

## Review Article

# Present Status on the Taxonomy and Morphology of *Echinococcus Granulosus*: A Review

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## Abstract

*Echinococcus granulosus* has been researched extensively and previously discussed in detail as it is the species that is most widely distributed throughout the world. It is a cyclozoontic infection which has important global implication as it is found in many animals and humans and involves a large group of countries. The high incidence and wide distribution of this parasitic infection that man shares with animals make the disease one of the most serious zoonoses in many parts of the world. Epidemiological studies indicate that the sheep strain of *E. granulosus* is the leading agent of cystic echinococcosis in humans. The common intermediate host of *E. granulosus* is many domesticated mammals such as sheep, cattle, pigs, goats and camels. Sheep, which harbor the most fertile hydatid cysts, are the most important intermediate host and represent the most important source of infection to dogs through the feeding of infected offal, giving rise to high prevalence rates as shown in many countries of the world.

**Keywords:** Taxonomy; Morphology; *Echinococcus granulosus*

## Introduction

Echinococcosis or hydatid disease, caused by the larvae of the closely related species *Echinococcus granulosus* and *E. multilocularis* is the most serious tapeworm infection occurring in man and domesticated animals. This is not because it is particularly common but because of the lack of an effective chemotherapeutic agent and the difficulty of surgery often results in a poor prognosis. The two species have been clearly differentiated and the presence of strains (regarded by some as subspecies, and of each, adapted to various hosts) had been established as early as the 1950s, but until today there is still much confusion in various aspects of the disease, especially epidemiology. The present review is an attempt to re-visit some important non-molecular aspects of the disease.

## History of Hydatid Disease

Hydatidosis is a disease with an extremely long history as it has been known since the time of Hippocrates, and it is caused by the tapeworm *Echinococcus granulosus*. According to [1] *Echinococcus granulosus* has been known since ancient times, for example, Aretaeus and Galen were familiar with hydatid cysts. The generic name *Echinococcus* is from the Greek words “echinos”, which means hedgehog and “kokkos” which means berry, while the species term *granulosus* is from the Latin word “granulum” which means little grain. The term hydatid is from the Greek word “hydatis” which means a drop of water [1,2].

At present *Echinococcus granulosus*, the causative agent of hydatidosis is almost ubiquitous. It was Redi in 1684, Hartmann in 1685, and Tyson in 1691 who first suspected their animal and the bladder were really worms. In 1766, Pallas first mentioned the similarity of hydatids in man and other mammals and Goeze in 1782 first studied the protoscoleces of the metacestoda and recognized their relationship to those of taenial origin and differentiated the

hydatid cyst from the cysticercus. In 1695, Hartman first observed the adult worms in the dog's intestine, and later Rudolphi in 1808 studied details of the adult worms. Then Von Siebold in 1852 followed by Haubner, Leuckart, Kuchenmeister and Nettlehip fed protoscoleces of cysts on domestic animals to dogs and observed the development of the adult worms in the intestines of the hosts. Later Naunyn, 1863 in Germany, Krabbe, 1863 in Iceland, and Thomas, 1885 in Australia obtained adults worms in dogs from protoscoleces of human origin [2].

## Taxonomy of *Echinococcus Granulosus*

According to Yamaguti, Braithwaite [3,4] and Thompson (1986), the tapeworms whose larval stage causes hydatid cysts belong to the following:

Phylum: Platyhelminthes.

Superclass: Eucestoda.

Class: Cestoidea.

Subclass: Cestoda.

Order: Cyclophyllidea Ben; Braun, 1900.

Family: Taeniidae Ludwig, 1886.

Genus: *Echinococcus* Rud, 1801.

The genus *Echinococcus* was established for the larval cestoda which was earlier designated *Taenia visceralis socialis granulosus* by Goeze in 1782 obtained from the liver of sheep. In 1786, Batsch adapted the binary system of nomenclature of Linnaeus and gave the name *Hydatigene granulosus* to the taxon described by Goeze [5]. In 1963, Rausch and Nelson reviewed the species of *Echinococcus* and concluded that the status of *E. felidis* Ortlepp, 1937 and *E. patagonicus* Szidat, 1960 was uncertain, but that both were possibly

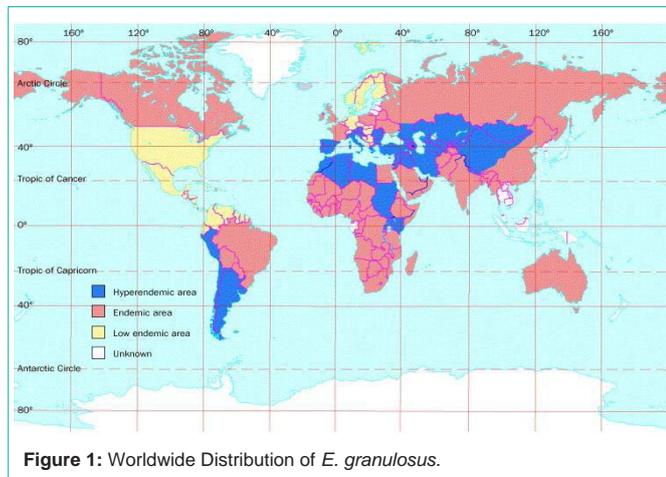


Figure 1: Worldwide Distribution of *E. granulosus*.

co-specific with *E. granulosus*. In addition, *E. cameroni* Ortlepp, 1934; *E. intermedius* Lopez-Neyra and Soler, 1943; *E. longimanubrius* Cameron, 1926; *E. lycaontis* Ortlepp, 1934; *E. minimus* Cameron, 1926, and *E. Ortlepp* Lopez-Neyra and Soler 1943 were considered synonyms of *E. granulosus* Rausch and Nelson 1963.

### Strains of *Echinococcus Granulosus*

*Echinococcus granulosus* has been divided into several strains according to the host [6]. *Echinococcus granulosus* has been researched extensively and discussed in detail as it is the species that is most widely distributed throughout the world. For example, it has six strains which have been identified as G1 genotype (common sheep strain), G2 genotype (Tasmanian sheep strain), G4 genotype (horse strain), G3, G5 genotypes (cattle strain), G6 genotype (camel strain), G7 genotype (pig strain) [7,8]. In addition, Haag *et al.* [9] recorded five potential hybrid genotypes between cattle and sheep strains found only in Southern Brazil.

### Distribution of *Echinococcus Granulosus*

According to Belding, Beck and Davies, Beaver *et al.*, Schantz *et al.*, Shambesh [1, 10-12] *E. granulosus* has a worldwide distribution. Indeed as Abdou, Matossian *et al.*, Polydorou [13-15] point out, hydatidosis is a cyclozoonotic infection which has important global implication as it is found in many animals and humans and involves a large group of countries. For example, hydatid disease is considered endemic in humans and animals in North Africa, while in the rural areas of Libya, Tunisia, Algeria and Morocco, it is classified as hyper endemic. In addition, it is prevalent in countries in Latin America, the Middle and Near East, the Mediterranean littoral, a number of African countries and several European ones. The high incidence and wide distribution of this parasitic infection that man shares with animals make hydatidosis one of the most serious zoonoses not only in Egypt, but also in the Middle East, Cyprus, Iraq, Jordan, Kuwait, Lebanon, Iran and Syria.

Epidemiological studies indicate that the sheep strain of *E. granulosus* is the leading agent of cystic echinococcosis in humans. It has been extensively studied in a number of different areas and is now present in Asia, Africa, South and Central America and the Mediterranean region and also common in parts of Europe, especially the United Kingdom and Australia [11,12]. Those regions with the

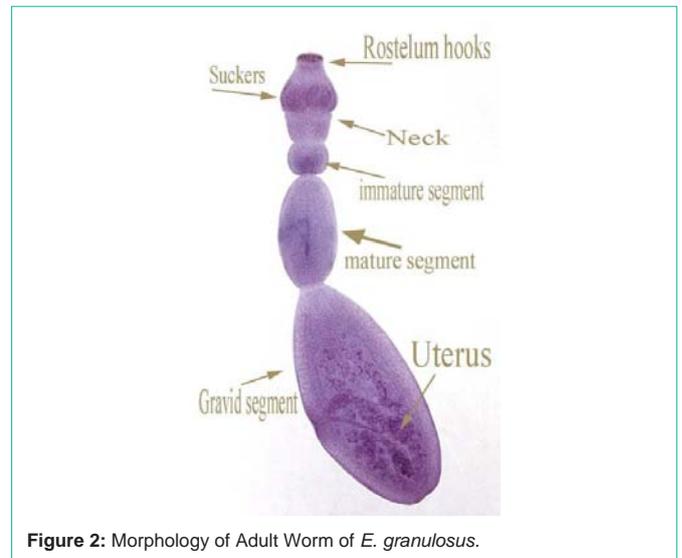


Figure 2: Morphology of Adult Worm of *E. granulosus*.

most extensive and intensive *E. granulosus* infections are sheep and cattle-raising countries, including Tanzania and the southern half of South America and Paraguay [16]. In addition, human infection occurs frequently throughout northern, southern and eastern Europe, Siberia, Turkestan and Mongolia as illustrated in (Figure 1).

### Morphology of *Echinococcus Granulosus*

The adult *E. granulosus* lives attached to the mucosa of the small intestines of dogs and related animals. According to Sweatman and Williams, Belding, Beaver *et al.* it is a minute worm measuring 2 to 9 mm in length [1,17,18]. It consists of three or four segments and has a globular scolex of 0.3 mm in diameter containing a rostellum and four cuplike oval suckers. The rostellum is armed with a double crown of large and small hooklets. The total number of hooklets ranges from 25-44 [17], 28-40 [1], 28-50 [2], and 32-40 [18]. The majority of protoscoleces have two rows of hooks with an equal number of large and small hooks. The scolex is followed by a short neck and usually only one or two immature segments. The mature segment has fully developed reproductive organs consisting of testes and ovary. The gravid segment is the broadest and longest. In the gravid unit, the uterus contains as many as 500 eggs, which are discharged into the faeces from the ruptured segment (Figure 2). The subspherical egg is 34 to 41  $\mu$ m in diameter, has a brown hexacanth embryo, and is similar in appearance to those of other taenial worms [1] (Figure 3).

### Life cycle of *Echinococcus Granulosus*

#### Final host

According to Lewall [16], the final hosts of *E. granulosus* are dogs, wolves, jackals, dingoes, coyotes and foxes. Feline species are seldom infected naturally, but the parasite has been reported in cats, wild cats and leopards, which can also serve as hosts, but with low efficiency.

#### Intermediate host

The common intermediate host of *E. granulosus* is many domesticated mammals such as sheep, cattle, pigs, goats and camels. Sheep, which harbor the most fertile hydatid cysts, are the most important intermediate host and represent the most important source of infection to dogs through the feeding of infected offal, [19].

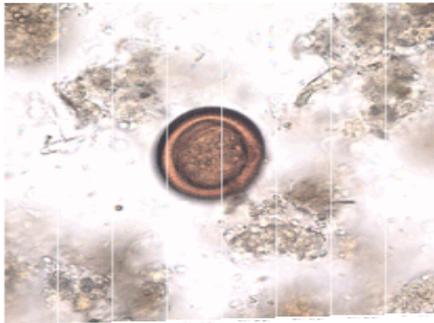


Figure 3: Morphology of egg of *E. granulosus*.

In Canada, deer, moose, bison, wild boar and horse are often infected and can serve as hosts. Animal hosts differ from area to area [10]. Humans are accidental intermediate hosts.

### Development

The intermediate host ingests eggs of *E. granulosus*, which are passed in the faeces of the final host and are immediately infective. They are resistant to external conditions and are capable of development even after months outside the body [1]. Following ingestion by an intermediate host, they hatch in the small intestine and the resulting oncospheres invade the blood vessels of the wall. The hatching process uses the disaggregation of the keratin-like blocks of the embryophore by pepsin, pancreatic enzymes, etc., followed by the activation of the contained oncospheres [20].

The liberated muscular oncosphere uses its six hooks to attach itself to the microvilli of the jejunal region of the small intestine [21] and enters the lymphatic or mesenteric venules and becomes lodged in various organs. This probably in turn affects the differential distribution of the metacestodes between the liver and lungs. Within twelve hours after ingestion, it arrives at the liver, where if not destroyed by phagocytic cells, it develops into a hydatid cyst [1]. They then settle in the liver, forming a respective cyst, which is the origin of an *Echinococcus*. However, the liver is not always the primary filtration site [22]. Inhaled eggs can also cause pulmonary hydatid disease as it has been shown that eggs administered to sheep by a tracheostomy develop into lung cysts [16]. The larvae of *E. granulosus* may also develop in the heart, spleen, kidneys, brain, eyes and long bones (Dunn, 1978). The speed of development of the embryo to the fully formed metacestoda is slow, and during the first 10-14 days, it involves cellular proliferation, degeneration of the oncosphere hooks, and formation of a central cavity and development of the laminated and germinal layers. For example, the time taken to produce the first brood capsules from eggs is reported to be not less than 7 months in mice [23], 10-12 months in pigs [24], and 10-48 months in sheep [21].

When a final host ingests or inhales these hydatid cysts, the protoscoleces project their heads and secure a firm hold among the villi of the small intestine and mature into adults in 40-50 days. Since each worm stays in a host for 5-29 months, the eggs of *E. granulosus* are liberated after detachment of a gravid segment, which occurs every two weeks. Thus, the number of eggs produced by an adult is less than those for other cestodes [18]. In addition, the small intestine may finally become full of adults as a result of repeated infections or intake of a large number of cysts. Each scolex that is ingested is

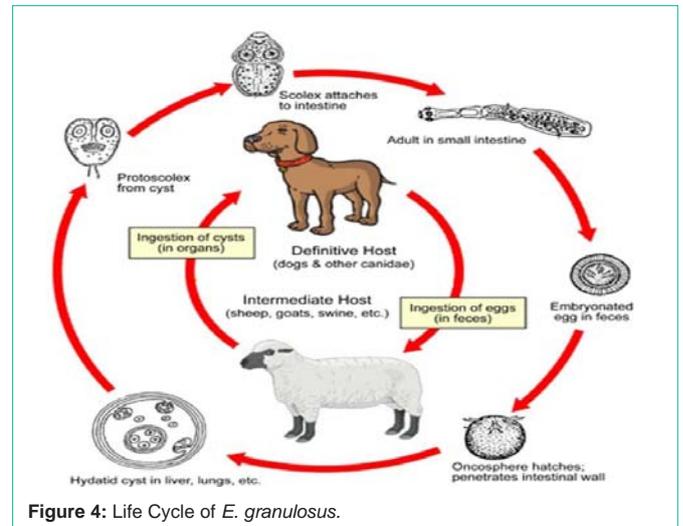


Figure 4: Life Cycle of *E. granulosus*.

capable of developing into an adult worm in the intestinal tract in about seven weeks [10]. In heavily endemic areas, 50% of the dogs are infected with adult worms, and up to 90% of sheep and cattle and 100% of camels may be infected with hydatid cysts [25] as illustrated in Figure 4. Borrie *et al.* recorded the mode of transmission to be a direct transfer of eggs by hand or unwashed vegetation to the mouth [26]. However, experimental evidence has been reported that echinococcosis can become established in the lungs of sheep from eggs without their prior ingestion through intratracheal route.

The pathology caused by the presence of a single unilocular cyst depends very much on its site in the body. In the liver, the cyst may cause compression of the liver cells, leading to biliary stasis and cholangitis. Lung cysts are always intracapsular and their rupture may result in protoscoleces being coughed up in the sputum. Hydatid cysts in the brain or spinal cord are usually small and may cause symptoms earlier than in other sites. Renal cysts sometimes occur and, if they burst into the kidney pelvis, may become secondarily infected.

### Unilocular Hydatid Cyst

The hydatid cyst in *E. granulosus* is usually unilocular; a spherical cyst the size of a child's head or larger. The larval growth occurs through evagination with hollow protuberances of the cyst wall, and by exogenous budding of solid and bare extensions of the germinal membrane with progressive invasion of the organ [27]. The cyst increases in size, attaining in the course of its growth a diameter of about one mm in one month, 10 mm in five months, and 200 mm after several years. The final cyst usually grows to a maximum of 10-12 cm in diameter [1]. By the fourth day, larvae reach a diameter of 40 μm, when they begin to develop a cystic cavity. By the end of three weeks the young cyst has attained a diameter of 250 μm [2]. The cyst is filled with pale-yellow fluid and comprises three layers: a thick connective tissue capsule formed by the reaction of the host, a median laminated layer and an internal thin germinal membrane about 22-25 μm thick which produces the brood capsules containing protoscoleces.

The laminated layer can be up to five mm thick; with non-nucleated hyaline supporting curricula, also a brood capsule is a spherical body of about 0.15 mm in diameter [28]. From the germinal

layer, masses of cells are budded out into the cystic cavity. These cells become vacuolated and later stalked [2]. The thin-stalked brood capsules often break away from the germinal layer and may rupture, releasing invaginated protoscolecemes, which settle down to add to the brood capsules and sediment also containing separated hooks and other components. It is called hydatid sand [29].

Daughter cysts which are free in the cavity of the main hydatid cyst appear to be quite common in certain hosts, such as humans. The endogenous daughter cyst with a thin, transparent wall develops in the cystic fluid and at times may produce granddaughter cysts [28]. The number of protoscolecemes thus formed within a mother *Echinococcus* varies, and may be as numerous as two million. Each protoscolex can develop in the canine final host into a new egg-producing adult tapeworm in 5-8 weeks [5]. These cysts are usually described as fertile cysts. However, hydatid cysts often fail to produce brood capsules or protoscolecemes, and such sterile (infertile) cysts are quite common. For example, Thompson (1977) found 27% of horse cysts and 51% of sheep cysts to be sterile. Some become sterile by bacterial invasion or calcification [2].

Hydatid cysts can survive for the entire lifespan of the host, and maximum longevity of 16 years has been recorded for horse cysts [30] and 53 years in humans [31]. Although much larger cysts containing several liters of hydatid fluids have been recorded [32], *Echinococcus* lacking protoscolecemes may sometimes arise, and the brood capsules never produce protoscolecemes. Such incomplete cysts are called acephalocyst and are seen mainly in cattle [18]. According to Elamin *et al.*, a sterile cyst was seen in a 4-year-old female camel, which showed a large vesicle on its back, and when excised, the cyst weighed 1750 g and contained 2.5 L of fluid [33].

In addition, a variety of unilocular cyst is osseous hydatid, that, it is found in the bones. Osseous hydatid is confined by dense osseous tissue and the laminated layer is poorly developed. The osseous hydatid migrates along, for example, the bony canal as a naked protoplast, frequently eroding the surrounding osseous tissue [2]. According to Mahmoud and El-Garhy the cyst wall contains a carbohydrate-protein substrate complex, collagen and possibly calcium. Calcium is also reported in protoscolecemes of hydatid sand [34].

### Diagnosis of hydatid cysts

As most *E. granulosus* infections remain asymptomatic for many years before the increasing number of cysts are able to cause symptoms in the infected organs, different methods have been widely used in the diagnosis of hydatid disease including imaging techniques in humans, immunodiagnosics in livestock, final hosts and humans [35].

Hydatid fluid (hydatid sand) aspirated from a cyst through the opening of a cyst may show the presence of protoscolecemes. Normally the protoscolecemes are invaginated. The presence of protoscolecemes is diagnostic and based on morphology of cyst [36]. The presence of protoscolecemes indicates activity of the cyst. However, if they are absent, they are an indication for growth of cyst or degeneration [36].

### Prevalence of hydatid cysts in livestock

The eggs adhere to the coat of the final host, which are usually dogs, and can be found concentrated particularly on the hair near

the mouth and anus. In addition, they are also found in dust and vegetation with a particularly high concentration around kennels, but in water, they sink rapidly. Apart from those activities associated with dogs by which eggs spread other methods by which eggs are spread include wind, flies and beetles [37]. Also, Dowling *et al.* reported that studies have shown that taeniids eggs can be dispersed over a wide area by blowflies and birds [38].

Sweetman and William and Gemmell reported that eggs of *E. granulosus* might remain infective for several weeks, although sunlight and heat have been reported to be lethal during the first 3 weeks [17,37]. The eggs are still infective after they had been kept in tap water at 6 °C for 7 months. In addition, Gemmell observed that eggs of *E. granulosus* were made harmless by boiling water, but because heat penetrates dog faeces slowly, infective material should be boiled at least 5 minutes to render the eggs harmless [37].

### North Africa

In Tunisia, Deve reported hydatid cysts in 20.6% of sheep, 16% of goats, 30% of camels and in all the cattle examined at different abattoirs in that country [39]. In addition, Benosman [40] found a 6.9% infection rate in sheep, 19.4% in cattle, 28.8% in pigs, 66.2% in camels and 5% in horses while Brahmi reported a prevalent rate of infection of 2.8% in sheep, 8% in cattle, 19% in pigs and 17.5% in camels [41].

In Morocco, little was published on the incidence of hydatid disease until recently when Pandey *et al.* reported an 80% infection rate in 35 camels [42]. In 1988, Pandey *et al.* reported that 5.3% of sheep and 44.6% of cattle examined from Quarzazate in southern Morocco had hydatid cysts.

In Algeria, Jore [43] found 21.9% of sheep and 30% of cattle infected in different Algerian abattoirs, while Larbaoui *et al.* found that 42.1% of a large sample of camels had hydatid cysts [44].

In Egypt, hydatid cysts have been reported in different livestock hosts. For instance, Elkordy recorded 31% infection in camels, 10% in cattle, and 1.5% in sheep at a Cairo abattoir [45]. Moreover, he observed calcified cysts in 36.4% of animals examined. At the same abattoir, Abdou recorded 30% infection in camels, 10% in cattle and 5% in sheep, with slightly lower levels at an Alexandria abattoir [13]. Furthermore, Elrafaie *et al.* found 3.4% of camels at Cairo abattoir infected with hydatid cysts [46]. In another survey on the incidence of hydatid disease in slaughtered camels, it was found that 26.5% were infected at Assiut abattoirs during 1985-1989 [47]. All the surveys also revealed that the liver was the most commonly infected organ at 64% of the infected cattle, and 75% of the infected sheep. Lung infections represented 36% in cattle and 4.5% in sheep. There were a few cysts in the spleen and other organs of some of the animals. The highest levels of fertile cysts occurred camels at 68.4% and sheep at 63.6%, and the lowest from those in cattle at 11.3%.

In Libya, data on the disease and its epidemiology is still extremely limited, although the problem is acknowledged as serious in both humans and livestock [48]. Hydatid cysts infection in livestock was first reported by Medulla [49], who found that hydatid infections were common in camels and other livestock animals. In 1961, Cicogna investigated the prevalence of unilocular hydatid cysts in livestock

and found that 40% of sheep and 70% of cattle were infected. Gusbi *et al.* [50] recorded studies in Libya that show that livestock animals drink from open water sources and have free access to vegetables gardens, which were often unfenced, thus this is one of the reasons that help in the prevalence of infection hydatid disease.

However, apart from incidental information collected from previous records, at abattoirs during routine work at meat inspection nothing is known about the prevalence of hydatid disease in farm animals. For example, Dar and Taguri simply collected incidental abattoir data for the period, (1975-1977) reporting prevalence of 3.1-63.4% in sheep, 5.5-18.1% in goats, 1.4-34.7% in camels and .7-4.9% in cattle [51]. In addition, Gusbi *et al.* [50] reported high prevalence in sheep and Gusbi *et al.* [52] found that 5.4% of cattle at 14 different areas were infected, and 35.9% of camels were infected. Tashani *et al.* [48] recorded the infection rate in Benghazi city at 20% in sheep, 3.4% in goats, 11% in cattle and 13.6% in camels. Aboudaya [53], reported a larger collection of data from 46 abattoirs, covering the months of 1976 from June to December. The prevalence of hydatid disease was 6.6% in cattle, 4.3% in sheep and 27.25% in camels. Finally, Gusbi *et al.* [52] recorded the intensity of infection in camels from Benghazi, Alsa, Sebha, and Tripoli. Of 193 cysts obtained, 68 (35.2%) were in the liver and 125 (64.8%) in the lung. Finally, Elmajdoub *et al.* [54] reported the fertility rates in the Misurata region in Libya were 62.7% in sheep and 60.3% in camels, but all examined cysts from cattle were sterile.

## Other Locations

Hydatidosis is common in the sheep population with the prevalence in some areas as Kazakhstan reaching over 50% in old sheep [55]. Similarly, Mobedi *et al.* [56] and Motakef *et al.* (1976) recorded that sheep were commonly infected, and act as important intermediate host of *E. granulosus* and the prevalence of infection and cyst fertility rates were high. However, although a high proportion of cattle were infected with *E. granulosus*, the fertility rate of hydatid cysts was low. In the case of Iran, hydatid cysts are most common in camels, and the cysts have a high fertility rate. For example, Hosseini [57] recorded the prevalence of hydatid cysts in some regions from Iran 1.5-16.8% in sheep, 6-14.7% in cattle and 11.3%-64.0% in camels. In addition, Hosseini [57] recorded fertility rates of 88% in sheep, 83.7% in cattle, and 13% in camels and the viability rates of protozoa were 60% in sheep, 75% in cattle, and 60% in camels in Iran. In the case of Jordan, Abo-Shehada [58] reported that the infection rates for sheep, cattle and camels were 1.3-71.1%, 1.3-12.9%, and 8.8-11.1% respectively, while Abdel-Hafez and Al-Yaman [59] reported the infection rate in spleen from sheep was 7.6% in Jordan. Molan [60] recorded infection rates of 4.5-44% in sheep, 4.3-13.9% in cattle and 20.4-72% in camels from different regions in Iraq. Hydatid cyst is endemic in Iraq, but in spite of the high incidence of this disease in livestock [61]. Lyagoubi *et al.*, [62] suggested that hepatic cysts developed at a slower rate than pulmonary cysts, and this has been attributed to a lower allowance of hydatid cyst development in pulmonary tissue. The intensity of *E. granulosus* infection in sheep increased with age in a linear pattern, and this implies that *E. granulosus* is in an endemic fixed state with no evidence of protective immunity in the intermediate host (Torgerson *et al.*, 1998). The distribution of parasites followed a negative binomial distribution [63].

In New Zealand, hydatid disease is still a major problem although the incidence rate has been reduced, with about 70 new clinical cases per year. The most heavily infected countries in Europe appear to be upper Greece, Italy, and Spain. Also, throughout southwestern Asia and northern Africa where sheep, goats and camels and to a lesser extent cattle and pigs are slaughtered hydatid infection in the people remains a health problem [64].

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