Life Cycle of Echinococcus Parasite in Dogs: Its Transmission and Impacts on Humans

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Abstract

Dogs as carriers of zoonotic parasites of the Genus Echinococcus pose a threat to human wellbeing as close companions. *Echinococcus granulosus*, *E. multilocularis,* and *E. vogeli* utilize dogs as definitive hosts in their life cycle. Livestock serving as intermediate hosts suffer economic losses due to a reduction in milk, meat, and wool quality. *E. vogeli* in the neotropical region, *E. multilocularis* in the northern hemisphere and *E. granulosus* world over (except Antarctica) infect humans when eggs released in the environment along with dog feces, either through direct or indirect transmission are ingested by humans leading to the development of various forms of echinococcosis; cystic, alveolar and polycystic in organs primarily liver. Infected individuals can go decades before the development of significant clinical symptoms and treatment with chemotherapy is lifelong to suppress the cysts while surgical procedures are not viable due to the possibility of resurgence. Untreated infections have a high chance of mortality.

Introduction

The word parasite refers to a person eating at another's table. It comes from the Ancient Greek word "parasitos" (Para = beside, Sitos = meal). Parasites being an essential component of the biosphere can affect host health, behavior and population size, food web interactions, and community structure among other things, because they are so varied and widespread that essentially every free-living organism is infected by them (Raga et al., 2009).

Dogs were the first species to be domesticated, and they are now considered vital members of cultures all over the world. They serve humans in a variety of capacities, such as hunting, hauling loads, protecting people, providing company, helping with law enforcement and military tasks, and aiding people with impairments (Ahmed et al., 2014). Owning a beloved pet can, however, pose potential public health risks. In addition to the potential likelihood of being bitten, scratched, and developing an allergic reaction, dogs serve as primary hosts for many zoonotic parasites in their infective stages (Molyneux, 2004). Because dogs carry infectious stages of several parasites that are transmissible to people and other domestic animals, the close relationship between dogs and humans poses a serious threat to public health and is becoming a cause of concern (Overgaauw et al., 2020; Robertson et al., 2000).

Parasites present on the surface of dogs (ectoparasites) commonly include ticks, fleas, lice, and mites (Kumsa & Mekonnen, 2011). Dogs are commonly left to wander freely on city streets, where they forage for food scraps close to garbage dumps which makes them more susceptible to parasite infections and external parasite infestations (Oguntomole et al., 2018) Such dogs often harbor skin-dwelling parasites that feed on their blood (Agbolade et al., 2008).

Endoparasites, as the primary cause of intestinal diseases, are the most frequently faced pathogens in companion animals by veterinary caregivers (Blagburn et al., 1996). Dogs serve as hosts for many intestinal macroparasites, such as helminths (roundworms, flatworms, hookworms, whipworms, and tapeworms) and protozoa (*Giardia duodenalis*, Cystoisospora spp., Sarcocystis spp., Toxocara spp., and *Neospora caninum*). Young dogs (less than a year old) are found to be more susceptible to gastrointestinal disorders by these parasites than older dogs. (Mendoza & Otranto, 2023; Ilić et al., 2021; Kamani et al., 2021; Morandi et al., 2020; Bogitsh et al., 2018; Barutzki & Schaper, 2003).

A few dog parasites can spread to humans. Direct transmission through touch or indirect transmission via food and water infected with zoonotic agents from the environment contaminated with animal secretions and excreta can result in diseases in humans (zoonosis) (Majewska et al., 2021; Bugg et al., 1999). This review will focus on the *E. granulosus* complex, while referring to it as a whole in *E. granulosus*, along with other members of the genus, *E. multilocularis* and *E. vogeli* with respect to the life cycle in dogs, transmission in humans as well as the resulting impacts on human life and economy.

Echinococcus Parasite in Dog

Echinococcus is a genus of parasitic tapeworms within the family *Taeniidae,* order *Cyclophallidae,* class *Cestode*, of phylum *Platyhelminths* (Dandan et al., 2019; Craig et al., 2007). This hermaphrodite tapeworm has a triploblastic body plan consisting of 3 layers: the endoderm, mesoderm, and ectoderm. The gut is absent and metabolic exchange occurs through the outer surface, the tegument. The worm has a short neck, two to six reproductive units (proglottids), and an anchoring structure, scolex which has 4 muscular suckers and two rows of big and small hooks present on the rostellum (Thompson & McManus, 2001)

The genus Echinococcus presently has eight known species and is found worldwide except Antarctica. Some Echinococcus species exploit the life cycles of wild animals, while domestic animals can also help spread the disease. Other species are disseminated by predator-prey cycles, including those of domestic animals (Romig et al., 2017). Although all species have been identified as having zoonotic potential or are suspected of such, two species—*E. granulosus* and *E. multilocularis*—pose a significant concern to public well-being. They are the most dangerous helminths known for causing cystic and alveolar echinococcosis in humans as well as financial losses in animals (Deplazes et al., 2017; Wang et al., 2004). Another significant form of echinococcosis in humans is polycystic echinococcosis which is brought on by two other species, *E. vogeli* and *E. oligarthrus* (Nakao et al., 2010) (Table 1)

Table 1: Echinococcus species and form of echinococcosis caused by them

Species	Size of Adult Stage	Form of Echinococcosis
E. granulosus	2-7mm	Cystic Echinococcosis (CE)
E. multilocularis	1.2-4.5mm (approx. < 5mm)	Alveolar Echinococcosis (AE)
E. vogeli	5.6mm	Polycystic Echinococcosis (PE)

E. granulosus is a species complex referred to as *E. granulosus sensu lato* (Santolamazza, et al., 2020). 5 different species make up this complex, according to recent phylogenetic analyses based on nuclear and mitochondrial DNA: *Echinococcus granulosus sensu stricto* (s.s.) (genotype G1, G2, G3), *Echinococcus equinus* (Genotype 4), *Echinococcus ortleppi* (Genotype 5), *Echinococcus felidis* (lion strain), and the genotypic cluster *Echinococcus canadensis* (Genotype 6, 7, 8, & 10) (Lymbery, 2017; Knapp et al., 2011; Nakao et al., 2010; Thompson et al., 2002). The genotypic cluster *E. canadensis* may be resolved into new species in the future as *E. intermedius* (G6/G7), *E. borealis* (G8), and *E. canadensis* (G10) but no consensus has been made yet (Vuitton et al., 2020; Laurimäe et al., 2018) (Table 2). The most commonly reported genotypes among canids are the *E. granulosus* sensu stricto (G1-G3) and G6/7 genotype of the *E. canadensis* cluster (Shams et al., 2022).

Table 2: Genotypes within E. granulosus sensu lato

Species Complex	Species	Genotype
E. granulosus sensu lato	*E. granulosus sensu stricto*	G1
		G2
		G3
	E. equinus	G4
	E. ortleppi	G5
	E. felidis	Lion strain
	E.canadensis	G6
		G7
		G8
		G10

Echinococcus granulosus
Morphology

Adults typically range in length from 2-7 millimeters and their anatomy is characterized by a segmented body (strobila) which consists of 3-4 segments, a rounded scolex (0.3 mm-diameter) with 4 cup-like ovoid suckers, and rostellum laced with hooks (Manterola et al., 2023; Magambo et al., 2006). About 823 eggs are present in a mature proglottid (Eckert & Deplazes, 2004).

Life Cycle

Dogs and other canids (jackals and hyenas) house adult tapeworms in their intestines serving as definitive hosts while sheep, cattle, goats, horses, and other ungulate animals play the role of intermediate hosts for the larval stage of *E. granulosus*. Humans infected by mistakenly consuming the eggs become dead-end intermediate hosts (Tamarozzi et al., 2020; Rokni, 2009). At the domestic level, lack of supervision of slaughterhouses (allowing wandering dogs to obtain meat scrapes), deliberate feeding of infected viscera after backyard slaughter, or roaming of stray or semi-stray dogs through grassland to feed on livestock cadavers are the three main ways that dogs become infected (Romig et al., 2017). Eggs may also be carried by the dog on its fur after release in the stool (Torgerson and Heath, 2003).

The small intestine of a dog harbors the adult form of the parasite which sheds its eggs (approx. 40 mm in diameter) from the gravid proglottids that are passed out of the body through feces. After being consumed by the intermediate hosts (by touching the infected dog or by intaking a meal contaminated with fecal matter), the eggs transform into a six-hooked embryo (oncosphere) that pierces the intestinal mucosa, infiltrates the blood circulation, and shifts to the liver, lungs, or any other internal organ forming the hydatid cyst, or metacestode. Multiple organs may be infected (Manterola & Claros, 2021; Nunnari et al., 2012; Manterola et al., 2003). Several protoscoleces (head larvae) develop

inside the thick-walled cyst increasing its size. A germinal layer develops over the cyst in a period of several months. This membrane gives rise to brood capsules, which contain one or more invaginated heads (protoscoleces). These mature into adult tapeworms in 32–80 days when the cyst-bearing organ is engulfed by a dog or other canid host (Figure 1) (Moro and Schantz, 2009).

Fig. 1: Life Cycle of *Echinococcus granulosus*
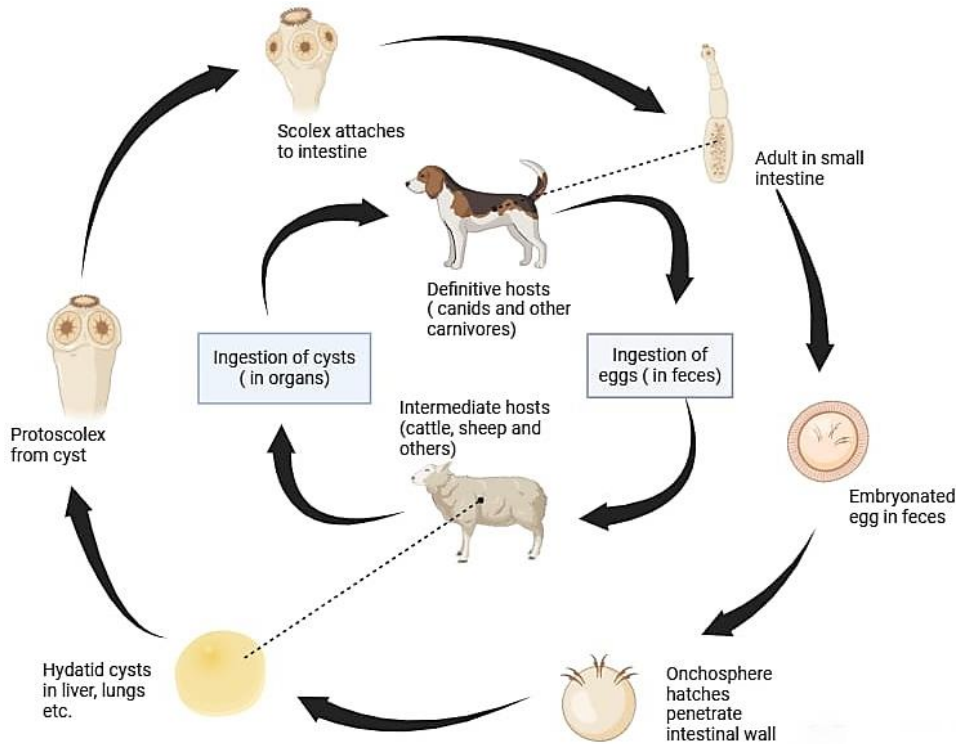
When intermediate hosts (sheep, cattle) are alive, there are no significant visible symptoms of cysts in the liver or lungs. When these animals are taken to slaughterhouses and cut open only then the damage is revealed (Taylor et al., 2015; Carmena & Cardona, 2013). Rodents and cats may also develop cysts. In such a case they are not important hosts for reproduction of the parasite and indicate the range of accidental hosts that can be infected by the metacestode (Yang et al., 2009). Even though canid infections with the metacestode stage (that usually infects the intermediate host) are uncommon, they can occur if a dog comes across plants bearing the eggs or they ingest eggs released after initial infection with mature tapeworms (Corsini et al., 2015; Haller et al., 1998).

Echinococcus multilocularis
Morphology

Echinococcus multilocularis is exclusively found in the Northern Hemisphere as the most potentially life-threatening helminthic parasite of human illness in its metacestode stage (Santaro et al., 2024; Knapp et al., 2015). Adult *E. Multilocularis* is about 1.2 to 4.5 (approx. <5) mm in size. It is characterized with a head (scolex), neck and strobila. The scolex has a rostellum with 28-30 hooks and 4 suckers. The strobila has about 4-5 segments and the gravid proglottid is inflated like a sack (Eckert et al., 2001).

Life Cycle

Just like *E. granulosus, E. multilocularis* requires a definitive and intermediate host for reproduction. Even though red foxes (Vulpes vulpes) are most common final hosts, other canids such as wolves, domestic dogs, coyotes, raccoon dogs and to some point felid species can get infected by adult tapeworm. Small mammalian rodents such as voles (grassland voles, bank voles, gray-sided voles etc.), field mice and pika species as well as ungulates can serve as intermediate hosts as observed in areas of Europe and Japan along with other regions (Romig et al., 2017; Kapel et al., 2006; Ohbayashi, 1996; Rausch, 1986;).

The adult of *E. multilocularis* lives attached to the small intestine of definite hosts. Its gravid proglottid detaches from the rest of the body and releases a number of eggs (30-40 mm in diameter) which exit the animal along with its feces. These eggs are consumed by intermediate hosts and move from the intestine into the blood and reach the liver where they transform into multi-chambered thick-walled cysts. The cysts may invade other organs. These cysts develop protoscoleces within them. The definitive host feeds on and consumes the cyst infected organs. Protoscoleces adhere to walls of intestine and take 32-80 days to mature into adults. (Massolo et al., 2014; Eckert & Deplazes, 2004; Eckert, 1998) (Figure 2).

Wild dogs that hunted rodents were reported to have high susceptibility for infection (Antolova et al., 2009). In domesticated dogs there is little to no evidence supporting the maintenance of parasite life cycle without the involvement of wild canids (Romig & Wassermann, 2024). Within a locality, the dispersal of the definitive host's fecal matter and local climatic adjusters limiting the survival of the eggs dictate how the eggs are transmitted to intermediate hosts (Giraudoux et al., 2002).
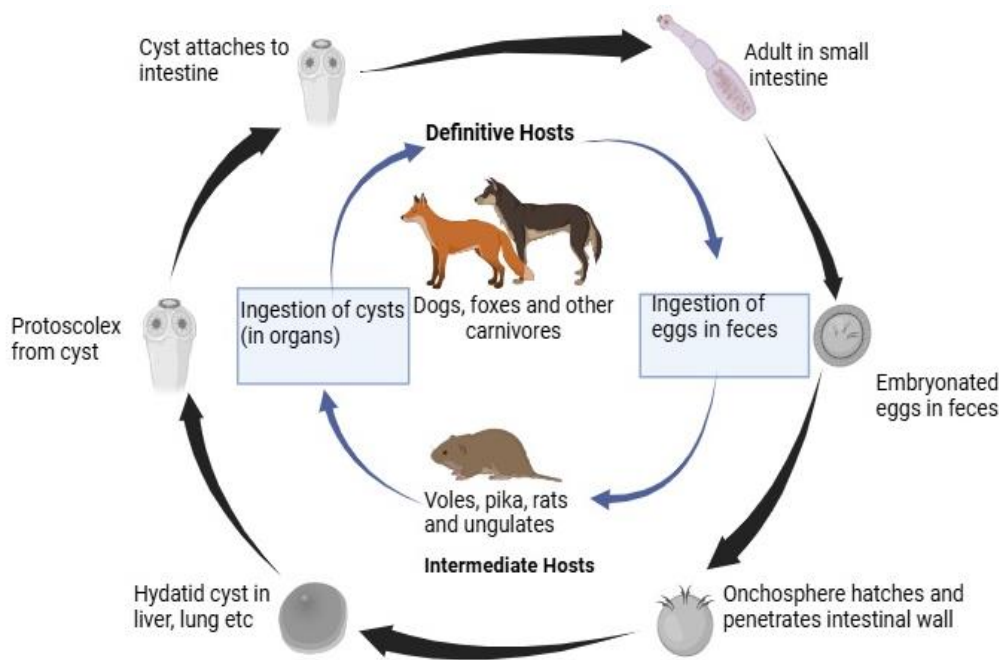
Fig. 2: Life Cycle of *Echinococcus multilocularis*

E. vogeli

E. vogeli, with distribution only in Central and South America, is the causative agent of polycystic echinococcosis (Nunnari et al., 2012). Adult can reach up to 5.6 mm and cysts in intermediate hosts are similar to those formed by E. granulosus but they have multiple chambers (Eckert et al., 2001).

Bush dog acts as the definitive host of E. vogeli and intermediate hosts are paca and agouti species (D'Alessandro, 1997). Although dogs are not the common definitive host, they can be infected for experimental purposes and one domestic dog has also been shown to have the adult tapeworm in its intestine. (Rausch & D' Alessandro, 2002). It is assumed that domestic dogs become infected when they consume infected organs of intermediate hosts that are fed to them by humans after their hunting activities (Basset et al., 1998).

Transmission in Humans

Cestodes of the genus Echinococcus are the cause of human echinococcosis, often referred to as hydatidosis or hydatid disease. The disease caused by *E. granulosus* is referred to as cystic echinococcosis and it's the most common type. Alveolar echinococcosis is brought on by E. multilocularis, which is growing in frequency. (Siles-Lucas et al., 2017). Both types of echinococcosis infections are prevalent in low-income nations (Otero-Abad & Torgerson, 2013).

Cystic Echinococcosis

Humans are incidental intermediate hosts of the causative parasite and are infected either indirectly via consumption of contaminated berries, mushrooms, raw meat or water or via direct close contact (Eckert et al., 2001). The spread of the parasite from animals to people might be aided by several conditions. Free dog wandering, feeding dogs viscera, owning a dog, killing at home, inadequately regulated slaughterhouses, living in a rural area, and having a poor income are all possible risk factors linked to CE (Possenti et al., 2016).

Eggs are dropped in the feces of dogs and are consumed by humans. The hexacanth embryos inside the eggs hatch after they reach the intestine, pierce the intestinal wall, and enter portal circulation. The oncospheres can enter almost any organ of the intermediate host and grow into hydatid cysts (Moro & Schantz, 2009). Oncospheres migrate to organs and form a germinal layer that supposedly shields them from host's immune system (Gottstein et al., 2017). The highest frequency of cysts is observed in liver (70 %) followed by lungs, brain and other viscera (McManus et al., 2003; Chin, 2000) (Figure 3).

It is believed that the typical growth in cyst diameter is 1 cm / year (Sierra et al., 1985). The organ implicated, the diameter of the cyst and its placement in respect to affected organ, interaction between increasing cysts and its vicinity, and problems from cyst rupture all affect the range of expression of symptoms. Most echinococcosis patients, particularly those in the early stages, have no symptoms (McManus et al., 2003).

Symptoms: Incubation time varies from patient to patient, and clinical indications may take months or 10 to 12 years to appear. When symptom do show up, they usually include ascites, portal hypertension, biliary cirrhosis, cholestasis, hepatomegaly, abdominal distension and upper abdominal discomfort (McManus et al., 2012). Individuals with cysts in lungs show symptoms like chest pain, dyspnea, chronic cough, blood with sputum and elevated body temperature (Tsaroucha et al., 2005)
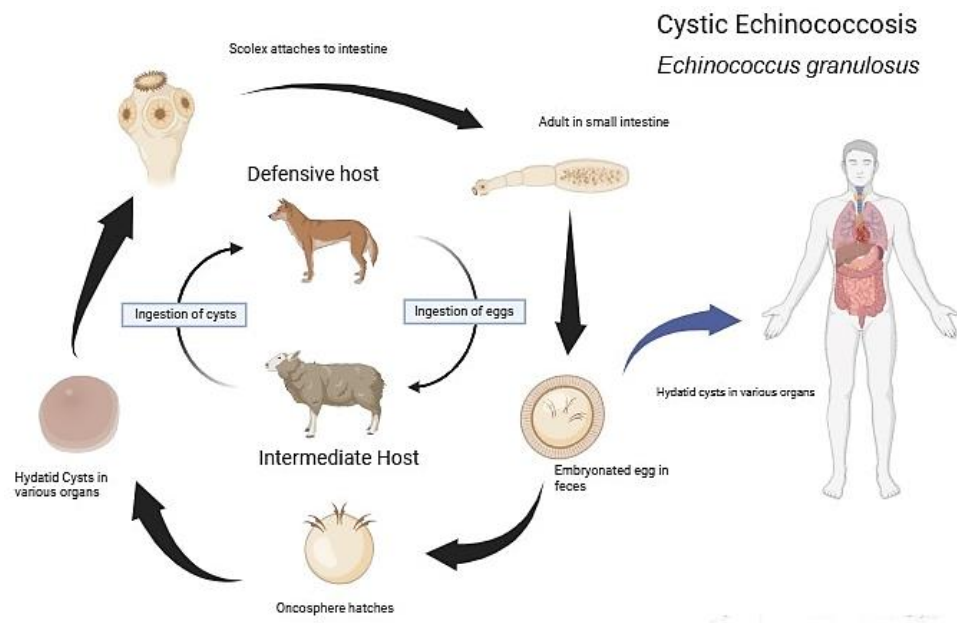
Cystic Echinococcosis
Echinococcus granulosus

Diagnosis: Imaging techniques like computed tomography (CT) scans, x-ray and magnetic resonance imaging (MRI) are utilized for visualization of cysts in liver and lungs. Further confirmation is done by serological testing along with cystic fluid antigen testing (Stojkovic et al., 2012; Carmena et al., 2006).

Treatment: Mebendazole, albendazole, and praziquantel treatment have been demonstrated to be beneficial. Removal of cystic mass with surgery is only feasible for 20 to 50% of patients due to incomplete removal of metacestodes (Kern et al., 2017; Taylor et al., 2015)

Alveolar Echinococcosis

Either through direct interaction with infected canids or indirectly through polluted surroundings, individuals get afflicted when they inadvertently consume eggs of *E. multilocularis* that are dropped in the excrement of definitive hosts (Ammann and Eckert, 1995).
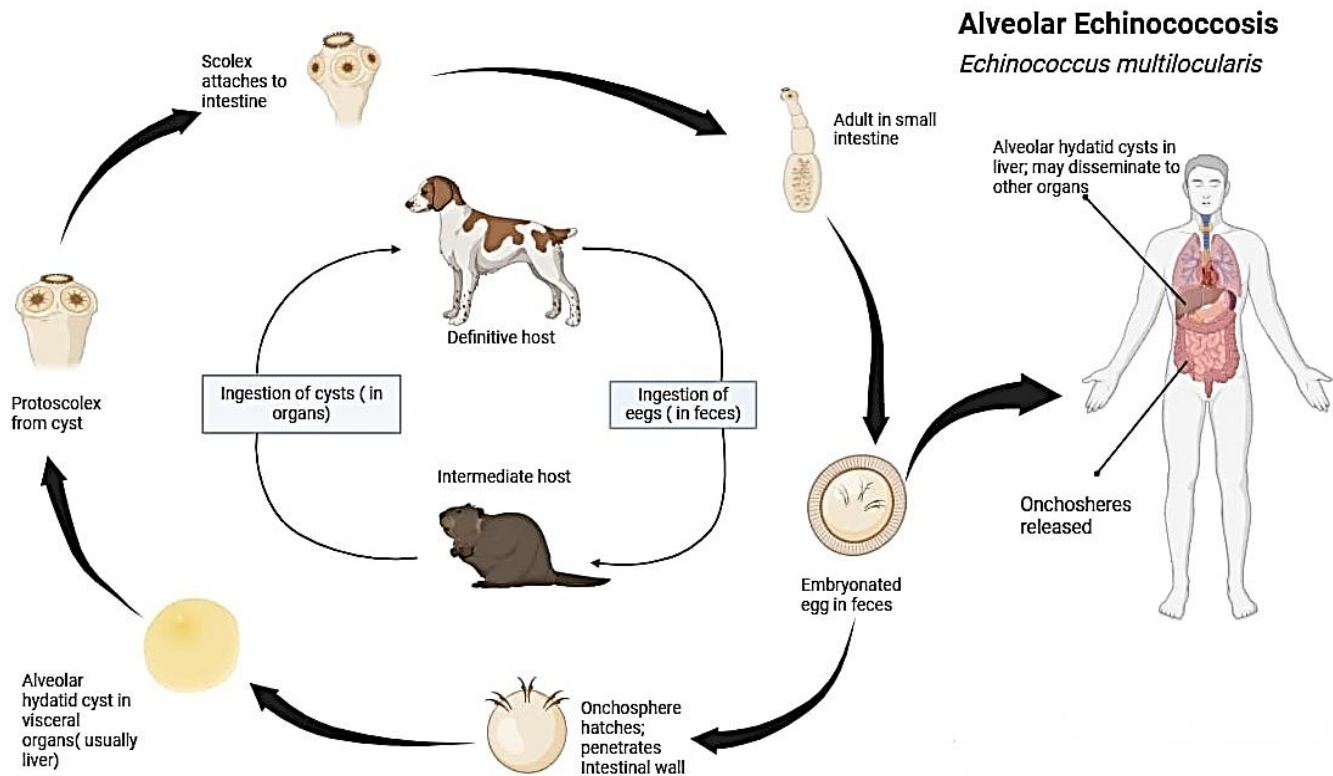

Alveolar Echinococcosis
Echinococcus multilocularis

Fig. 4: Transmission of *E. multilocularis* in humans

The larva stage is first found only in the liver and later metastasizes into other organs (lungs, spleen, abdomen, brain & bones). At first, the cysts are small and start forming outgrowths (buds) that usually remain associated with the cysts but may break off to develop a multilocular metacestode. Affected by the response of the immune system, this metacestode keeps on multiplying. Metacestodes may grow in size up to 15-20 cm. Symptoms such as abdominal discomfort, jaundice, hepatomegaly, and extreme liver dysfunction appear when the metacestodes have taken over a large portion of the liver disrupting normal liver function. If left unchecked it can lead to death as shown in Figure 4 (Gottstein et al., 2017; Eckert, 1998).

Diagnosis: All the techniques that are used for the diagnosis of cystic echinococcosis can be used for its identification: Ultrasonography, CT scans, MRI and x-rays (Eckert et al., 2001)

Treatment: Chemotherapy with albendazole and mebendazole treatment is applied (Reuter et al., 2000). Radical surgery for the removal of lesions is usually the first choice and may lead to a cure. Transplantation of liver is not feasible as parasite remnants go undetected and may cause disease again. Individuals must undergo chemotherapy for 2 years post-surgery (both radical and transplantation) and monitoring for at least 10 years to catch any resurgence due to leftover parasitic remnants (Pawlowski et al., 2001; Amman and Eckert, 1995).

Polycystic Echinococcosis

The rarest type of echinococcosis is caused by *E. vogeli* which is restricted to Neotropical region of the world where native people keep dogs in close proximity (Tappe et al., 2008; D'Alessandro et al., 1981). These dogs accompany people during hunting activities and are fed viscera of hunted pacas for their help (Siqueira et al., 2013). In humans, metacestodes unusually develop in the liver and proliferate to form multicompartment cysts containing small daughter cysts within. Cysts later spread to other organs such as spleen, lungs, abdomen and diaphragm forming secondary cysts (Rausch & D'Alessandro, 1999).

Symptoms of infection resemble those of AE and may take years to appear. Cysts within liver cause hepatomegaly, abdominal discomfort, jaundice, anemia and fever. Cysts in lungs cause chest pain and breathing difficulties. When an infection reaches advanced stages, mortality rate increases (D'Alessandro, 1997). Treatment involves the same techniques as cystic echinococcosis, surgery and chemotherapy with albendazole and mebendazole (Eckert et al., 2001)

Impacts on Humans

Although E. granulosus is widespread worldwide, infections are more prevalent in Central Asia, Western China, and several regions of South America, including Argentina, Chile, and Peru. Within these areas, rates of infection can be 5-10% (Tamarozzi et al., 2017; Moro et al., 2005). Disability-adjusted life years (DALYs) that are reduced are between 184,000 and 3.6 million annually, affecting around 1.2 million people (Craig et al., 2007; WHO, 2015). Additionally, about 1-2% of CE infections are fatal (Torgerson et al., 2003).

Cystic echinococcosis poses significant financial problems in farm animals due to liver destruction. The output of meat and milk, as well as the value of the wool from diseased sheep, might be significantly reduced leading to an annual ~ $2 billion loss (Torgerson et al., 2001; Cardona et al., 2013). In Pakistan, two strains of E. granulosus (G1 and G3) were found prevalent among livestock. CE in patients due to G1 strain correlates to transmission due to unhygienic and poor slaughter practices of cattle in the region (Latif et al., 2010).

Survivability of untreated AE may be < 29 %, 10 years after diagnosis which may fall to 0 % after 15 years (Kern et al., 2006). AE causes a median of approx. 18,000 cases worldwide, with a yearly burden of 666,433 DALYs (Torgerson et al., 2017). Human infections usually happen in rural, pastoral, and impoverished settings with sheep and cattle, where dogs are frequently kept near homes (Agudelo Higuita et al., 2016). This makes dog companionship a major risk (Rojas et al., 2018).

Conclusion

Helminths of genus echinococcus cause serious zoonosis in humans and are found all around the world. Dogs as definitive hosts spread eggs leading humans to harbor the intermediate stages of the parasites. In addition to causing human infections, the cestodes also contribute to economic losses pertaining to decrease in carcass weight, reduced life span, and reduction in wool and milk yield in livestock due to contamination of internal viscera. Most cases in poor countries are due to inadequate slaughter practices where stray dogs having access to contaminated meat roam freely spreading the disease. Infections in humans can be asymptomatic for a long time and after diagnosis, with the aid of different imaging techniques, the treatment is life-long usually involving chemotherapy to cease cyst growth while surgical procedures prove to be ineffective due to incomplete cyst removal. The risk associated with dog companionship as well as the issue of stray dogs highlights the importance of proper hygiene and supervised slaughter practices in reducing the incidence of echinococcosis.

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