.4 percent), buffalo (7.19 percent and 84.3 percent), goats (5.48 percent and 79.09 percent) and cattle (5.18 percent and 75.25 percent). Phylogenetic analysis of the cytochrome oxidase-1 gene showed that the common sheep (G1) and buffalo (G3) strains cycle among livestock and that they are highly adapted to goats, camels and cattle. Both morphological and molecular results support earlier studies suggesting that *Echinococcus* of sheep and buffalo origin are phenotypically and genetically similar, adding further evidence to support its recognition as one species, *Echinococcus granulosus* sensu stricto [129]. The first cases of *E. granulosus* G6 genotype in both human and animal (cattle) samples from Khyber Pakhtunkhwa have recently been recorded. On epidemiological grounds camels appear to be an important reservoir for human infections but studies suggest that the G6 genotype has low or no infectivity for humans [130].

Saudi Arabia

The huge demand for meat in Saudi Arabia derives from the need to supply an affluent indigenous population, the vast numbers of immigrant workers and the annual influx of millions of pilgrims for Islam's religious festivals. Native livestock are unable to service the demand and much of the supply shortfall is therefore accommodated by imports. Cultural and religious practices mean that the demand is for fresh meat; slaughtered lawfully ('halal') so animals are imported live and killed within the country. These imported animals are often blamed for the high levels of disease reported from abattoirs.

Two studies provided varying results on the presence of hydatid cysts [131,132]. Hydatid cysts were found in 16 percent of 200 camels sacrificed at Mekka abattoir Cysts were present in the liver, lung or both. Only two camels (6.3 percent of those with cysts) harboured fertile cysts. Serological positives were achieved in 37.5 percent of infected camels when screened by indirect haemagglutination (IHA) but 1.2 percent of the 168 non-infected camels gave false positive results [133].

Cyst infections in Al Baha region were found in 6.56 percent of 3,578 goats, 8.28 percent of 2,668 cattle, 12.61 percent of 6,518 sheep and 32.85 percent of 140 camels. Prevalence varied in relation to site, season, age class and sex. The most commonly

infected organs were liver (48.75 percent) and lungs (32.83 percent). Liver cysts had higher fertility (38.79 percent) than those of lungs (25.13 percent). Viability of protoscoleces of liver fertile cysts (62.20 percent) was higher than of lung cysts (52.73 percent) [134]. In the major North Jeddah abattoir 3.63 percent of 615 cattle, 6.86 percent of 541 camels, 19.85 percent of 48,370 goats and 69.60 percent of 41,822 sheep showed hydatid cysts under macroscopic and microscopic examination. The liver was the major site of infection in all animals [135].

Somalia

The lungs were the main site of infection in the 27 percent of 300 slaughtered camels infested with hydatid cysts at Mogadishu abattoir [136]. It has been said that hydatid cysts are seen exceptionally in sheep and goats, seldom (1.75 percent) in cattle and frequently (14.82 percent) in camels. In spite of the infection rate in camels and the favorable opportunities for contracting the disease, human hydatidosis has not been recorded in Somalia. Evidence from analysis and epidemiological studies indicate that the camel form of the parasite may represent a new strain [137].

A recent study in the Somali region of eastern Ethiopia (with possible relevance to western Somalia) showed that 23 percent of 400 camel at Jijiga slaughterhouse were positive for hydatid cysts. The highest proportion of 56.0 percent was recorded in lungs with 33.9 percent in the liver, 7.3 percent in the spleen and 2.8 percent in the kidneys. Infection rates varied significantly among age (older animals more infected), sex (female's ore than females) and body condition score (higher rates in animals in poor condition). Some 59.7 percent of cysts were fertile of which 69.8 percent were viable. Pulmonary and hepatic cysts had fertility rates of 63.7 percent and 57.4 percent. The direct financial loss as a result of organ condemnation was equivalent to US$7.77 per camel [139].

Sudan

Sudan has more livestock than any other country in Africa and also has the greatest numbers of camels. Domestic animals are vital for people's livelihoods and, as export of both live animals and meat, to the national economy and foreign exchange earnings. For more than 100 years the veterinary services have attempted to diagnose and control disease in this vast resource. Echinococcosis was first reported in the country in 1908 when it was found in a camel slaughtered in Khartoum [140].

Since then there have been multiple publications on camels and hydatid disease [141-144]. In a survey covering several states no evidence of infection by hydatid cysts was found in 1,876 goats but infection rates of 0.01 percent with a fertility of 50.0 percent were found in 18,571 sheep carcasses, of 0.12 percent with a fertility 50.0 percent in 2,806 cattle and of 22.0 percent (but as high as 80 percent in some areas) with a fertility rate of 20.0 percent in camels [145]. In another study in central Sudan (Omdurman, Tambool and Wad Medani) infection rates in cattle (n = 2,368) were 3.0 percent, in sheep (n = 5,595) were 6.9 percent and in camels (n = 242) were 44.6 percent. Cysts from cattle and camels where more fertile (22 percent and 24 percent) than from sheep (1 percent) [146]. A similar study in the same area showed infection rates of 2 percent in 5,565 goats, 6 percent in 4,893 cattle, 11 percent of 10,422 sheep and 59 percent of 779 camels. When examined by PCR 98.7 percent of cysts could be allocated to *Echinococcus canadensis* G6/7. The number of cysts per infected animal was much higher in camels (5.1) than in the other species (1.0-1.3) and cyst fertility was higher in camels and cattle (74 percent and 77 percent) than in goats and sheep (31 percent and 19 percent). Fertile cysts from five human patients from hospitals in Khartoum and Juba belonged to *E. canadensis* (G6). This study confirms the predominance of the "camel strain" in Sudan and its infectivity for humans [147]. At Tambool slaughterhouse, south of Khartoum, 26.5 percent of 200 camels were infected with hydatid cysts, 90 percent being in the lungs and 10 percent in the liver [148]. In other studies at the same slaughterhouse 20 percent of 80 camel livers were found to harbour hydatid cysts [149, 150].

A recent PhD Thesis provides a wealth of information human and animal echinococcosis in Sudan and has an extensive bibliography [151].

Syria

There is one early study of echinococcosis in Syria [152]. A somewhat later report indicated hydatid cyst infection rates of 28.5 percent in 1,596 sheep and goats and 100 percent of 6 camels, of 41.4 percent in sheep and 13.8 percent in goats with a total number of 551 animals and 100 percent of 5 camels in Homs and in 27.8 percent of 1,126 sheep and goats and 100 percent of 4 camels in Aleppo [153]. A secondary source indicates an infection rate of 18.2 percent for camels and 3.0 percent for goats [83].

Tunisia

Early reports attest to the interest in echinococcosis in Tunisia by both military and civil authorities in both the colonial and post colonial periods [154-158].

In more recent studies there has been an increased interest in molecular characterization of *Echinococcus granulosus.* In one such no cysts were found in 103 camels from Ke´bili, while 19 of 188 camels from Benguerden (10.1 percent) were infected. Of cysts found, 95 percent were considered fertile with presence of protoscoleces and 80 percent of protoscoleces were considered viable. Molecular techniques demonstrated infection with the G1 sheep strain of *E. granulosus*. Modelling data suggested that older camels would have a relatively high prevalence rate reaching a likely value of 32 percent at 15 years and could represent an important transmission source to dogs and hence indirectly to man. In common with similar studies on other species, there was no evidence of parasite-induced immunity in camels [159]. In another study the camel strain G6 of *G. granulosus* was uniquely found in three camel isolates and not in 50 human, 166 cattle and 153 sheep isolates [160]. *Echinococcus granulosus* isolates of sheep and camel were identified as G1 and G6 strains based on polymorphism of the mitochondrial cytochrome C oxydase CO1. Single strand conformation polymorphism (SSCP) was used to examine the genetic variation within and between the G1 and G6 strains and to estimate the extent of selfing. The camel isolates were genetically distinct from those of sheep (high value of genetic variation between populations: Fst= 0.46). No significant

deficiency in heterozygotes was found in sheep isolates whereas heterozygote deficiency (suggesting selfing) was found in a limited number of camel isolates [161]. Other sources indicate the prevalence of cystic echinococcosis in production animals as 2.9 percent in goats, 6 percent in dromedaries, 8.48 percent in donkeys, 8.56 percent in cattle and 16.42 to 40.42 percent in sheep [162].

United Arab Emirates

Antibodies to echinococcosis determined by indirect haemagglutination were found in 2.6 percent of 117 animals [163].

Yemen

Prevalence of cystic echinococcosis caused by *Echinococcus granulosus* was investigated in four central abattoirs in Aden Governorate in south Yemen from October 2008 to March, 2009. The overall infection rate in carcasses of 7507 livestock was 0.7 percent with 1.1 percent in 2,576 sheep, 0.5 percent in 4,809 goats, 2.6 percent in 117 cattle and 0.0 percent in 5 camels) [164]. A total of 244 outpatient and inpatients at public and private hospitals and 257 cattle, 62 sheep, 61 goats and 5 camels slaughtered in Dhamar and Taiz Governorates from May to October 2013 were examined to determine the prevalence of cystic echinococcosis. Prevalence in humans was 2.87 percent with significantly more livers than lungs affected and a higher rate of infection in Dhamar than in Taiz. Highest infection rates were in the age group < 20 years old and the lowest in the group 41-60 years old. All infected patients were females. In animals overall prevalence was 22.9 percent with a higher rate in Dhamar than in Taiz. Infection rates in 257 cattle were 24.51 percent; in 62 sheep were 19.35 percent, in 61 goats 19.5 percent and in 5 camels 20 percent (one animal!) [165]. In another study of slaughtered animals at Taiz abattoirs carried out in 2012 there was a 0.0 percent infection rate in 47 sheep, 6.13 percent in 636 goats, 33.76 percent in 311 cattle and 41.66 percent in 12 camels [166].

Other countries

Hydatidosis is "Reported present or known to be present" in Cameroon where camels are sometimes found in the far north (but no publications have been found in the literature search for this review). There is "No information available" for Qatar, Turkey, Chad, the Central African Republic and Senegal but the disease is "Present" in Eritrea and in Djibouti [167]. This source, however, should be treated with caution as there are several clear errors in the presentation: for Sudan, for example, there is "No information available" which is clearly nonsense and simply means that OAU/IBAR has not received official correspondence for Sudan's government.

DISCUSSION AND CONCLUSIONS

Infection by hydatid cysts of *Echinococcus granulosus* is a worldwide problem in both man and animals. It has serious health consequences in humans and can often only be cured by surgical removal of the cysts. The parasite infects all species of domestic livestock and many wild animals. In livestock the presence of the parasite results in greatly reduced productive performance of economic products such as meat and milk. The disease is said to endemic on the Arabian Peninsula [168] but is also endemic in other parts of Asia and throughout Africa within and without the normal range of the one-humped camel. This disease in livestock is on the list of those notifiable to the World Organisation for Animal Health (OIE) [167], but is often not a notifiable disease in humans.

The volume of literature on hydatidosis in the one-humped camel attests to it as an economically important production disease. In most studies covering a range of domestic species the camel usually has higher infection rates – often much higher – than sheep, goats or cattle. In camels the disease is characterized by the dominance of pulmonary localizations whereas in sheep and cattle it is the liver that is most affected. In many areas socio-economic conditions (people in close contact with their livestock and with the dog as primary host) are favourable for the disease and for the maintenance of high levels of infection. Identification and control of hydatid disease warrant serious attention. Appropriate control and prevention measures need to be taken in order to minimize the economic loss associated with condemnations of slaughter products and to mitigate and prevent the zoonotic risk to human public health.

Camels were for long neglected by administrators, policy makers, the veterinary services and research scientists, mainly on the grounds that they were "uneconomic" animals serving as a livelihood support for a small number of nomadic pastoralists. Since the beginning of the 21st century, however, greater – although not necessarily great – attention has been given to the role of the camel in the global environment and economy. If article metrics are to be given credence and from the number of views and downloads of papers on camel hydatidosis are to be considered as an indication of the value of the animal (positive) and its diseases (negative) then it may be possible in the future to mitigate the worst effects of the disease and to improve the productivity of the camel.

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