Echinococcosis

Echinococciasis,
Hydatidosis,
Hydatid Disease

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Importance

Echinococcosis is a zoonotic disease caused by tapeworms in the genus *Echinococcus*. The organisms live in the intestines of the definitive hosts as adults, and in the internal organs of intermediate hosts as cyst-like larvae. Some species of *Echinococcus* circulate in domestic animals; others occur in wildlife (sylvatic) cycles or have both domestic and sylvatic cycles. Adult tapeworms are usually carried asymptomatically in their definitive hosts, which can include dogs, cats and wild carnivores. Dogs are particularly important in zoonotic transmission due to their defecation habits and close relationships with humans. Many mammals and marsupials, including humans, livestock, pets and wildlife, can act as intermediate hosts. Intermediate hosts are usually asymptomatic in the initial stages, but the growing larvae, which often develop in the liver or lungs, may eventually cause illness and sometimes death.

Echinococcosis is a major public health problem in some countries, and it may be emerging or re-emerging in some areas. Cystic echinococcosis, the most common form of the disease, is caused by the members of the *Echinococcus granulosus sensu lato* complex. Because the larvae of these organisms usually develop as discrete single cysts, it is the least severe and most treatable form. *E. multilocularis* (alveolar echinococcosis) and *E. vogeli* (polycystic echinococcosis) are more serious and difficult to treat. The latter organisms can proliferate in intermediate hosts, forming masses that can infiltrate entire organs and may disseminate to distant sites including the brain.

Etiology

Echinococcosis is caused by members of the genus *Echinococcus*, parasitic tapeworms in the family Taeniidae, subclass Cestoda. Larval *i*nfections in the intermediate host are also called hydatid disease. Species known to affect humans or domestic animals include *E. multilocularis,* the members of the *E. granulosus sensu lato complex, E. shiquicus, E. vogeli* and *E. oligarthrus.* The name of the last organism can differ between publications: while it has been called *E. oligarthrus* since the 1920s, some authors now argue that this was based on a misspelling and is inconsistent with naming practices, and it should be called *E. oligarthra.*

Until the last 10 years, the *E. granulosus s.l.* complex was considered to be a single species divided into 9 or 10 strains or genotypes. Some of these genotypes have now been elevated to species. They include *E. granulosus sensu stricto, which* comprises the former G1, G2 and G3 strains; *E. canadensis,* which incorporates the G6, G7, G8 and G10 strains; *E. equinus* (G4); *E. ortleppi* (G5); and *E. felidis* (the lion strain). Some have proposed further dividing *E. canadensis* into two or three species, but this is controversial. A G9 strain, which was isolated from a human case in Poland, is now considered to be a variant of G7. There might be additional species of *Echinococcus*, particularly among wildlife.

Echinococcus larvae develop differently in the intermediate host, resulting in diseases with different clinical courses. The disease caused by *E.* multilocularis is called alveolar echinococcosis. Cystic echinococcosis is caused by the members of the *E. granulosus* s.l. complex. *E. oligarthrus* and *E. vogeli* cause polycystic echinococcosis (or neotropical polycystic echinococcosis), based on their larval forms in their usual intermediate hosts. Others use the term unicystic echinococcosis for *E. oligarthrus* and polycystic echinococcosis for *E. vogeli,* after the forms of the larvae seen, to date, in human cases.

Species Affected

Echinococcus cycles between one or more definitive and intermediate hosts, typically in a predator/ prey or scavenger/prey cycle involving mammals and/ or marsupials. In some intermediate hosts, larvae tend to form noninfectious ("sterile") rather than infectious ("fertile") cysts. These hosts (which may also be called accidental or aberrant hosts) can become ill but do not contribute significantly to the organism's life cycle. Whether a host is a true intermediate host or an aberrant host is not clear in many cases, especially when only a few animals have been investigated.

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Carnivores, especially canids, felids, mustelids and hyaenids, usually act as definitive hosts, while most intermediate hosts are herbivores or omnivores. There are a few old reports of hydatid cysts in birds, but the accuracy of these reports has been questioned.

Echinococcus granulosus s. s.

Dogs are usually the definitive hosts for *E. granulosus s.s.* in the domestic cycle. Sylvatic cycles are perpetuated by wild canids including various species of foxes, dingoes (*Canis lupus dingo*), golden jackals (*C. aureus*), wolves (*C. lupus*) and hyenas. This organism has also been detected in genets and wild lions (*Panthera leo*).

Sheep are thought to be the most important intermediate hosts, but infections have been found in many other species including goats, cattle, water buffalo, yaks, pigs, wild boar, warthogs (*Phacochoerus* spp.), camelids, horses and other equids, cervids and other wild ungulates, European hares (*Lepus europaeus*) and cats. Macropod marsupials such as wallabies (*Macropus* spp. and *Wallabia* spp.) and kangaroos (*Macropus* spp.) are important in a wildlife cycle in Australia.

Echinococcus equinus

The definitive hosts for *E. equinus* are canids, including dogs. Infected lions and black-backed jackals (*C. mesomelas*) have been found in parts of Africa.

Equids such as horses, donkeys and zebras are the major intermediate hosts. A few sterile *E. equinus* cysts were found in experimentally infected sheep. One attempt to infect rhesus macaques (*Macaca mulatta*) failed, which led to the belief that this organism does not affect primates; however, it was recently found in a captive red ruffed lemur (*Varecia rubra*) and a ring-tailed lemur (*Lemur catta*).

Echinococcus ortleppi

The definitive hosts for *E. ortleppi* are canids. Known hosts include dogs and jackals.

Cattle are important intermediate hosts, but *E. ortleppi* has also been reported in water buffalo, sheep, goats, pigs, camels, a zebra, oryx (*Oryx gazella*), a captive Philippine spotted deer (*Rusa alfredi*), at least two nonhuman primates (a captive ring-tailed lemur and a captive red-shanked douc langur, *Pygathrix nemaeus*) and a captive crested porcupine (*Hystrix cristata*).

Echinococcus canadensis

Dogs and other canids are the definitive hosts for *E. canadensis*. Wolves are thought to be major hosts in some sylvatic cycles, but other wild canids may be regionally important.

E. canadensis occurs in diverse intermediate hosts including cervids, camels, cattle, small ruminants, pigs, wild boar and other species. The G8 and G10 genotypes mainly infect cervids (including semi-domesticated reindeer, *Rangifer tarandus*), while the G6 and G7 genotypes generally occur in other hosts; however, G6 has been described in reindeer, and G8/G10 occurred in a muskox (*Ovibos moschatus*) and two mountain goats (*Oreamnos americanus*), with possible additional reports in a pig and an American bison (*Bison bison*).

Echinococcus felidis

Lions are important definitive hosts for *E. felidis. This organism also occurs in* spotted hyenas (*Crocuta crocuta*) but an attempt to infect dogs was unsuccessful.

Reported intermediate hosts include zebras (*Equus quagga*), wildebeest (*Connochaetes* spp.), warthogs, bushpigs (*Potamochoerus larvatus, P. porcus)*, hippopotami (*Hippopotamus amphibius*), African buffalo (*Syncerus caffer*) and various species of antelope. Some cysts in warthogs and hippopotami were confirmed as *E. felidis* by genetic methods, and zebras were substantiated as an intermediate host by experimental infection of lions, but it is possible that some hosts were infected with other species of *Echinococcus*.

Echinococcus multilocularis

Foxes are the most important definitive hosts for *E. multilocularis*. Red foxes (*Vulpes vulpes*) and Arctic foxes (*Alopex lagopus*) are major hosts, while Tibetan foxes (*V. ferrilata*) and sand foxes (*V. corsac*) are regionally important. Other canids including wolves, coyotes (*C. latrans*), raccoon dogs (*Nyctereutes procyonoides*), golden jackals and dogs can also be infected. Dogs have a minor role in most areas, but they are important hosts in a few regions, such as parts of China and certain indigenous communities in northwestern Alaska (St. Lawrence Island). *E. multilocularis* has also been reported in felids such as lynx (*Lynx* spp.), wild cats (*Felis silvestris*) and housecats. The importance of housecats in shedding eggs is debated, but most individuals seem to have a low tapeworm burden and cats are generally said to have a minimal role. A few mature tapeworms were found in experimentally infected pine martens (*Martes martes*), and immature tapeworms were described in experimentally infected American black bears (*Ursus americanus*); however, bears and mustelids are not generally thought to be good hosts for this organism.

Rodents and other small mammals (e.g., voles of the species *Microtus* and *Alticola;* water voles, *Arvicola* spp; shrews; muskrats, *Ondatra zibethicus*; nutria, *Myocastor coypus*) are the usual intermediate hosts. Infections have been also been reported in diverse other species including lagomorphs, hyraxes, pigs and wild suids, horses, macropods, dogs and cats, and various non-human primates. Some hosts, such as pigs and horses, are not thought to be involved in perpetuating the parasite, as cyst development usually seems to stop at an early stage.

Echinococcus shiquicus

Echinococcus shiquicus has been described in plateau pikas (*Ochotona curzoniae*), which serve as the intermediate host, and Tibetan foxes (*Vulpes ferrilata)*, which are the definitive hosts. Its tapeworms can mature in dogs.

Echinococcus vogeli

The bush dog (*Speothos venaticus*) is the most important definitive host for *E. vogeli*. *Cerdocyon thous*, the crab-eating fox, has been infected experimentally, and other wild canids might be susceptible. Dogs can be infected with these tapeworms.

Pacas (*Cuniculus paca*) seem to be the most important intermediate hosts, but larvae have also been reported in agoutis (*Dasyprocta* spp.), nutrias and nine-banded armadillos (*Dasypus novemcinctus*), as well as in captive nonhuman primates.

Echinococcus oligarthrus

The definitive hosts for *E. oligarthrus* are wild felids including the pampas cat (*Leopardus colocolo*), Geoffroy's cat (*L. geoffroyi*), ocelot (*L. pardalis*), jaguarundi (*Herpailurus yagouaroundi*), jaguar (*Panthera onca*),and puma (*Puma concolor*). *E. oligarthrus* was found in a bobcat (*Lynx rufus*) in northern Mexico, and it can mature in experimentally infected housecats.

Intermediate hosts for *E. oligarthrus* include agoutis, spiny rats (*Proechimys* spp.) and pacas. Infections have also been reported in opossums (*Didelphis marsupialis*) and eastern cottontails (*Sylvilagus floridanus*). Climbing rats (*Tylomys panamensis*), cotton rats (*Sigmodon hispidus*) and Mongolian gerbils (*Meriones unguiculatus*) have been infected experimentally.

Zoonotic potential

As of 2020, *E. granulosus s.s.*, *E. canadensis, E. ortleppi, E. multilocularis, E. vogeli* and *E. oligarthrus* have been detected in people, though *E. oligarthrus* seems to be very rare. There are no reports of human infections with *E. equinus* or *E. felidis* to date. One organism found in a person in Africa appeared to be related to *E. granulosus s.s.* and *E. felidis* but could not be assigned to any of the known genotypes of *E. granulosus s.l.* and might be an unknown wildlife strain.

Geographic Distribution

The E. granulosus s.l. complex occurs worldwide, with a few exceptions such as Iceland and Greenland. Its distribution tends to be focal. Human illnesses are particularly common in parts of South America, the Mediterranean Basin, Eastern Europe and Asia. Of the members of this complex, *E. granulosus s.s.*, *E. canadensis* and *E. ortleppi* are cosmopolitan and widespread. There are scattered reports of *E. equinus* in parts of Europe, the Middle East and Africa, and it probably also occurs elsewhere. One case in a horse in the U.S. was thought to be *E. equinus,* but genetic methods were not used for confirmation. *E. felidis* is thought to exist only in Africa.

E. multilocularis has been reported in much of northern and central Eurasia eastward to Japan. It is widely distributed in continental Europe. It also occurs in the northern regions of North America, where it is primarily found in Canada, Alaska and the north central U.S. from Montana to central Ohio. There are scattered reports of *E. multilocularis* in the southern hemisphere, but at least some of the cases in South America might have been *E. vogeli*.

E. vogeli and *E. oligarthrus* have been found in Central and South America. *E. shiquicus* has only been reported from the Tibetan plateau in China.

Transmission and Life Cycle

Echinococcus tapeworms have an indirect life cycle, which can only be completed with both an intermediate and a definitive host, typically a predator or scavenger and its prey. Adult tapeworms develop in the small intestine of the definitive host, and the larval metacestodes form bladder-like hydatid cysts in the intermediate host, usually in the internal organs.

Echinococcus granulosus s. l.

Definitive hosts become infected when they ingest infectious *E. granulosus s. l.* cysts in raw or undercooked tissues from an intermediate host. The larvae develop into tiny tapeworms, which consist of a scolex attached to the intestinal wall, followed by the parasite's neck and a short series ($\leq$ 7 segments) of flattened immature, mature and gravid proglottids (segments). Gravid proglottids containing eggs detach from the worm and are shed in the feces. Most animals have an average of 50-200 tapeworms, but some individuals may carry more than a thousand. The patent period usually ranges from 32 to 80 days, depending on the host animal and species of *Echinococcus*. Adult tapeworms usually stop laying eggs after 6-10 months in dogs, though they can sometimes remain alive for up to three years.

Echinococcus eggs are infectious immediately, and their sticky coat can adhere to fomites, including the animal's fur. In the environment, they survive best under moist conditions and in moderate temperatures. They are destroyed quickly if exposed to direct sunlight and desiccation: 90% of eggs placed in direct sunlight in a petri dish may become nonviable within a day. Under ideal conditions, however, they *can* remain infectious for several weeks or months, with some reports of survival up to a year. In one study, some eggs still hatched and developed into cysts in sheep after being kept outside in canine feces for almost 3.5 years in Argentina. However, these eggs no longer seemed able to complete their life cycle: all of the cysts examined appeared to be sterile (noninfectious to the definitive host).

Intermediate hosts become infected when they eat eggs or gravid proglottids, often in plant material (pastures, vegetables, fruits), but also on other contaminated foods, water, hands and other fomites. The eggs hatch in the intestine, and the larvae (oncospheres) penetrate the intestinal wall and are carried in blood or lymph to their final location, where they develop into cysts. Although cysts can be found almost anywhere, the vast majority develop in the liver and, less frequently, the lungs.

Each fluid-filled cyst is surrounded by a fibrous wall from the host and contains two walls derived from the parasite, including an inner membrane called the germinal layer. Structures called brood capsules, each of which contains one to several protoscolices, develop from the germinal layer. Each protoscolex can develop into an adult tapeworm if it is ingested by the definitive host. Brood capsules either float freely or adhere to the cyst wall. Loose capsules and protoscolices are known as "hydatid sand" and can develop into new cysts if they are released into the body, for instance if a cyst ruptures. Sterile cysts never produce brood capsules or protoscolices. Bacterial infections can also render cysts sterile.

E. granulosus s.l. cysts tend to grow slowly, generally increasing their diameter from < 1 cm to 5 cm each year. Sometimes they may persist unchanged for years. Cysts can also spontaneously degenerate and die, and may become calcified. Degenerating cysts may still contain viable hydatid sand for a time, though heavily calcified cysts are usually no longer infectious.

Echinococcus multilocularis

The life cycle and transmission of *E. multilocularis* is very similar, but the form of the larva is different and dogs and cats (but not foxes) can become intermediate as well as definitive hosts. *The patent period in the definitive host is* 28-35 days. Experimentally infected dogs and foxes shed eggs for 1 day to 4 months, with shedding becoming more irregular toward the end of this time. The adult worms probably survive in the definitive host for about 5 months. *E. multilocularis* eggs remained viable in the environment for 2-8 months under various climatic conditions in Germany, and for 2 years or more in some other reports.

E. multilocularis larvae almost always develop initially in the liver of the intermediate host. The germinal membrane proliferates externally, rather than internally, to form a multilocular (multichambered) mass with many small cysts, which may be embedded in fibrous connective tissue or a semisolid matrix The structure can contain hundreds to thousands of protoscolices in some intermediate hosts, and few or none in others. The mass is not encapsulated and it is very invasive. It can completely infiltrate the liver as it grows, may spread to nearby organs and tissues, and can metastasize to distant body sites. However, this aggressive course does not occur in all individuals; in some cases, the primary cyst dies early in its development.

Echinococcus vogeli

E. vogeli cysts are mainly found in the liver of the intermediate host, but they can also occur in the lungs and other organs. In pacas, which are the usual intermediate host, *E. vogeli* forms fluid-filled cysts, 2-80mm in diameter, which occur singly or as aggregates and may be interconnected. In accidental hosts such as primates, it also undergoes exogenous proliferation to form multichambered cysts with endogenous daughter cysts, resulting in an invasive mass that resembles *E. multilocularis*. Exogenous proliferation does not seem to occur in the natural host.

Echinococcus oligarthrus

E. oligarthrus cysts have been found in the muscles, subcutaneous tissues and internal organs (e.g., heart, lungs) of its usual intermediate hosts. They resemble *E. vogeli* and can reach up to 5 cm in diameter. Exogenous proliferation has not been reported in any species Individual single or multiple cysts were seen in the rare cases in humans.

Disinfection

Echinococcus eggs can be inactivated by heat (e.g., 70°C/ 158°F for 30 minutes, boiling), freezing at –80°C (-112°F) for 48 hours or –70°C (-94°F) for 4 days, or desiccation. They are particularly sensitive to a combination of elevated temperatures and desiccation. Laboratories can be decontaminated by setting the environmental conditions to ≤ 40% humidity and 30°C (86°F) for at least 48 hours.

Taeniid eggs are resistant to chemical disinfectants, though they can be dissolved by prolonged exposure to various hypochlorites and some copper-based compounds. Sodium hypochlorite works most quickly when it is strongly alkaline; more neutral solutions are slower. Some disinfectants such as formalin, chlorine gas, certain freshly-prepared iodine solutions (but not most iodides) or lime can inhibit hatching of the embryo and reduce the number of viable eggs; however, some embryos may remain viable and can be "rescued" by conditions that dissolve the egg coat, such as brief exposure to sodium hypochlorite. One study found that a commercial disinfectant containing 3.75% sodium hypochlorite destroyed a significant percentage of *Echinococcus* eggs within a short time, though all sources of sodium hypochlorite do not seem as effective. *E. granulosus* eggs treated with 5-10% glutaraldehyde for one hour had reduced infectivity in mice, and treatment of eggs with 1.6 mg/ml bunamidine hydrochloride for 1 hour also seemed to be promising.

Infections in Animals

Incubation Period

Echinococcus cysts grow slowly and do not usually become symptomatic until they damage adjacent tissues and organs. *E. granulosus s.l.* cysts probably have an incubation period of years in many cases, but *E. multilocularis* can kill its rodent intermediate hosts within weeks.

Clinical Signs

Definitive hosts

Echinococcus spp. tapeworms are usually carried asymptomatically in their definitive hosts. Large numbers of parasites may be able to cause enteritis and diarrhea, but this seems to be rare; dogs and foxes can have thousands of tapeworms with no clinical signs.

Intermediate hosts –cystic echinococcosis (Echinococcus granulosus s. l.)

Clinical cases caused by *E. granulosus s.l.* have been reported sporadically in diverse species including sheep, reindeer, nonhuman primates, macropod marsupials (kangaroos, wallabies) and a cat, but livestock are often slaughtered before the cysts become symptomatic. If clinical signs are seen, they are those of a mass lesion and vary with the organ affected. Most cysts occur in the liver or lungs. Cysts in the liver can cause hepatic signs including abdominal distention and discomfort/pain, ascites and jaundice, as well as nonspecific signs such as poor growth, malaise or weakness. Cysts in the lungs sometimes lead to respiratory signs including bronchopneumonia and respiratory compromise. Cysts may be found occasionally at many other sites such as the CNS, bone, heart or abdominal cavity, with diverse signs including heart failure, abdominal distention or lameness. Sudden death has been reported in some zoo animals.

Intermediate hosts – alveolar echinococcosis (Echinococcus multilocularis)

E. multilocularis usually affects the liver, but in advanced cases, metastatic lesions may be found in other organs such as the lungs, spleen, bone and brain. Metastatic disease may cause severe illness and death within weeks. Progressive abdominal enlargement, often without severe clinical signs, is the most commmon presentation of alveolar echinococcosis in dogs. Ascites, abdominal masses, hepatomegaly, dyspnea, intermittent diarrhea, nausea, vomiting and nonspecific signs of illness (e.g., lethargy, weight loss) may also be seen. Fever is possible but uncommon. Unusual cases have also been reported: one dog had a single cystic lesion in the subcutaneous tissues. Alveolar echinococcosis in nonhuman primates resembles the illness in dogs. Pigs, wild boar and horses can have asymptomatic hepatic lesions (either calcified, degenerated cysts or fertile cysts) as an incidental finding at necropsy.

Intermediate hosts – polycystic echinococcosis (Echinococcus vogeli and E. oligarthrus

At least two outbreaks caused by *E. vogeli,* one affecting nutrias and the other in nonhuman primates, have been reported in zoos. Orangutans (*Pongo abelii*) and gorillas (*Gorilla gorilla)* developed severe clinical signs including abdominal distension, and a number of animals died or had to be euthanized. *E. vogeli* does not seem to be symptomatic in pacas, the natural host, unless the cysts become very large.

E. oligarthrus localizes in the internal organs, subcutaneous tissues and muscles of its normal intermediate hosts. It has not been documented in domestic animals.

Post Mortem Lesions

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Tapeworms are found in the small intestine of the definitive host but they are not usually accompanied by significant lesions. Adult *E. multilocularis* are typically around 1-4 mm, *E. oligarthrus* approximately 2-3 mm, *E. granulosus* 2-11 mm and *E. vogeli* 4-6 mm. Most species have five or fewer segments, but some individual specimens may have up to seven.

E. granulosus s.l. larvae usually form individual fluid-filled cysts, surrounded by a fibrous wall, in their intermediate hosts. Multilocular cysts have been reported occasionally. The cysts are generally most common in the liver, followed by the lungs and, less often, other organs or tissues including the bones. They are usually around 1-7 cm in diameter, but some can become much bigger. Some cysts may be calcified, necrotic or infected. Early lesions appear as small white nodules and are easily missed. Cysts that are not visible can sometimes be detected by palpation or found when the target organs are incised.

E. multilocularis usually develops initially in the liver, though there are rare reports of single lesions at other sites (e.g., the omentum, subcutaneous tissues). Disseminated disease can affect many organs and tissues, particularly the lung and CNS. *E. multilocularis* forms multilocular cysts with a semisolid matrix that often infiltrates the tissues and can resemble a malignant tumor. The mass may be firm and lobulated or contain viscous yellowish fluid, and can have many scattered transparent or whitish cysts a few millimeters to centimeters in diameter.. Large necrotic cavities are sometimes present in its interior. Fibrosis is prominent in the lesions of some (but not all) aberrant intermediate hosts such as dogs or gorillas, but not the usual small mammal hosts. Damage to the liver can result in various lesions including granulomatous inflammation, icterus or signs of peritonitis. In pigs, which are relatively resistant to this organism, *E. multilocularis* lesions may appear as sharply demarcated, dense white foci, approximately 1-20 mm in diameter.

In their natural hosts, the cysts of *E. vogeli* and *E. oligarthrus* can occur singly or as aggregates. *E. vogeli* lesions in aberrant intermediate hosts can resemble *E. multilocularis*.

Diagnostic Tests

Definitive hosts

Echinococcus eggs may be detected during routine fecal examination, though taenid eggs are not concentrated efficiently by the usual flotation techniques for helminth eggs. Some flotation solutions and flotation/ sedimentation methods are more effective than others. If echinococcosis is not suspected, infected animals can be missed because the eggs are morphologically indistinguishable from *Taenia* spp., and the tiny proglottids are rarely noticed in the feces. Coproantigen ELISAs and PCR tests (copro-DNA assay) can identify *Echinococcus* antigens or nucleic acids, respectively, in fecal samples or recovered eggs. They can detect both prepatent and patent infections. At present, these tests are used mainly in research. Some PCR tests can distinguish *Echinococcus* species.

Surveillance programs in endemic areas have sometimes employed purgation with arecoline compounds or other agents to detect tapeworms in dogs; however, this is labor-intensive and arecoline is potentially toxic. A hand lens can be used to examine the intestines for the parasites at necropsy. The species of *tapeworm can be identified by morphology or genetic techniques (e.g., P*CR followed by sequencing or restriction fragment length polymorphism analysis).

Intermediate hosts

In live hosts, ultrasound and other imaging methods can help visualize the cysts. Biopsies, fine needle aspiration or exploratory surgery can also be used. The possibility of cyst leakage or rupture, which could disseminate the parasites or cause anaphylaxis, should be considered if fine needle aspiration is employed. Recovered cyst fluid can be examined for protoscolices, hooklets and other evidence of the parasites, though they may not be found in all cases (e.g., sterile cysts). Various stains including Ziehl-Neelsen, Wheatley trichrome or Ryan trichrome blue, Baxby and modified Baxby can be helpful. Cyst fluid can also be tested for *Echinococcus* antigens with an ELISA, or for parasite DNA with PCR tests. Many cysts in animals are found at necropsy. Cysts in tissues can be identified by histology and the species can be distinguished with various DNA techniques. Immunohistochemistry can also be helpful, though it is not widely available.

Serological tests are not used routinely for diagnosis in domestic animals. Where available, they might be of some value in conjunction with imaging, though cross-reactions with *Taenia* are an issue. ELISA tests have been developed for serological diagnosis of infected sheep flocks, but they are not reliable in individual animals.

Treatment

Definitive hosts can be treated with various anthelminthic drugs. Praziquantel, the most commonly used agent, is effective against both immature and adult *tapeworms*.

There is relatively little experience in treating animal intermediate hosts, especially those infected with *E. multilocularis* or *E. vogeli.* Surgery is often the treatment of choice for cysts that can be completely resected. Long-term treatment with benzimidazoles (e.g., albendazole or mebendazole) may suppress some cysts and/or prolong the animal's life in non-surgical cases. Drugs are also used as an adjunct to surgery, especially for *E. multilocularis.* Non-curative debulking of an *E. multilocularis* mass is no longer recommended in humans infected with this organism, and there was no evidence that it was helpful in a few dogs.

Control

Disease reporting

Veterinarians who suspect echinococcosis should follow their national and/or local guidelines for disease reporting. State regulations should be consulted in the U.S.

Prevention

Intestinal carriage of *Echinococcus* can be prevented in cats, dogs and captive carnivores by not feeding them raw or undercooked animal tissues (e.g., sheep entrails) and by not allowing them to hunt or roam. Potentially infected tissues can be cooked or frozen before feeding to destroy the parasite.

Echinococcosis in the intermediate host is controlled by reducing its exposure to parasite eggs. Periodic deworming of farm dogs is the cornerstone of control or eradication programs for *E. granulosus s.s.* in sheep. Dogs that might be infected with *Echinococcus* should not be allowed onto pastures where livestock may graze. Stray dogs have been culled in control programs in some areas, particularly where echinococcosis is an issue in humans. In some countries, foxes are treated with praziquantel in bait to decrease the incidence of *E. multilocularis. Foxes have also been culled, but these programs are controversial, the effects on the fox population can be complex, and their effectiveness is debated.*

One zoo with *E. multilocularis* issues in nonhuman primates set up a program to safeguard the animals' food by washing and steaming vegetables, sourcing vegetables to be fed raw from areas where this organism is not thought to occur, and storing all food indoors. Wood chips used in the exhibit are heat treated.

A recombinant vaccine (EG95) for *E. granulosus* in sheep has been licensed in a few countries. It can reduce the risk of infection but is not useful against existing cysts. This vaccine may also be also effective in goats and cattle.

Morbidity and Mortality

The prevalence of *E. granulosus s.l.* in livestock can vary significantly: more than 30% of dogs and up to 80-100% of sheep and/or cattle have been infected in some areas, while the incidence in other locations is much lower. Infections in livestock often increase with age. *Echinococcus* tapeworms seem to cause little or no morbidity in the definitive host. Most *E. granulosus s.l.* cysts in livestock also seem to be asymptomatic, probably due to the relatively short lifespan of these animals. Clinical cases are more likely to be seen in animals that live out their natural lifespan, such as pets or zoo animals. Untreated cases may eventually be fatal.

E. multilocularis tapeworms can be found in 1% to > 60% of wild canids (especially foxes), depending on the region. This parasite typically infects < 1% of dogs and cats; however, up to 12% of dogs may carry it in a few areas, such as parts of China. Surveys have also found *E.*

multilocularis cysts in < 0.5% to 10% of livestock. Susceptibility to this organism differs between host species. Pigs seem to be relatively resistant, and the growth of the larvae is suppressed. In contrast, the infection can sometimes progress quickly in dogs and nonhuman primates, with some animals becoming symptomatic while they are still young. In some outbreaks at zoos, the disease disproportionately affected one species (e.g., gorillas, ring-tailed lemurs), possibly due to their susceptibility to this organism and/or behavioral factors. A suspected spontaneous recovery, with a small, inactive calcified cyst, was reported in a Celebes crested macaque (*Macaca nigra*) during one outbreak. Untreated clinical cases caused by *E. multilocularis* are expected to be fatal in a high percentage of animals. The efficacy of treatment is influenced by the stage of the disease.

Infections in Humans

Incubation Period

Clinical signs in humans usually appear months to years after infection. The incubation period can be as long as 20-30 years in cystic echinococcosis if the cyst is not in a critical location. Most cases of alveolar echinococcosis are thought to become apparent in about 5-15 years.

Clinical Signs

The symptoms of echinococcosis vary with the size, number and the location of the cysts. Cysts are usually asymptomatic until they become large enough to damage adjacent tissues.

Cystic echinococcosis (Echinococcus granulosus s. l.)

The symptoms of cystic echinococcosis usually resemble those of a slowly growing tumor, and vary with the organ. Cysts can also be incidental findings at surgery or autopsy. Some cysts that have degenerated and died can leave a calcified lesion.

Most people have only a single cyst, most often in the liver and, less frequently, the lungs. Common symptoms of liver cysts are abdominal pain, nausea, vomiting and indigestion. In some cases, there may also be hepatomegaly, anemia, pleural pain, ascites or portal hypertension. Cysts that obstruct the biliary system can mimic gallstones, resulting in pain or cholestatic jaundice. Fever or nonspecific signs such as anorexia, weight loss and weakness may also be seen. Cysts in the lungs sometimes cause respiratory signs including chronic cough, chest pain, dyspnea and/or hemoptysis.

Cysts are found occasionally in the bones, kidneys, spleen, peritoneal cavity or CNS, and uncommonly in numerous other locations (e.g., heart, ovary, muscles, salivary gland, appendix, periorbital tissues). Cysts in the spleen and kidneys often have no early signs and an insidious progression, though pain or discomfort is possible, and urinary signs (e.g., hematuria, fever associated with pyelonephritis), have been reported. Cysts in the bones may result in spontaneous fractures, pain, swelling, functional impairment and/or muscle wasting. They tend to infiltrate the bone, destroying its structure.

Cysts affecting the CNS generally occur in the brain; spinal cord involvement is rare. Unlike cysts in other organs, these cases often become symptomatic in children and young adults. The most common signs in children are those of elevated intracranial pressure and may include headache, nausea, vomiting and papilledema. Focal neurological signs are also common in adults. The specific signs depend on the location of the cyst, and can include visual disturbances, speech disorders, seizures or motor disturbances including hemiparesis.

Leakage of cyst fluid can cause allergic reactions such as shaking, chills and/or fever, asthma, pruritus, urticaria or life-threatening anaphylaxis. It can also seed larvae to other locations if hydatid sand is released. The rupture of a cyst may result in acute abdomen, if the cyst is located in the liver or peritoneal cavity. Ruptured cysts in any location can cause anaphylactic shock. Cysts may also become secondarily infected by bacteria and develop into abscesses.

Alveolar echinococcosis - (Echinococcus multilocularis)

E. multilocularis sometimes dies early in its development in humans, but cysts that survive behave like tumors, progressively infiltrating tissues and sometimes metastasizing to distant sites. The initial lesion almost always occurs in the liver, and the course of the disease in immunocompetent people is usually slow. Patients are typically asymptomatic in the early stages, but they eventually develop signs that may include hepatomegaly, epigastric pain, or cholestasis with or without jaundice. Some cases are diagnosed during a workup of fatigue or enlarged liver. Ascites, malnutrition and signs of hepatic failure may occur in the later stages. Possible complications include biliary cirrhosis, portal hypertension, cholangitis (which may result in septicemia), bacterial infection of necrotic cavities in the lesion, chronic Budd-Chiari syndrome or stroke. Metastatic lesions at other sites (e.g., brain, lung, mediastinum) can cause additional signs related to the location. Metastatic disease can be rapidly fatal.

Polycystic hydatidosis (E. vogeli and E. oligarthrus)

Illnesses caused by E. vogeli tend to resemble alveolar echinococcosis, with invasive lesions that usually occur initially in the liver and can metastasize to other sites. In some cases, however, the initial lesions have occurred at other sites such as the mesentery or stomach. In one atypical case, a person had a single well-circumscribed hepatic cyst that was initially thought to be *E. granulosus*. Some *E. vogeli* larvae may spontaneously die and degenerate, leaving calcified cyst remnants.

E. oligarthrus has been reported only rarely in humans. In two cases, a single cyst behind the eye caused irritation of the eye, exophthalmia and blindness. Cysts were also found in the heart of a person who had died of tetanus. The lesions included an enlarged heart, myocarditis and excess pericardial fluid.

Diagnostic Tests

In humans, echinococcosis is usually diagnosed with imaging techniques such as ultrasound, radiology, magnetic resonance imaging (MRI) or CT scanning, supported by serology. A number of serological tests may be available, including ELISAs, indirect immunofluorescence, indirect hemagglutination, immunochromatographic tests and immunoblotting. Immunoblotting is generally used as a confirmatory test for other assays. False negative and false positive reactions are relatively common in serological tests. False negative reactions are particularly prevalent in people infected with *E. granulosus s.l.*, though they may also be seen with *E. multilocularis,* especially in the early stage when the cyst is still small.

As in animals, ultrasound-guided fine-needle puncture can distinguish cysts from tumors, abscesses and other lesions. When a lesion in the lungs has opened into the airways, protoscolices are sometimes found in sputum or bronchial washings. Histopathology may be sufficient to identify recovered cysts as *Echinococcus* in tissues, but immunohistochemistry or PCR tests can be valuable in some cases. *Echinococcus* species can be distinguished by PCR on cyst tissues, followed by sequencing or restriction fragment length polymorphism analysis.

Treatment

Treatment can include surgery, anthelmintic drugs, the PAIR (puncture, aspiration, injection, and re-aspiration) technique and occasionally other methods. Surgery is often used for *E. granulosus s.l.* cysts and smaller *E. multilocularis* lesions that can be completely resected. Palliative (debulking) surgery is no longer recommended for *E. multilocularis,* as it is not superior to drug treatment alone. Anthelmintic drugs are an alternative to surgery in some cases. Long-term drug treatment also helps prevent the growth of metastatic cysts after surgical removal of *E. multilocularis*. Commonly used anthelmintic drugs for *Echinococcus* spp. include albendazole, mebendazole, or a combination of albendazole and either praziquantel or nitazoxanide.

The PAIR technique is an option for cystic echinococcosis but not alveolar echinococcosis. In this technique, most of the cyst contents are removed under ultrasound guidance, and a chemical (e.g., hypertonic saline, 95% alcohol or cetrimide) is introduced into the cyst to destroy its germinal layer. A modified method evacuates the complete cyst after chemical inactivation. Bone lesions can be particularly difficult to treat, and radiation has been used in rare instances when they failed other treatments. Sometimes a "wait and see" approach might also be appropriate, such as with small inactive cysts in certain locations. In severe cases of alveolar echinococcosis, a liver transplant may be an option, though the effects of immunosuppression on any metastases must be considered. Autotransplantation of the patient's own unaffected sections of liver is under investigation.

Prevention

Control programs directed at *Echinococcus* spp. in domestic animals, especially regular deworming of dogs and cats, reduce human exposure. In some areas, foxes have been treated with antiparasitic drugs in bait to decrease human exposure to *E. multilocularis*.

Food safety precautions such as thorough washing of fruits and vegetables, combined with good hygiene, can reduce exposure to eggs on food. The hands should always be washed after handling pets or farming, gardening or preparing food, and before eating. Water from unsafe sources such as lakes should be boiled or filtered. Meat, particularly the intestinal tract of carnivores, should be thoroughly cooked before eating. PPE reduces the risk of infection when working with animal tissues or fecal samples, and periodic surveillance of high-risk populations (e.g., laboratory personnel) may help detect cysts in the early stages when they are most treatable.

Morbidity and Mortality

Cystic echinococcosis

The annual incidence of cystic echinococcosis ranges from < 1 case per 100,000 population to greater than 50 cases per 100,000. This disease is particularly common in rural areas. Although cystic echinococcosis has been diagnosed even in infants, most clinical cases occur in adults due to the slow growth of the parasite. Many cysts are asymptomatic throughout the individual's life, and may be incidental findings at surgery or autopsy. CNS involvement, estimated to occur in approximately 1-3% of cases, is more likely to be seen in children than other forms.

Cystic echinococcosis is usually treatable; however, infections can be fatal if the cyst ruptures and causes anaphylactic shock or if it damages vital organs. Some evidence suggests that certain members of the *E. granulosus s.l.* complex might be more virulent than others. *E. granulosus s.s.* seems to be particularly common in clinical cases, while *E. canadensis* often seems to cause milder infections, with small cysts that may heal spontaneously. The latter organism can nevertheless cause severe illnesses as well, and some evidence suggests that it might be more likely to localize in the CNS than *E. granulosus s.s.*

Alveolar echinococcosis

Where *E. multilocularis* is mainly carried in wild canids, alveolar echinococcosis is an uncommon disease. Hunters, fur trappers, fur traders, wildlife veterinarians and

wildlife biologists may have an increased risk of infection. The average annual incidence is 0.03–0.20 cases per 100,000 population in endemic countries in Europe, with an incidence of < 10 cases per 100,000 in one region where 70% of foxes are infected. Alveolar echinococcosis is almost 100 times more common in humans where *E. multilocularis* is common in dogs, such as western China.

E. multilocularis does not become established in everyone who is exposed to the eggs. Some individuals seem to seroconvert with no apparent lesions. In other cases, a cyst forms but degenerates, and may appear as an asymptomatic, calcified lesion on screening. How often cysts remain alive and grow is uncertain, but some estimates suggest this might occur in 1-10% of those who are exposed. *E. multilocularis* lesions usually grow slowly in healthy people, but they can progress quickly if the person is immunosuppressed. Many clinical cases are diagnosed late, when a complete surgical cure is less likely.

Without treatment, 90-100% of symptomatic cases are fatal. Treatment can be curative or it may prolong survival and ameliorate the symptoms. Improved survival has been reported with modern treatment methods: the 10-year survival rate of patients on long-term drug treatment is reported to be 80%, and in Europe, the average life expectancy at diagnosis increased from 3 years in the 1970s to 20 years by 2005.

Polycystic echinococcosis

Polycystic echinococcosis is uncommon but likely to be underdiagnosed. Approximately 170 cases, mainly caused by *E. vogeli,* had been reported as of 2007, but some historical cases attributed to *E. multilocularis* in South America were probably also caused by this organism. As of 2013, clinical cases that could be treated surgically had a 95% long-term survival rate; survival was about 85% in cases treated either surgically or with anthelmintics.

E. oligarthrus has been reported very rarely in people. The reason for this is uncertain; however, the definitive hosts are wild felids, and burial of the feces may decrease exposure.

Internet Resources

Centers for Disease Control and Prevention (CDC). Echinococcosis
https://www.cdc.gov/parasites/echinococcosis/index.html

European Centre for Disease Prevention and Control. Echinococcosis
https://www.ecdc.europa.eu/en/echinococcosis

Food and Agriculture Organization of the United Nations (FAO). Manual on Meat Inspection for Developing Countries
http://www.fao.org/docrep/003/t0756e/t0756e00.htm

Public Health Agency of Canada. Pathogen Safety Data Sheets
https://www.canada.ca/en/public-health/services/laboratory-biosafety-biosecurity/pathogen-safety-data-sheets-risk-assessment.html

The Merck Manual
http://www.merckmanuals.com/professional

The Merck Veterinary Manual
http://www.merckvetmanual.com/

World Organization for Animal Health (OIE)
http://www.oie.int

OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals
http://www.oie.int/international-standard-setting/terrestrial-manual/access-online

OIE Terrestrial Animal Health Code
http://www.oie.int/international-standard-setting/terrestrial-code/access-online

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* Link is defunct